**State of California**
**The Resources Agency**
**DEPARTMENT OF FISH AND WILDLIFE**

**2012 CDFW FRGP REPORT**

# LOWER REDWOOD CREEK JUVENILE SALMONID (SMOLT) ABUNDANCE PROJECT 2004 – 2012 Seasons CDFW PROJECT 2a7

**Fisheries Restoration Grants Program (Project Number: P0810509)**

# FINAL

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# LOWER REDWOOD CREEK
# JUVENILE SALMONID (SMOLT) ABUNDANCE PROJECT
# 2004 – 2012 Seasons
# PROJECT 2a7 [1/]

Prepared by

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Northern Region

## ABSTRACT

Juvenile anadromous salmonid trapping was conducted for the ninth consecutive year in YR 2012 in lower Redwood Creek, Humboldt County, California during the spring/summer emigration period (April – September). Trapping in YR 2012 was continued into September to account for delays in migration, attributable to above average streamflows during the study period. The purpose of the study was to describe juvenile salmonid out-migration and estimate smolt population abundances for wild 0+ Chinook salmon, 1+ Chinook salmon, 0+ coho salmon, 1+ coho salmon, 1+ steelhead trout, 2+ steelhead trout, and cutthroat trout using mark/recapture methods. 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 for Viable Salmonid Population Analysis.

A rotary screw trap and fyke net/pipe trap collectively operated 159 out of 160 days/nights possible, and captured 77,893 0+ Chinook salmon (ocean type), 18 1+ Chinook salmon (stream type), 7,301 0+ steelhead trout, 3,356 1+ steelhead trout, 478 2+ steelhead trout, 73 cutthroat trout, zero 0+ pink salmon, 78 0+ coho salmon, and 82 1+ coho salmon to total 89,279 juvenile salmonids. Ten adult cutthroat trout were also captured. Average weekly trapping efficiencies were 36% for 0+ Chinook salmon, 20% for 1+ Chinook salmon, 8% for 1+ steelhead trout, 9% for 2+ steelhead trout, 24% for cutthroat trout, 20% for 0+ coho salmon, and 5% for 1+ coho salmon. The 0+ Chinook salmon population abundance in YR 2012 equaled 210,370 individuals (95% CI = 198,509 – 222,231), and for 1+ Chinook salmon equaled 64 individuals (95% CI = 7 – 120). The low abundance of yearling Chinook salmon indicated they are relatively rare in Redwood Creek. Population abundances with 95% confidence intervals in YR 2012 equaled 35,174 (28,867 – 41,480) for 1+ steelhead trout; 3,748 (2,592 – 4,904) for 2+ steelhead trout; 201 (138 – 264) for 0+ coho salmon; 458 (254 – 661) for 1+ coho salmon, and 201 (135 – 266) for coastal cutthroat trout. The abundance of 1+ coho salmon smolts in YR 2012 was alarmingly low. The population abundances of 0+ Chinook salmon, 0+ coho salmon, 1+ coho salmon, and cutthroat trout each showed a (preliminary) non-significant trend over study years ($p > 0.10$), and for 1+ and 2+ steelhead trout significant, negative trends were detected ($p < 0.10$). The trend in abundance for 0+ Chinook salmon was significantly negative over time when flood type

flows in the upper basin were added to the linear model ($p < 0.10$), which indicated that the Chinook salmon populations passing through the lower basin were influenced by the Chinook salmon population abundances and flood type flows in the upper basin. The abundances of 1+ and 2+ steelhead trout over time were also negatively related to flood type flows in the upper basin. 0+ Chinook salmon, 1+ steelhead trout, 2+ steelhead trout, 0+ coho salmon, and 1+ coho salmon each showed a temporal delay in population out-migration in YR 2012, which may be attributable to higher than average streamflows during the trapping period. The two most important months for migration in YR 2012 were June/July for 0+ Chinook salmon, 1+ steelhead trout, 2+ steelhead trout, and 0+ coho salmon; May/June for 1+ Chinook salmon and 1+ coho salmon, and June/July for cutthroat trout. Considerably more 1+ steelhead trout emigrated downstream than 2+ steelhead trout each study year, and may indicate that stream habitat conditions are limiting the abundance of the older age class, or favoring a change in the life history to a younger smolt age.

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[1]This paper should be referenced as: Sparkman MD. 2013. Lower Redwood Creek juvenile salmonid (smolt) abundance project, study year 2012: a report to the Fisheries Restoration Grants Program (Project No. P0810509). CDFW AFRAMP, study 2a7: 78 p.

# INTRODUCTION

This report presents results of the ninth consecutive year of juvenile salmonid downstream migrant trapping in lower Redwood Creek, Orick, California during the spring/summer emigration period of YR 2012. The study was conducted by the California Department of Fish and Wildlife's Anadromous Fisheries Resource Assessment and Monitoring Program (CDFW AFRAMP) in YRS 2004 – 2012, and is a cooperative effort between the department, United States Geological Survey, Humboldt State University, and the landowner where the trap is located. Funding for YR 2004 was provided by the department's Steelhead Report Card Program and AFRAMP, and in YR 2005 funding was provided by the Steelhead Report Card Program, AFRAMP, and the Fisheries Restoration Grants Program (FRGP). In YRS 2006 – 2007 funding was provided by AFRAMP and FRGP, and in YR 2008 provided by CDFW AFRAMP, CDFW Steelhead Trout Report-Restoration Card Program, FRGP, and Save the Redwoods League. In YRS 2009 - 2012 funding was provided by CDFW AFRAMP and FRGP (YR 2012: P0810509).

The initial impetus for this study was to determine how many wild salmon and steelhead trout smolts were emigrating from the majority of the Redwood Creek basin before entering the Redwood Creek estuary and Pacific Ocean. The 'majority' of the Redwood Creek basin includes all anadromous waters upstream of the first major tributary (Prairie Creek, river mile RM 3.7) to Redwood Creek. Areas downstream of Prairie Creek are generally not used for spawning by adult salmonids; thus, the only smolt production the trap will miss is from the Prairie Creek watershed. Beginning in YR 2011, CDFW and USGS California Cooperative Fish and Wildlife Research Unit have operated a smolt trap in lower Prairie Creek. In YR 2004, CDFW AFRAMP successfully determined juvenile Chinook salmon and steelhead trout smolt population abundances from the majority of Redwood Creek for the first time in Redwood Creek's anadromous salmonid monitoring history. Additionally, AFRAMP and the Redwood Creek Landowners Association (RCLA) have successfully determined smolt population abundances for juvenile Chinook salmon and steelhead trout emigrating from upper Redwood Creek for the past thirteen consecutive years (Sparkman, 2012). Prior to our studies on juvenile salmonid downstream migration and smolt abundance in Redwood Creek, scientific studies which quantified anadromous salmonids within the Redwood Creek watershed were primarily limited to the estuary (juveniles) and Prairie Creek (adults and juveniles).

Adult salmon and steelhead trout populations are difficult to monitor in Redwood Creek because the adult fish migrate upstream during fall or late fall, winter, and early to mid-spring. Thus, when the adults are present, the streamflow is often high and unpredictable, which limits the reliability and usefulness of any adult weir. Additionally, streamflow during this time period often carries large amounts of suspended sediments, which render visual observations of adult fish and redds (e.g. 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 using a coho salmon sampling frame (CDFW AFRAMP). Scientific studies which focus on adult 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 of Redwood Creek.

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 (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 (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 results of trapping in YR 2012 with various comparisons to the average of the previous eight years (YRS 2004 – 2011), and YR 2011.

## Site Description

Redwood Creek lies within the Northern Coast Range of California, and flows 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, about 49.7 miles long, and 6.2 miles wide (Cashman et. al 1995). The study area upstream of the trap site (Rm 4) encompasses approximately 151,922 acres of the Redwood Creek basin, with about 93 stream miles (150 km) of accessible salmon and steelhead habitat (Cannata et al. 2006).

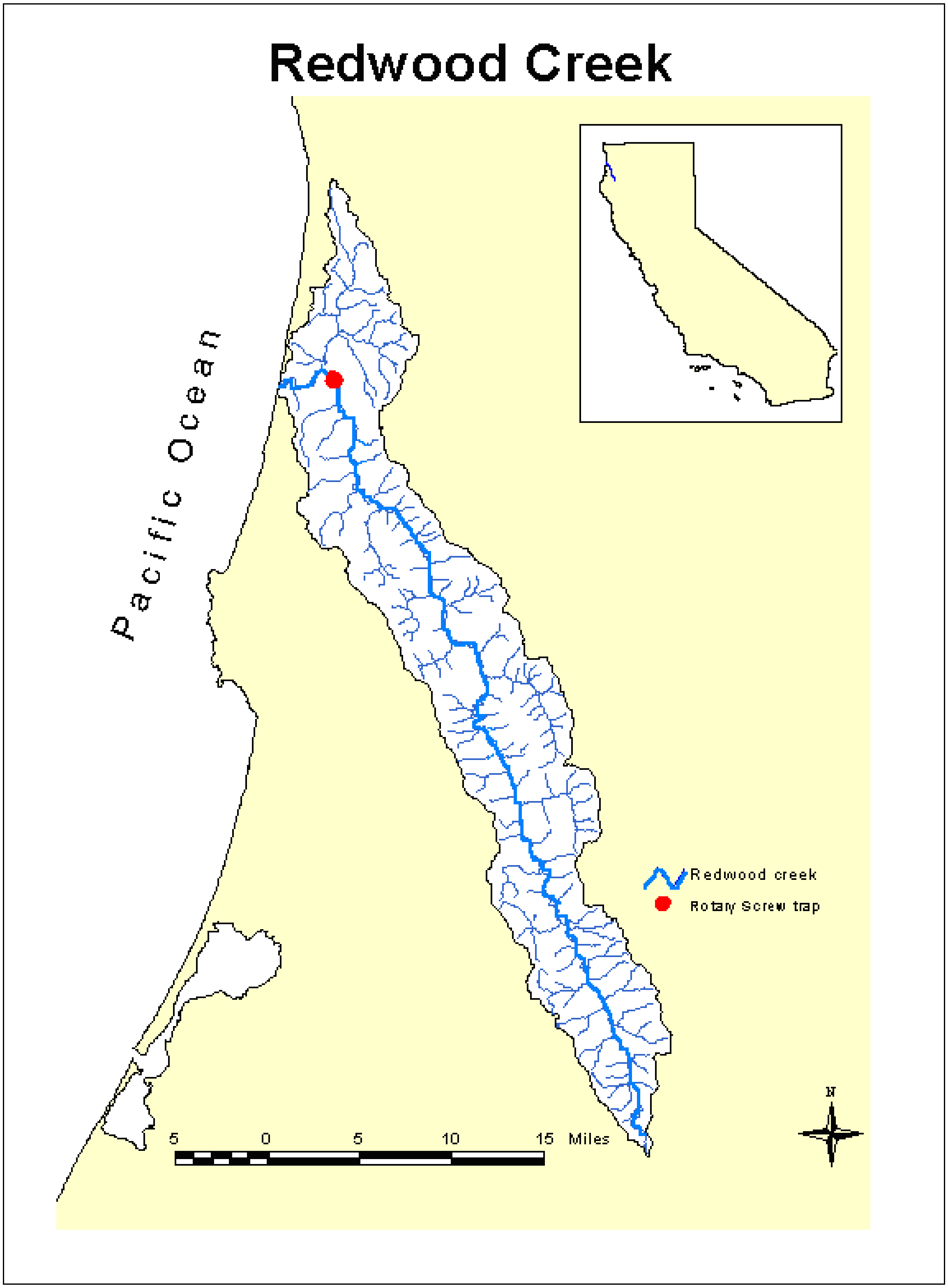


**Figure 1. Redwood Creek basin with rotary screw trap location (RM 4), Humboldt County, CA. (scale is slightly inaccurate due to reproduction process, Charlotte Peters pers. com. 2001).**

## 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 (CDFW 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).

## Climate

The climate of the 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. Snowfall is common during winter months in the upper basin and relatively rare in the lower basin.

## Stream Discharge

A USGS gauging station (#11482500) is located about 850 m downstream of the trap site in lower Redwood Creek. The gauging station is downstream of the confluence of Prairie Creek with Redwood Creek, thus the station is influenced by Prairie Creek streamflow. Streamflow records for the Orick gage cover the periods of 1911 – 1913, 1953 – 2012, and total 61 years (USGS 2013). High streamflows usually occur from November through May, and typically peak in January. However, the months of December, February, March, and April can experience peaks in high flows as well. Using all years' data (historic), mean monthly discharge was 1,006 cfs (28.5 $m^3$/sec), and ranged from 35 – 2,478 cfs (1.0 – 70.2 $m^3$/sec) (USGS 2013). Average monthly discharge in WY 2012 equaled 867 cfs (24.6 $m^3$/sec), ranged from 27 – 3,104 cfs (0.8 – 87.9 $m^3$/sec), and peaked in March (USGS 2013). Average stream flow in WY 2012 was about 14% less than the historic average (USGS 2013).

The 61 year average monthly flow during the majority of the (normal) trapping season (April – July) equaled 561 cfs (15.9 $m^3$/sec), and ranged from 87 – 1,262 cfs (2.5 – 35.7 $m^3$/sec) (USGS 2013). Average monthly discharge from April – July in YR 2012 equaled 859 cfs (24.3 $m^3$/sec), ranged from 119 – 2,446 cfs (3.4 – 69.3 $m^3$/sec), and was 1.53 times greater than the historic average for this time frame (USGS 2013). Due to the increase in discharge in YR 2012, trapping was extended until September 24th in order to fully account for the additional migration which occurred in August and September.

**Overstory**

The overstory of Redwood Creek 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*). The lower portion of Redwood Creek (ie within Redwood National Park boundaries) contains old growth Redwood, mixed with second growth redwood and other tree species.

**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 about 200 m upstream 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. The downstream migrant trap in lower Redwood Creek is located in an area of gravel aggradation, and gravel extraction does occur in this area. 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 and the study in upper Redwood Creek also show 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 range" (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 ESU (or Distinct Population Segment, DPS), 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 was most likely the fall/early winter-run Chinook salmon.

## Purpose

The purpose of this project is to describe juvenile salmonid downstream migration from the majority of the Redwood Creek basin, and to determine emigrant 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, cutthroat trout (age 1 and older), 0+ coho salmon (fry, parr), and 1+ coho salmon smolts. The primary long term goal is to monitor the status and trends of out-migrating juvenile salmonid smolts in Redwood Creek in relation to watershed condition and restoration activities in the basin; and to provide data needed for Viable Salmonid Population (VSP) analysis. Specific study objectives were as follows:

1) Determine the specie composition and temporal pattern of downstream migrating juvenile salmonids.
2) Determine population estimates for downstream migrating 0+ Chinook salmon, 1+ Chinook salmon, 1+ steelhead trout, 2+ steelhead trout, cutthroat trout, 0+ coho salmon, and 1+ coho salmon.
3) Record fork length (mm) and weight (g) of captured fish.

4) Collect genetic samples from 0+ Chinook salmon, 1+ Chinook salmon, 0+ steelhead trout, 1+ steelhead trout, 2+ steelhead trout and juvenile coho salmon (if present) for future analyses and comparisons (Appendix 1).
5) Collect and handle fish in a manner that minimizes mortality.
6) Statistically analyze data for significance and trends.
7) Compare data between study years.
8) Link data collected from the lower basin, upper basin, Prairie Creek, and estuary (Redwood National Park) to provide a complete study on the life history and abundance of emigrating juvenile salmonids (smolts) in Redwood Creek.

## METHODS AND MATERIALS

### Trap Operations

The methods and materials used in this study in YR 2012 were the same as previous study years (Sparkman 2012). A modified E.G. Solutions (5 foot diameter cone) rotary screw trap was deployed in lower Redwood Creek (Rm 4) on April 17th, 2012 at the same general location (± 100 m) as previous study years (YRS 2004 - 2011).

We operated the rotary screw trap continually (24 hrs/day, 7 days a week) from April 17th through September 24th, with exception to one day of missed trapping. The one day of missed trapping occurred when a large log jammed the traps' cone, which prevented fish from entering the livebox. Beyond September 7th, streamflow was too low to operate the rotary screw trap, and on September 7th we installed a fyke net/pipe trap. Weir panels were used to force all downstream migrating fish into the fyke net/pipe trap. The trapping season in YR 2012 (as well as in YRS 2010 and 2011) was extended compared to previous study years because smolt migrations in August and September were much higher than expected. Trapping was discontinued on September 24th when the catch distribution for each species at age reached zero, or when relatively few individuals were captured in consecutive days.

During periods of lesser streamflows, weir panels were used with the rotary screw trap to: 1) keep the trap's cone revolutions relatively high, and 2) maintain good trapping efficiencies by directing fish into the cone area. The weir panels were held in place using bailing wire and 6 - 8 ft long fence posts, and were first installed in May. Additional weir panels were later added to increase the overall length, and by July 10th the panels were within one foot of the cone's edge. Adjustments to trap placement and the use of weir panels in YR 2012 helped increase trapping efficiencies, trap catches, and cone revolutions.

The YR 2012 trapping season can be characterized as: 1) closely monitoring the trap in April and early May because of moderate increases in stream flows and subsequent increases of debris within the livebox, 2) making frequent adjustments to the trap configuration, 3) maintaining the trap's position in the thalweg, and 4) extensively using weir panels. The largest flow event occurred on April 20th, 2012 when the stream rose from 1,370 cfs (on April 18th) to 2,300 cfs (April 20th).

## Biometric Data Collection

Fishery technicians frequently removed debris (e.g. alder cones, leaves, sticks, detritus, etc.) from within the livebox at night to reduce trapping 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. Captured fish (0+ fish first, then 1+ and older) were placed into 5 gal. buckets and carried to the processing station. At the station, fish were placed into a 23.5 gal. ice chest modified to safely hold juvenile fish. The ice chest was adapted to continually receive fresh water from the stream using a 3,700 gph submersible bilge pump. The bilge pump connected to a flexible line (ID 4 cm or 1.6 in.) that connected to a manifold with four ports. "Y" type hose adapters were connected to each port. Garden hoses connected to the hose adapters, with one line feeding the ice chest, and four lines feeding recovery buckets for processed fish. Additional garden hoses were connected to the hose adaptors to quickly fill buckets if needed, and to relieve any excess back pressure. Plumbing inside the ice chest consisted of two PVC pipes: one that served to dissipate the stream water into the ice chest, and the other to adjust water height in the ice chest and to drain excess water. The system worked very well, did not require additional battery operated aerators, and decreased total fish processing time.

Random samples of each species at age (eg 0+ KS, 0+ SH, etc.) were netted from the ice chest for examination, enumeration, and biometric data collection. Each individual fish was counted by species at age, and observed for trap efficiency trial marks. The marks used for each species at age for the lower trap were different than those used for the trap in upper Redwood Creek. Marked fish from the trap in upper Redwood Creek (Sparkman 2013) were tallied separately from the marked fish used to determine trapping efficiencies for the lower trap.

### <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, if present), 1+ and greater cutthroat trout (CT), 1+ steelhead trout (1+ SH), 2+ and greater steelhead trout (2+ SH), 0+ coho salmon (0+ CO), 1+ coho salmon (1+ CO), and 0+ pink salmon (if present). Only fork lengths were taken from 0+ steelhead trout (0+ SH). A 160 and 350 mm measuring board (± 1 mm), and an Ohaus Scout ll digital scale (± 0.1 g) were used in the study. Fork lengths were taken every day of trap operation, and fork length frequencies of 0+ and older steelhead trout, coho salmon, and Chinook salmon were used to determine age-length relationships at various times throughout the trapping period. Scales were occasionally read to verify age class cutoffs. 0+ Chinook salmon and 1+ steelhead trout weights were taken 2 - 7 times per week; and 0+ and 1+ coho salmon, and 2+ steelhead trout weights were taken nearly every day of trap operation and collection due to expected, low sample sizes. Individuals were weighed in a tared plastic pan (containing water) on the electronic scale. The scale was placed in a large plastic bin when weighing fish to prevent any influences from wind, and was calibrated every day prior to data collection. 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 150 m downstream of the trap site and released in the margin of the stream; and aged 1 and older fish were transported 200 m downstream of the trap site and released near the middle of the stream when possible.

## 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+ Chinook salmon, 1+ steelhead trout, 2+ steelhead trout, cutthroat trout, 0+ coho salmon, and 1+ coho salmon using stratified and non-stratified mark-recapture methods described by Carlson et al. (1998). Population estimation methods in YR 2012 were identical to previous study years (Sparkman 2012). Annual variation in both population abundances and catches over the current nine year period were characterized by the standard deviation and standard error of the mean for each species at age.

## Physical Data Collection

A staff gage with increments in hundredths of a foot was used to measure the relative stream surface elevation (hydrograph) at the trap site each day from April 18$^{th}$ – September 24$^{th}$, 2012. A graphical representation of the data, along with average daily stream discharge data from the Orick gaging station (USGS 2013), is given in Appendix 2. 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. The probe was placed into a PVC cylinder with holes to ensure adequate ventilation and to prevent influences from direct sunlight. The probe recorded stream temperatures ($^{o}$C) every 30 minutes and recorded 7,680 measurements over the course of the study. The shallowest stream depth during which measurements were taken (in September) was about 1.5 feet.

## Statistical Analyses

The statistical analyses conducted in YR 2012 were the same as in previous study years (Sparkman 2012). 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 abundances of a given species at age were increasing or decreasing over the nine years of study. The tests are considered preliminary, and more data will be required to detect the true trends in population abundances over years. With respect to 0+ Chinook salmon, peaks in streamflows in lower Redwood Creek were great enough to potentially mobilize redd gravels each study year. Flood type flows capable of gravel scour (and deposition) in mid to lower Redwood Creek are generally thought to occur near 11,000 cfs (Randy Klein, Greg Bundros, Vicki Ozaki, Mary Ann Madej, pers. comm. 2003). Peak winter flows in upper Redwood Creek, coded as 1 or 0, were included in additional correlation tests with study year on population size for 0+ Chinook salmon, and 1+ and 2+ steelhead trout passing through the lower basin. High bedload mobilizing flows were coded as 1 (for population estimates in YRS 2005 and 2006) and non-bedload mobilizing flows as 0 (for population estimates in YRS 2004, 2007, 2008, 2009, 2010, 2011, and 2012) (Zar 1999). The test for 0+ Chinook salmon would indicate if the relationship of peak winter flows during egg incubation in spawning redds in the upper basin decreased survival, and hence impact the numbers migrating downstream, and tests for 1+ and 2+ steelhead trout would indicate if high winter flows were affecting population abundances of steelhead smolts from upper Redwood Creek with respect to over-winter survival. Flows considered great enough to mobilize the bedload in upper Redwood Creek (> 6,000) were identified by Redwood National Park hydrologists and Geologists), and based upon smolt data collected in the upper basin, appear to represent a threshold for survival.

Descriptive statistics were used to characterize the average FL (mm) and Wt (g) of each species at age on a study year basis. Linear regression was used to test the relationship of average daily discharge on average daily stream temperature, and correlation was used to test whether the average daily stream temperature increased over time (d) during the study period. If data violated tests of statistical assumptions (n = 4 tests for ANOVA, n = 3 tests for regression/correlation; NCSS 97), 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. 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 4/17/12 – 9/07/12 and trapped 142 days/nights out of a possible 143, and the fyke net/pipe trap operated from 9/07/12 – 9/24/12 and trapped 17 days/nights out of a possible 17. The one missed day of trapping occurred on 6/28/12 when a large log jammed the trap's cone. The trapping rate in YR 2012 was 99%, compared to 96% for the previous eight year average (ranged from 91 – 99%).

### Species Captured

**Juvenile Salmonids**

Species captured in YR 2012 included: juvenile Chinook salmon (*Oncorhynchus tshawytscha*), juvenile coho salmon (*O. kisutch*), juvenile steelhead trout (*O. mykiss*), and coastal cutthroat trout (*O. clarki clarki*). A total of 89,279 juvenile salmonids were captured in YR 2012 (Figure 2).

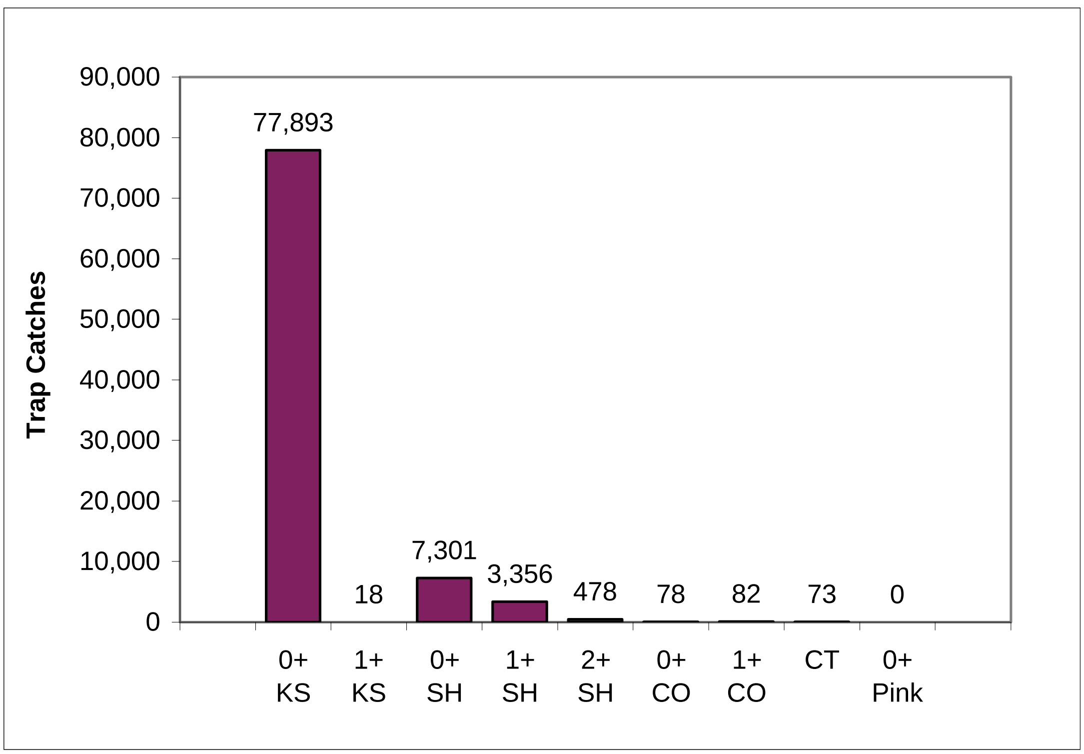


**Figure 2. Total juvenile salmonid trap catches (n = 89,279) from April 18th through September 24th, 2012, lower Redwood Creek, Humboldt County, CA. Numeric values above columns represent actual catches. 0+ KS = young-of-year Chinook salmon, 1+ KS = age 1 Chinook salmon, 0+ SH = young-of-year steelhead 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 (n = 9 years) equaled 72,451 (SD = 31,683; SEM = 10,561). The nine year average catch equaled 49,110 (SD = 23,490; SEM = 7,830) for 0+ Chinook salmon, 14 (SD = 18; SEM = 6) for 1+ Chinook salmon, 17,431 (SD = 16,260; SEM = 5,420) for 0+ steelhead trout, 4,857 (SD = 2,156; SEM = 719) for 1+ steelhead trout, 769 (SD =361; SEM = 120) for 2+ steelhead trout, 154 (SD = 131; SEM = 44) for 0+ coho salmon, 75 (SD = 69; SEM = 23) for 1+ coho salmon, 40 (SD = 26; SEM = 9) for cutthroat trout, and 0.3 (SD = 0.7; SEM = 0.3) for 0+ pink salmon.

## **Miscellaneous Species**

The trap caught numerous miscellaneous species in YR 2012, 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 specie (Table 1). Adult and juvenile captures occurred for Prickly Sculpin, Coast Range Sculpin, Sucker, 3-Spined Stickleback, and Pacific Lamprey. Many gravid sculpins (both species) were also captured. For the third time in nine consecutive years, a bullhead (catfish; *ameiurus* spp.) was captured in YR 2012.

**Table 1. Comparison of miscellaneous species captured by the smolt trap in YR 2012 with the previous eight year average, lower Redwood Creek, Humboldt County, CA.**

| Species Captured | Prev. 8 Yr Avg. | YR 2012 |
|---|---|---|
| Prickly Sculpin | 204 | 427 |
| Coast Range Sculpin | 1,202 | 1,478 |
| Sucker | 166 | 199 |
| 3-Spined Stickleback | 2,433 | 1,502 |
| Bullhead | 0.3 | 1 |
| Adult Pac. Lamprey | 9 | 11 |
| Juvenile Lamprey* | 117 | 51 |
| Brook Lamprey | 1 | 0 |
| Pac. Giant Salamander | 9 | 4 |
| Rough Skinned Newt | 6 | 1 |
| Red-Legged Frog | 4 | 0 |
| Yellow-Legged Frog | 3 | 5 |
| Tailed Frog** | 2 | 0 |
| Western Toad | 81 | 45 |
| Crawfish | 0.1 | 8 |
| Bull Frog | 0.1 | 0 |

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

## Days Missed Trapping

One day was not trapped during the course of study in YR 2012 (6/28/12) when a large log jammed the trap's cone, and prevented fish from entering the livebox. The one day of missed trapping would not have influenced 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 = 1 d) during the emigration period of April 17th through September 24th (as a percentage of total without missed days catch in parentheses), lower Redwood Creek, Humboldt County, CA., 2012.**

| Age/spp* | Catch | Population Level |
|---|---|---|
| 0+ KS | 1,489 (1.95%) | 3,821 (1.85%) |
| 1+ KS | 0 (0.00%) | 0 (0.00%) |
| 0+ SH | 90 (1.25%) | - |
| 1+ SH | 69 (2.06%) | 697 (2.06%) |
| 2+ SH | 6 (1.27%) | 75 (2.04%) |
| 0+ CO | 0 (0.00%) | 0 (0.00%) |
| 1+ CO | 0 (0.00%) | 0 (0.00%) |
| CT | 3 (4.11%) | 10 (5.03%) |

* 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 the known catches for a given stratum (week) and used in the population estimate for that stratum (Roper and Scarnecchia 1999).

## Trends in Trap Catches

*0+ Chinook Salmon*

Linear correlation detected a non-significant, positive relationship of trap catches over study years (n = 9, p = 0.15. r = 0.52, power = 0.29). The correlation of 0+ Chinook salmon trap catches and flood type flows in the upper basin (dummy variable) during egg incubation with study years showed a significant relationship (n = 9, p = 0.02, Adj. r = 0.80, negative slope for flood flow variables, positive slope for study year, power = 0.50). The linear regression of flood type flows in the upper basin on trap catches was also significantly negative (n = 9, p = 0.004, $R^2$ = 0.73, negative slope, power = 0.96).

*1+ Chinook Salmon*
Linear correlation detected a non-significant relationship of 1+ Chinook salmon trap catches (transformed) over study years (n = 9, p = 0.13, r = 0.54, positive slope, power = 0.32). The addition of flood type flows in the model did not change the test conclusion (n = 9, p = 0.35, adj. r = 0.25, positive slope for year, negative slope for flood type flows, power = 0.11).

*0+ Steelhead Trout*
Linear correlation detected a non-significant relationship of 0+ steelhead trout trap catches over study years (n = 9, p = 0.41, r = 0.31, negative slope, power = 0.12).

*1+ Steelhead Trout*
Linear correlation detected a non-significant relationship of 1+ steelhead trout trap catches over study years (n = 9, p = 0.22, r = 0.45, negative slope, power = 0.21). The correlation of trap catches and flood type flows in the upper basin (dummy variable) with study years was non-significant (n = 9, p = 0.37, Adj. r = 0.20, negative slope for both x variables, power = 0.11). The regression of flood type flows in the upper basin on trap catches in the lower basin was also non-significant (n = 9, p = 0.99, $R^2$ = 0.00, negative slope, power = 0.05).

*2+ Steelhead Trout*
Linear correlation detected a non-significant relationship of 2+ steelhead trout trap catches over study years (n = 9, p = 0.36, r = 0.35, negative slope, power = 0.14). The correlation of trap catches and flood type flows in the upper basin (dummy variable) with study years was non-significant (n = 9, p = 0.58, Adj. r = 0.00, negative slope for both x variables, power = 0.08). The regression of flood type flows in the upper basin on trap catches in the lower basin was also non-significant (n = 9, p = 0.98, $R^2$ = 0.00, negative slope, power = 0.05).

*0+ Coho Salmon*
Linear correlation detected a non-significant relationship of 0+ coho salmon trap catches over study years (n = 9, p = 0.69, r = 0.15, negative slope, power = 0.06).

*1+ Coho Salmon*
Linear correlation detected a non-significant relationship of 1+ coho salmon trap catches (transformed) over study years (n = 9, p = 0.68, r = 0.16, negative slope, power = 0.07).

*Cutthroat Trout*
Linear correlation detected a non-significant relationship of cutthroat trout trap catches over study years (n = 9, p = 0.10, r = 0.58, positive slope, power = 0.37).

## Trapping Efficiencies

The average trapping efficiency by week and seasonal trapping efficiency for 0+ Chinook salmon, 1+ Chinook salmon, 1+ steelhead trout, 2+ steelhead trout, 0+ coho salmon, 1+ coho salmon and cutthroat trout fell within the range of 5 to 36% (Table 3).

**Table 3. Average weekly and seasonal trapping efficiencies for 0+ Chinook salmon, 1+ Chinook salmon, 1+ steelhead trout, 2+ steelhead trout, 0+ coho salmon, 1+ coho salmon, and cutthroat trout in YR 2012, lower Redwood Creek, Humboldt County, CA.**

| | Trapping Efficiency (percentage) | |
|---|---|---|
| Study Year | Average Weekly | Seasonal |
| 0+ Chinook Salmon | 35.6 | 36.1 |
| 1+ Chinook Salmon | 20.4 | 15.4 |
| 1+ Steelhead Trout | 8.3 | 8.4 |
| 2+ Steelhead Trout | 8.6 | 9.1 |
| 0+ Coho Salmon | 19.6 | 21.0 |
| 1+ Coho Salmon | 5.4 | 7.1 |
| Cutthroat Trout | 24.2 | 25.8 |

## Population Estimates

**0+ Chinook Salmon**

The population abundance (or production) of 0+ Chinook salmon emigrating past the trap in lower Redwood Creek in YR 2012 equaled 210,370 individuals with a 95% CI of 198,509 – 222,231 (Figure 3). Population estimate error (or uncertainty) equaled $\pm$ 5.6%, or 11,861 individuals. Population abundance in YR 2012 was greater than YRS 2005 – 2011, and less than emigration in YR 2004 (Figure 3). Population abundance in YR 2012 was 1.1 times greater than the previous eight year average ($N_{avg\ 8yr}$ = 196,911). The average population abundance over the current nine year period equaled 198,407 (SD = 139,400; SEM = 46,467). Correlation of time (study year) on yearly population abundances indicated a non-significant, negative relationship (n = 9, p = 0.31, r = 0.38, power = 0.16) (Figure 3). Peaks in streamflows (11,000 cfs) capable of redd scour in lower Redwood Creek occurred each study year. The test of time and bedload mobilizing flows in upper Redwood Cr (O'Kane gaging station) on population abundance showed a significant, negative relationship over years (Regression, n = 9, p = 0.07, adj. r = 0.66, negative slope for both 'x' variables, power = 0.28).

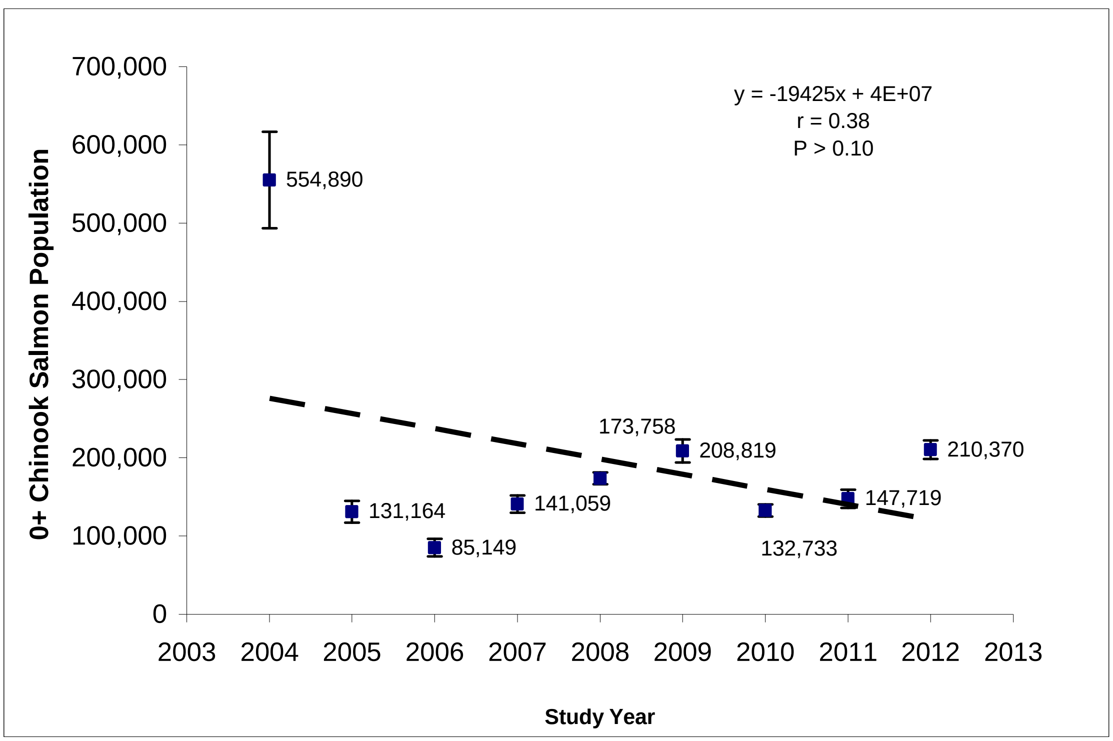


**Figure 3. 0+ Chinook Salmon population abundance estimates (error bars are 95% confidence interval) in YRS 2004 – 2012. Lack of 95% CI for YRS 2008, 2010, and 2011 is due to scale of "Y" axis. Numeric values next to box represent number of individuals. Line of best fit is a regression line (dashed line indicates non-significance) with corresponding equation, correlation value (r), and p value, lower Redwood Creek, Humboldt County, CA.**

The pattern in monthly population abundance in YR 2012 showed a temporal delay in migration compared to the previous eight year average; emigration in July, August, and September 2012 was much greater than for the previous eight year average (Figure 4). Monthly population emigration peaked in June (N = 91,525 or 44% of total) in YR 2012, however migration in July was close in value to emigration in June. The peak in migration for the previous eight year average also occurred in June (N = 94,171 or 48% of total) (Figure 4). In YR 2011, monthly emigration peaked in July (N = 75,872 or 51%). The two most important months for 0+ Chinook salmon population emigration were June and July (87% of total) in YR 2012, and June and July (72% of total) for the previous eight year average (Figure 4). In YR 2011, June and July were also the two most important months, and accounted for 74% of the total population abundance.

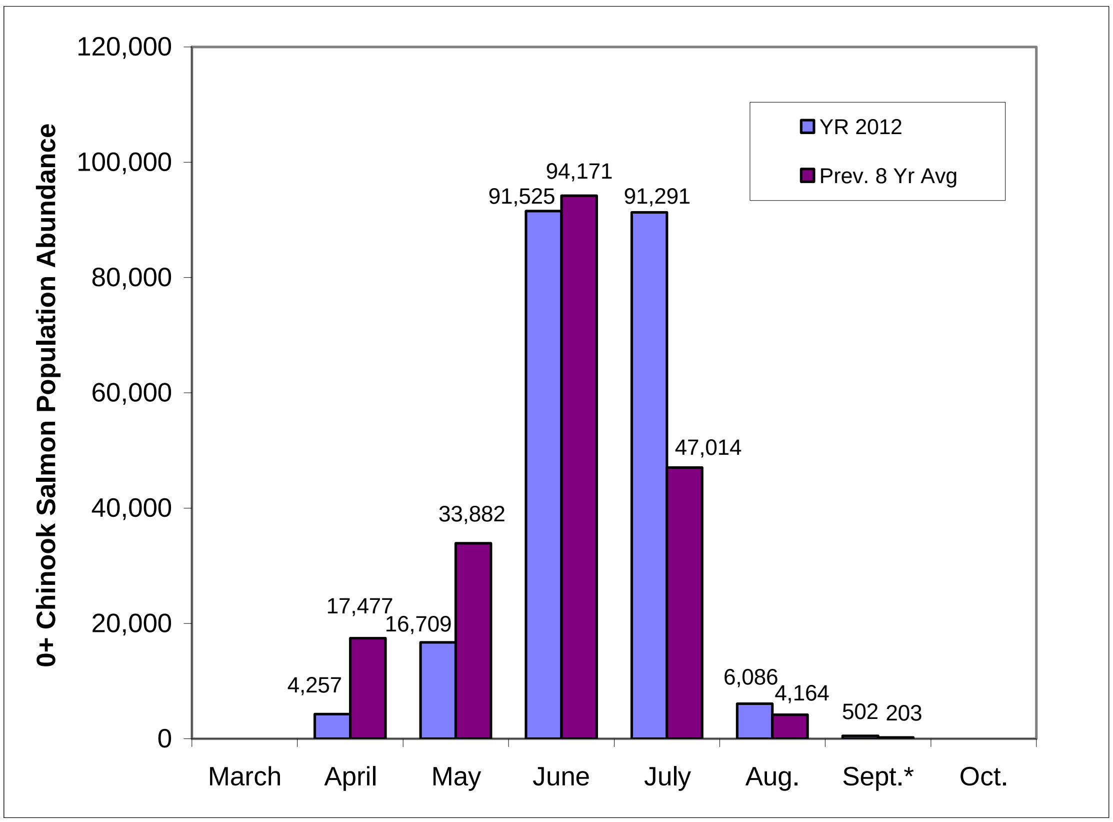


**Figure 4. Comparison of 0+ Chinook salmon population abundance by month in YR 2012 with the previous eight year average (* denotes monthly average of years 2010-2011), lower Redwood Creek, Humboldt County, CA.**

The peak in weekly population emigration in YR 2012 occurred 6/18 – 6/24, one week earlier than the peak in YR 2011 (Table 4). The average FL (mm) for 0+ Chinook salmon migrants during the modes in migration in YR 2012 equaled 50 mm for 5/21 – 5/27, 68 mm for 6/18 – 6/24, and 77 mm for 7/09 – 7/15 (Figure 5).

**Table 4. Date of peak weekly 0+ Chinook salmon population emigration by study year (number of individuals in parentheses), lower Redwood Creek, Humboldt County, CA.**

| Study Year | Date of peak in weekly emigration (number in parentheses) |
|---|---|
| 2004 | 6/18 – 6/24 (110,980) |
| 2005 | 7/16 – 7/22 (29,766) |
| 2006 | 6/11 – 6/17 (27,889) |
| 2007 | 6/18 – 6/24 (38,315) |
| 2008 | 6/25 – 7/01 (37,976) |
| 2009 | 6/18 – 6/24 (33,430) |
| 2010 | 7/16 – 7/22 (34,813) |
| 2011 | 6/25 – 7/01 (27,057) |
| 2012 | 6/18 – 6/24 (37,818) |

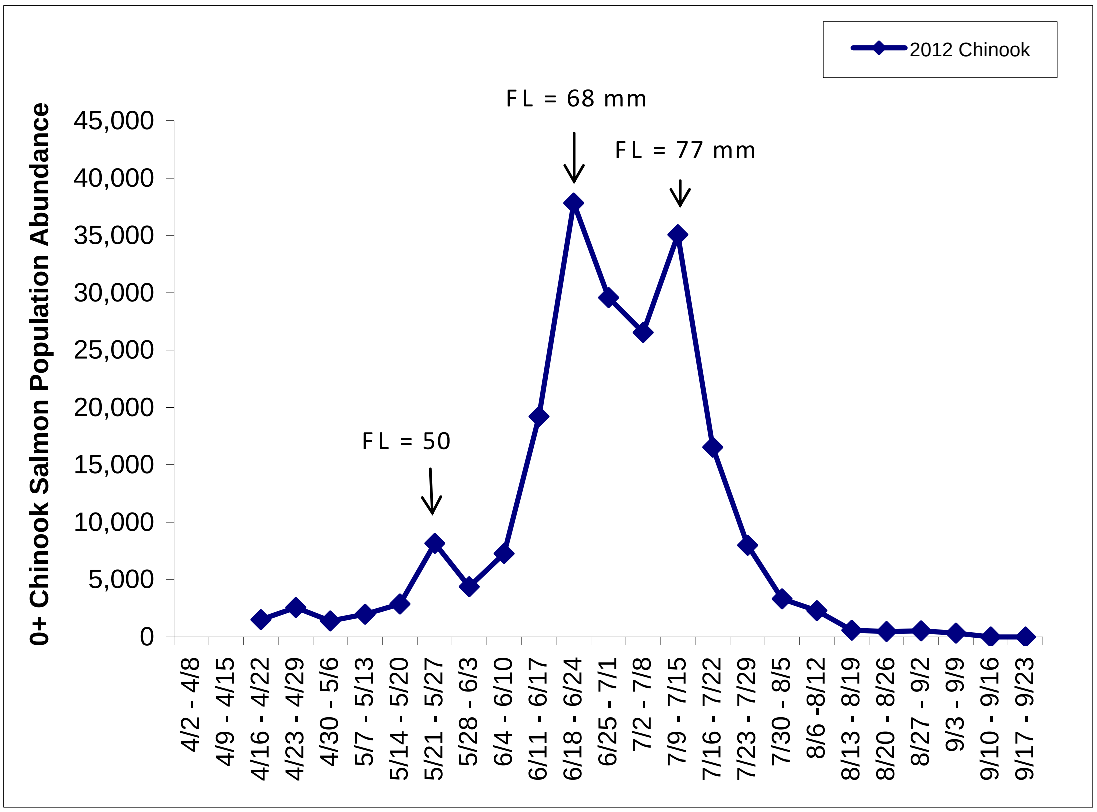


**Figure 5. 0+ Chinook salmon population abundance by week in YR 2012, lower Redwood Creek, Humboldt County, CA.**

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 2012, fry comprised 4.9% and fingerlings comprised 95.1% of the total Chinook salmon population abundance (Table 5).

**Table 5. Production of 0+ Chinook salmon partitioned into fry and fingerling categories each study year and for the previous eight year average (expressed as a percentage in parentheses for YR 2012 and the previous eight year average), lower Redwood Creek, Humboldt County, CA.**

| | 0+ Chinook Salmon production as: | |
|---|---|---|
| Study Year | Fry (FL < 45mm) | Fingerling (FL > 44 mm) |
| 2004 | 82,584 | 472,306 |
| 2005 | 2,052 | 129,113 |
| 2006 | 71 | 85,078 |
| 2007 | 3,772 | 137,287 |
| 2008 | 2,589 | 171,169 |
| 2009 | 9,839 | 198,980 |
| 2010 | 11,526 | 121,207 |
| 2011 | 27,809 | 119,910 |
| Avg. | 17,530 (8.9) | 179,381 (91.1) |
| YR 2012 | 10,259 (4.9) | 200,111 (95.1) |

## <u>1+ Chinook Salmon</u>

The population abundance (or production) of 1+ Chinook salmon emigrating past the trap in lower Redwood Creek in YR 2012 equaled 64 individuals with a 95% CI of 7 – 120 (Figure 6). Population estimate error (or uncertainty) equaled 88%, or 56 individuals. Average abundance for YRS 2009 – 2012 equaled 103 individuals (SD = 140;SEM = 70). Correlation of time (study year) on yearly population abundances indicated a non-significant, negative relationship ($n = 4$, $p = 0.31$, $r = 0.69$, power = 0.13) (Figure 6). May accounted for the majority of population abundance in YR 2012 (52% of total), and June accounted for the majority of population abundance in YR 2011 (59% of total). May accounted for the majority of abundance in YR 2009 (68%) and in YR 2010 (53% of total). The two most important months were May/June in YRS 2010 - 2012, and April/May in YR 2009.

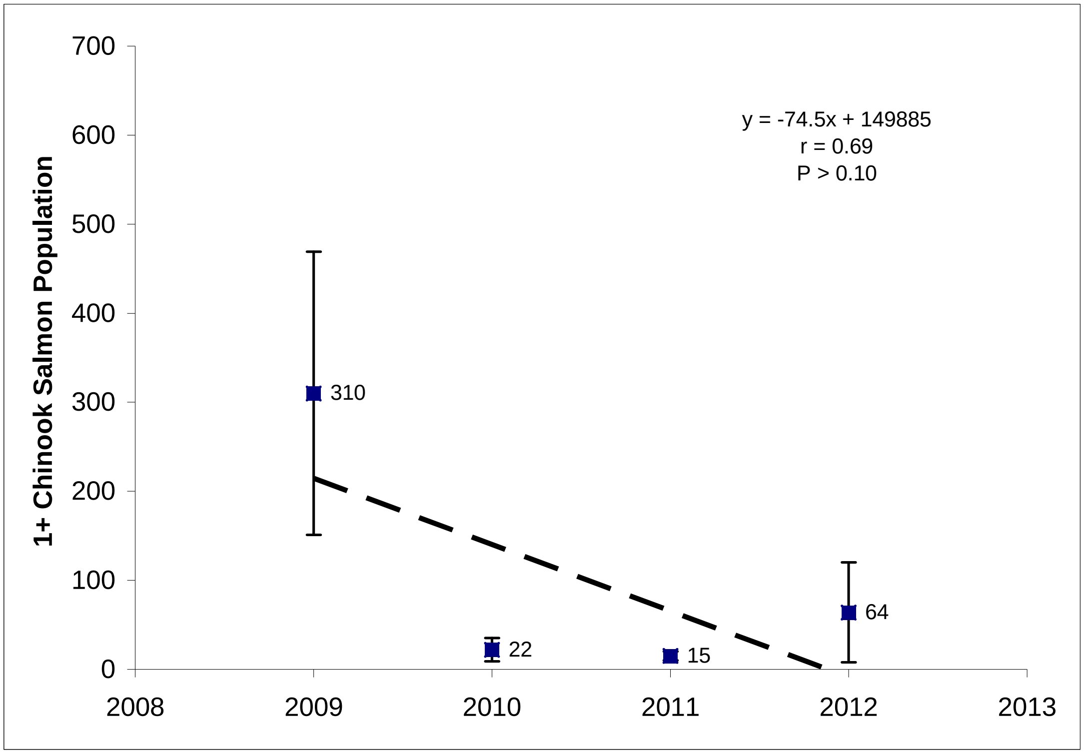


**Figure 6. 1+ Chinook Salmon population abundance estimates (error bars are 95% confidence interval) in YRS 2009 – 2012. Lack of 95% CI for YR 2011 is due to scale of 'Y' axis. Numeric values next to box represent number of individuals. Line of best fit is a regression line (dashed line indicates non-significance) with corresponding equation, correlation value (r), and p value, lower Redwood Creek, Humboldt County, CA.**

## 1+ Steelhead trout

The population estimate of 1+ steelhead trout emigrating past the trap site in lower Redwood Creek in YR 2012 equaled 35,174 individuals with a 95% CI of 28,867 – 41,480 (Figure 7). Population estimate error (or uncertainty) equaled ± 17.9%, or 6,306 individuals. Population abundance in YR 2012 was 1.7 times greater than abundance in YR 2011, and 13% less than the previous eight year average ($N_{avg\ 8\ yr}$ = 40,389). The average in population abundance over the current, nine year period equaled 39,809 (SD = 15,971; SEM = 5,324).

Correlation of time (study year) on yearly population abundances indicated a significant, negative relationship (n = 9, p = 0.04, r = 0.68, power = 0.56) (Figure 7). On average, there were 3,968 less individuals each study year (Figure 7). The test of time and bedload mobilizing flows in upper Redwood Cr (O'Kane gaging station) on population abundance also showed a significant, negative relationship over years (Regression, p = 0.04, adj. r = 0.74, negative slope for both 'x' variables, power = 0.38).

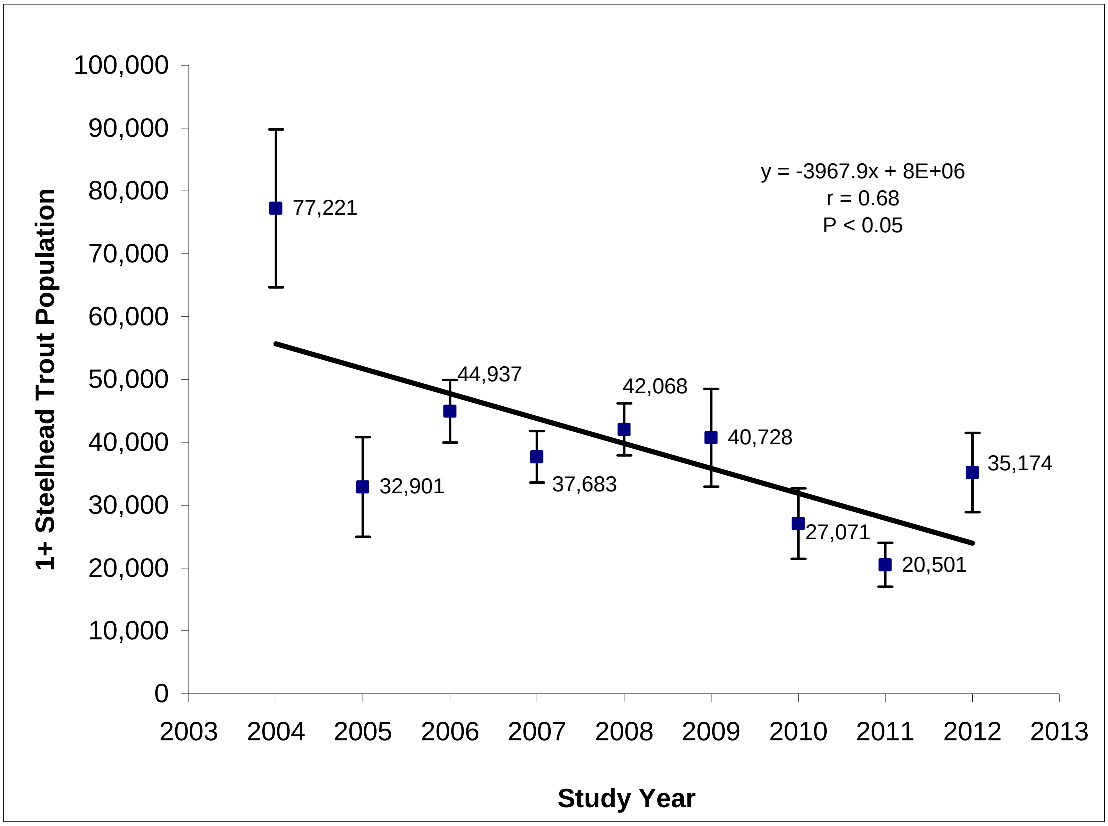


**Figure 7. 1+ steelhead trout population abundance estimates (error bars are 95% confidence interval) in YRS 2004 – 2012. Numeric values next to box represent number of individuals. Line of best fit is a regression line, with corresponding equation, correlation value (r), and p value, lower Redwood Creek, Humboldt County, CA.**

Monthly population emigration peaked in June in YR 2012 (N = 16,843 or 48% of total), and June for the previous eight year average (N = 13,424 or 33% of total) (Figure 8). In YR 2011 July was the most important month (N = 7,630 or 37% of total). The two most important months for 1+ steelhead trout population emigration were June and July in YR 2012 (69% of total), compared to May and June for the previous eight year average (66% of total). In YR 2011 June and July were the two most important months, and accounted for 57% of the total population abundance.

The peak in weekly population abundance in YR 2012 occurred 6/11 – 6/24, and occurred one week earlier than the weekly peak observed in YR 2011 (Table 6). For the nine study years, two peaks occurred in late April/early May, two peaks occurred in May, one in late May/early June, three in June, and one in late June/early July (Table 6).

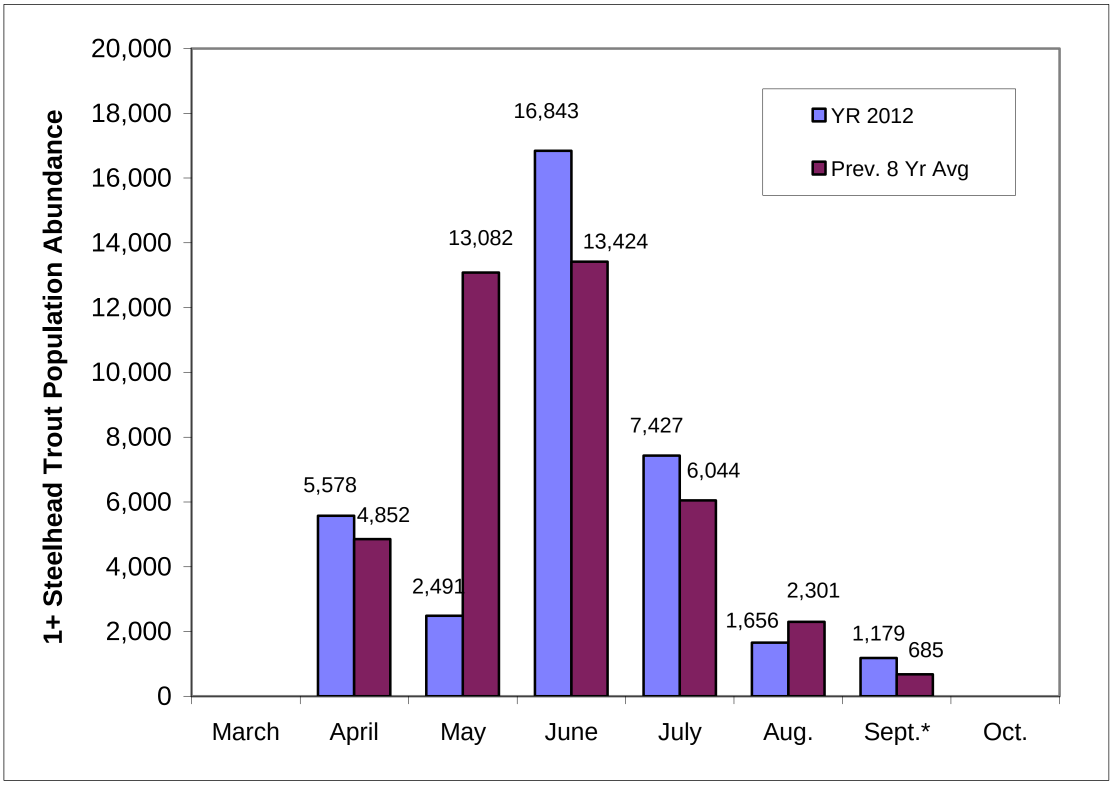


**Figure 8. Comparison of 1+ steelhead trout population abundance by month in YR 2012 with the previous eight year average (* denotes monthly average of years 2010-2011), lower Redwood Creek, Humboldt County, CA.**

**Table 6. Date of peak weekly 1+ steelhead trout population emigration by study year (number of individuals in parentheses), lower Redwood Creek, Humboldt County, CA.**

| Study Year | Date of peak in weekly out-migration (number in parentheses) |
|---|---|
| 2004 | 5/14 - 5/20 (9,985) |
| 2005 | 4/30 - 5/06 (7,494) |
| 2006 | 6/18 - 6/24 (10,440) |
| 2007 | 6/18 - 6/24 (5,483) |
| 2008 | 5/28 - 6/03 (5,533) |
| 2009 | 5/21 - 5/27 (7,855) |
| 2010 | 4/30 - 5/06 (4,934) |
| 2011 | 6/25 - 7/01 (3,647) |
| 2012 | 6/11 - 6/24 (4,850) |

**2+ Steelhead trout**

The population estimate (or production) of 2+ steelhead trout emigrating past the trap site in lower Redwood Creek in YR 2012 equaled 3,748 individuals with a 95% CI of 2,592 – 4,904 (Figure 9). Population estimate error (or uncertainty) equaled ± 30.8% or 1,156 individuals. Population abundance in YR 2012 was the second lowest of record, and 60% less than abundance for the previous eight year average ($N_{avg\ 8yr}$ = 9,399). The average in population abundance over the current nine year period equaled 8,771 (SD = 5,362; SEM = 1,787).

Correlation of time (study year) on yearly population abundances indicated a significant, negative relationship (n = 9, p = 0.008, r = 0.81, power = 0.87) (Figure 9). On average, there were 1,582 less individuals each study year (Figure 9). The test of time and bedload mobilizing flows (flood flows) in upper Redwood Cr (O'Kane gaging station) on population abundance also showed a significant, negative relationship over years (Regression, p = 0.02, adj. r = 0.80, negative slope for both 'x' variables, power = 0.50).

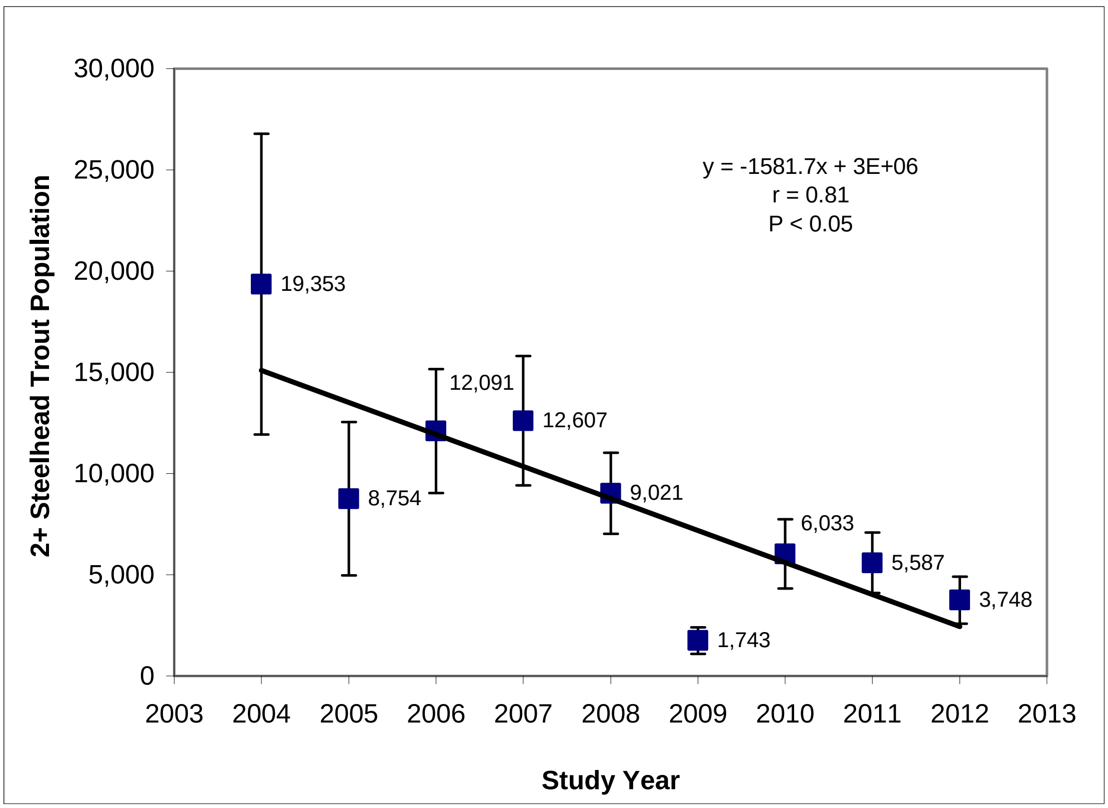


**Figure 9. 2+ steelhead trout population abundance estimates (error bars are 95% confidence interval) in YRS 2004 – 2012. Numeric values next to box represent number of individuals. Line of best fit is a regression line, with corresponding equation, correlation value (r), and p value, lower Redwood Creek, Humboldt County, CA.**

The pattern in monthly population abundance in YR 2012 showed a temporal delay compared to the pattern for the previous eight year average (Figure 10). Monthly population abundance in YR 2012 peaked in July (N = 1,421 or 38% of total), compared to May for the previous eight year average (N = 3,198 or 34% of total) (Figure 10). In YR 2011, monthly emigration peaked in June (N = 1,374 or 25% of total). The two most important months for 2+ steelhead trout population emigration in YR 2012 were June and July (73% of total), compared to May and June (68% of total) for the previous eight year average. In YR 2011, June and July were also the two most important months, and accounted for 47% of the total population abundance.

The peak in weekly abundance was much lower than most study years, and occurred 6/25 – 7/01 (Table 7). For the nine study years, two peaks occurred in late April/early May, one peak occurred during the middle of May, one peak occurred in late May/early June, two peaks occurred in June, two peaks occurred late June/early July, and one peak occurred in August (Table 7).

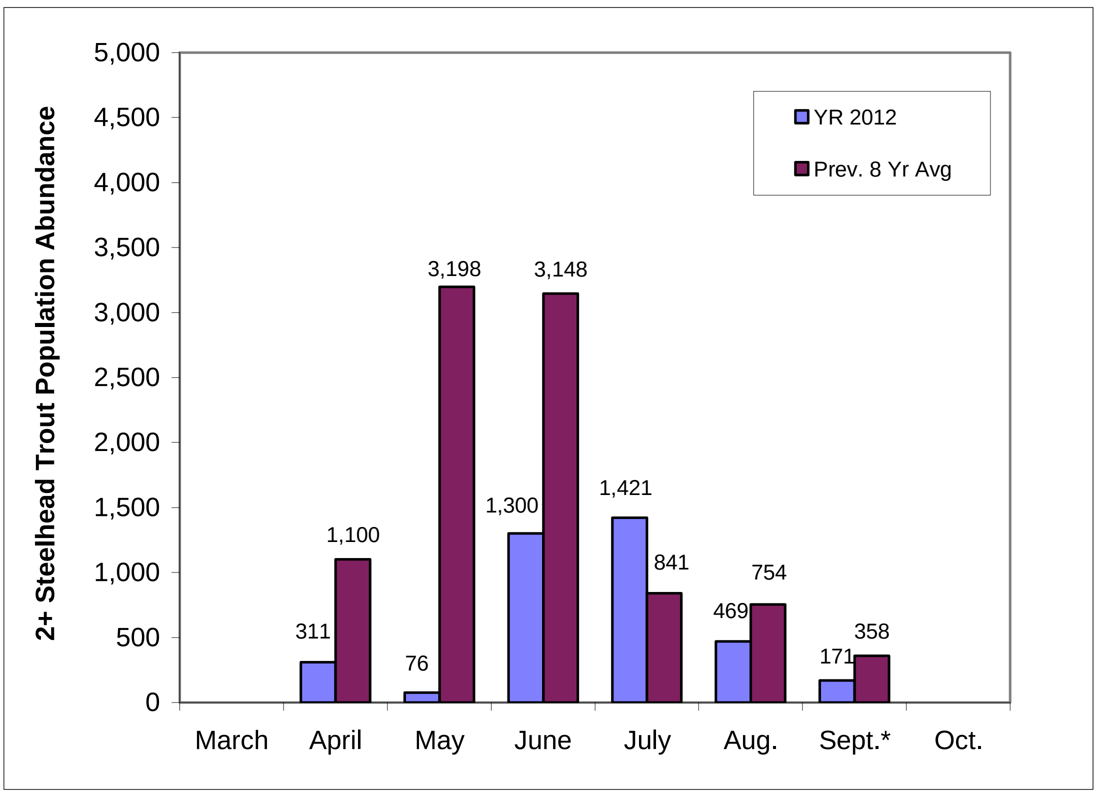


**Figure 10. Comparison of 2+ steelhead trout population abundance by month in YR 2012 with the previous eight year average (* denotes monthly average of years 2010-2011), lower Redwood Creek, Humboldt County, CA.**

**Table 7. Date of peak weekly 2+ steelhead trout population emigration by study year (number of individuals in parentheses), lower Redwood Creek, Humboldt County, CA.**

| Study Year | Date of peak in weekly out-migration (number in parentheses) |
|---|---|
| 2004 | 4/30 - 5/06 (3,604) |
| 2005 | 4/30 - 5/06 (2,232) |
| 2006 | 6/18 - 6/24 (2,883) |
| 2007 | 6/18 - 6/24 (3,066) |
| 2008 | 5/28 - 6/03 (2,322) |
| 2009 | 5/14 - 5/20 (314) |
| 2010 | 8/20 - 8/26 (913) |
| 2011 | 6/25 - 7/01 (1,283) |
| 2012 | 6/25 - 7/01 (600) |

**0+ Coho Salmon**

The population estimate of 0+ coho salmon emigrating past the trap site in lower Redwood Creek in YR 2012 equaled 201 individuals with a 95% CI of 138 – 264 (Figure 11). Population estimate error (or uncertainty) equaled ± 31% or 63 individuals. Population emigration in YR 2012 was the third lowest of record, and 73% less than the previous six year average. The average population abundance over the current seven year period equaled 658 (SD = 674; SEM = 255).

Correlation of time (study year) on yearly population abundances indicated a non-significant, negative relationship (n = 7, p = 0.43, r = 0.36, power = 0.11) (Figure 11).

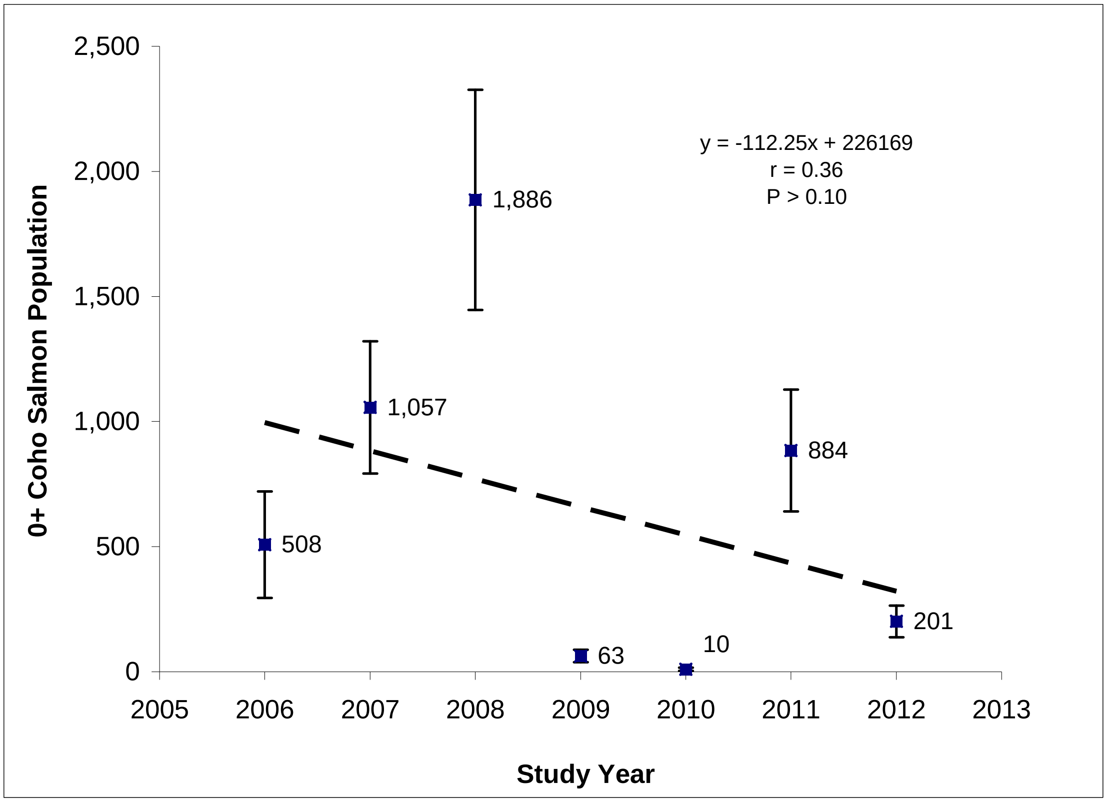


**Figure 11. 0+ coho salmon population abundance estimates (error bars are 95% confidence intervals) in YRS 2006 - 2012. Lack of 95% CI for YRS 2009 and 2010 is due to scale of Y axis. Numeric values next to box represent number of individuals. Line of best fit is a regression line (dashed line indicates non-significance), with corresponding equation, correlation value (r), and p value, lower Redwood Creek, Humboldt County, CA.**

The pattern in monthly population abundance in YR 2012 showed a temporal delay in migration compared to the previous six year average (Figure 12). Monthly population abundance in YR 2012 peaked in July (N = 86 or 43% of total), compared to June (N = 269 or 37% of total) for the previous six year average (Figure 12). In YR 2011, monthly emigration peaked in July (N = 365 or 41% of the total). The two most important months for 0+ coho salmon population emigration were June and July (65% of total) in YR 2012, and June and July (68%) for the previous six year average. In YR 2011, June and July were also the two most important months, and accounted for 73% of the total population abundance.

Weekly peaks in abundances occurred in early April, mid June, late June/early July, mid July, and late August (Table 8).

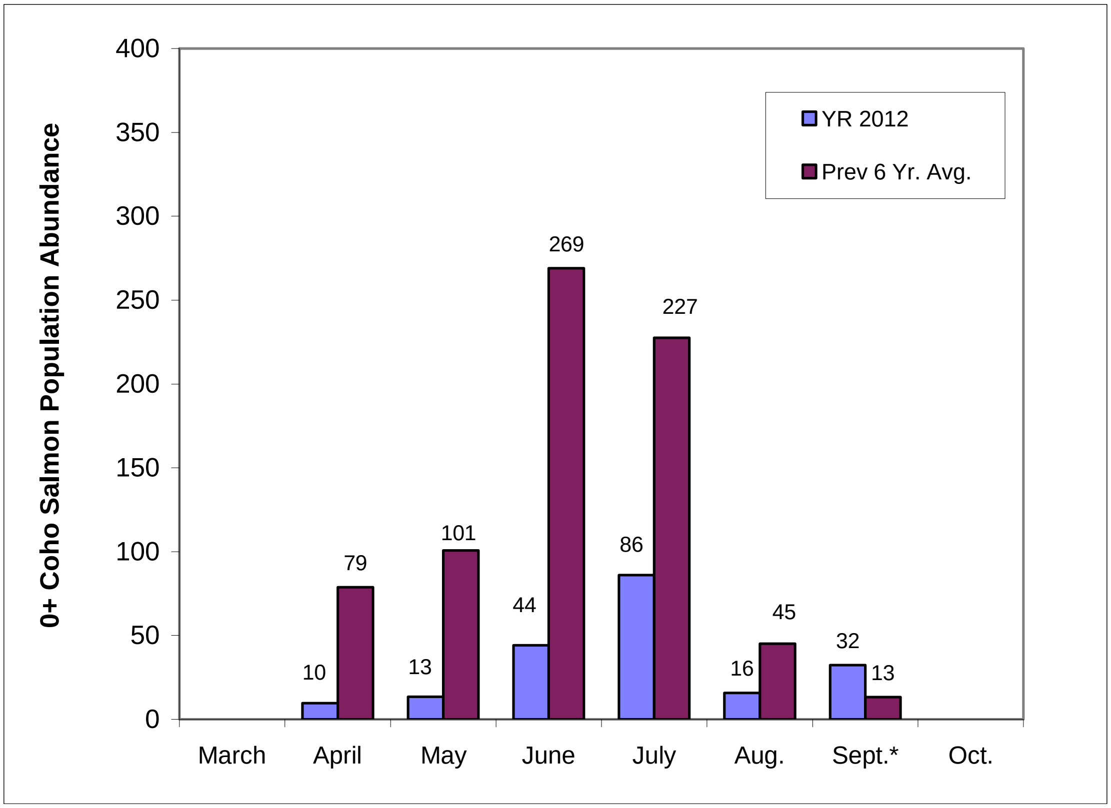


**Figure 12. Comparison of 0+ coho salmon population abundance by month in YR 2012 with the previous six year average (* denotes monthly average of years 2010-2011), lower Redwood Creek, Humboldt County, CA.**

**Table 8. Date of peak weekly 0+ coho salmon population emigration by study year (number of individuals in parentheses), lower Redwood Creek, Humboldt County, CA.**

| Study Year | Date of peak in weekly out-migration (number in parentheses) |
|---|---|
| 2006 | 6/25 - 7/01 (113) |
| 2007 | 6/11 - 6/17 (254) |
| 2008 | 4/02 - 4/08 (304) |
| 2009 | 6/25 - 7/01 (15) |
| 2010 | 8/20 - 8/26 (5) |
| 2011 | 6/25 - 7/01 (171) |
| 2012 | 7/16 - 7/22 (48) |

**1+ Coho Salmon**

The population estimate (or production) of 1+ coho salmon emigrating past the trap site in lower Redwood Creek in YR 2012 equaled 458 individuals with a 95% CI of 254 – 661 individuals (Figure 13). Population estimate error (or uncertainty) equaled ± 44%, or 203 individuals. Population abundance in YR 2012 was greater than the past two study years, and about 1.3 times greater than the previous eight year average ($N_{avg\ 8yr}$ = 345). The average population abundance over the current nine year period equaled 358 (SD = 273; SEM = 91).

Correlation of time (study year) on yearly population estimates indicated a non-significant, negative relationship (n = 9, p = 0.70, r = 0.15, power = 0.06) (Figure 13).

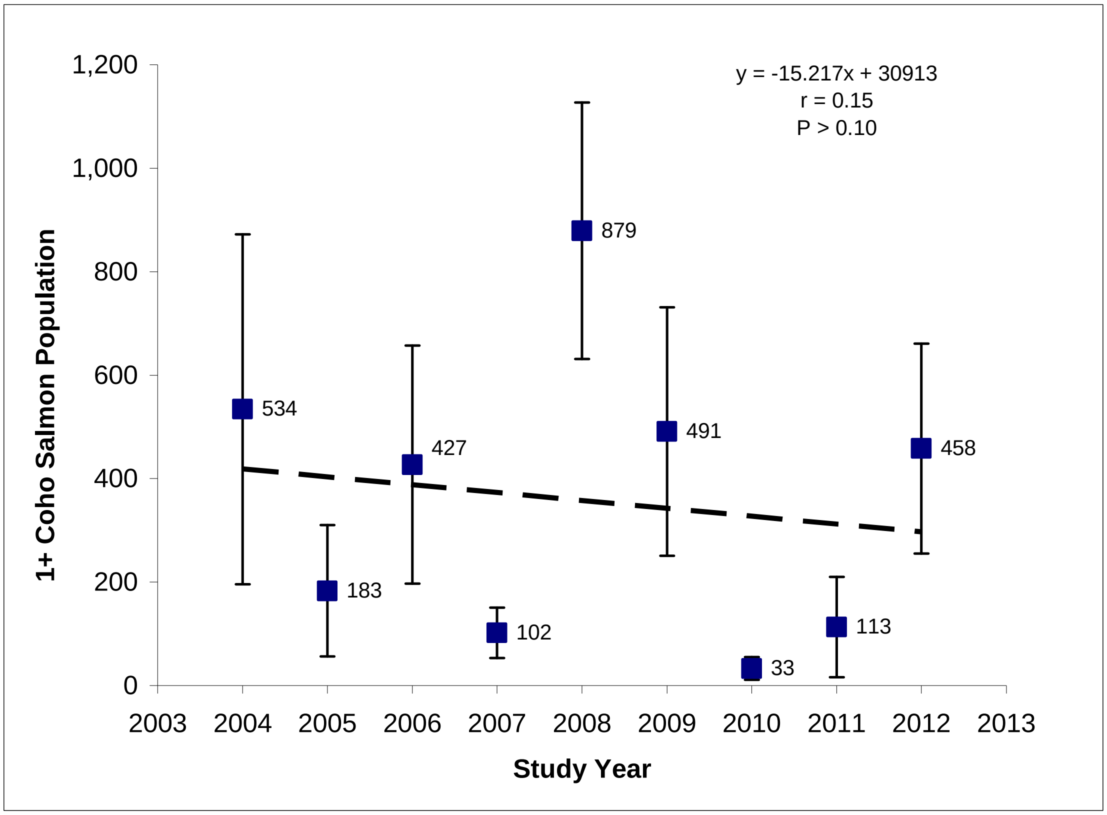


**Figure 13. 1+ coho salmon population abundance estimates (error bars are 95% confidence interval) in YRS 2004 – 2012. Lack of 95% CI for YR 2010 is due to scale of Y axis. Numeric values next to box represent number of individuals. Line of best fit is a regression line (dash line indicates non-significance), with corresponding equation, correlation value (r), and p value, lower Redwood Creek, Humboldt County, CA.**

Monthly population emigration peaked in May (N = 222 or 49% of total) in YR 2012, and May for the previous eight year average (N = 267 or 77% of total) (Figure 14). In YR 2011, monthly emigration also peaked in May (N = 102 or 90% of total). The two most important months for 1+ coho salmon population emigration were May and June in YR 2012 (75% of average), compared to April and May (92% of total) for the previous eight year average. In YR 2011, April and May were also the two most important months, and accounted for 90% of the total population abundance.

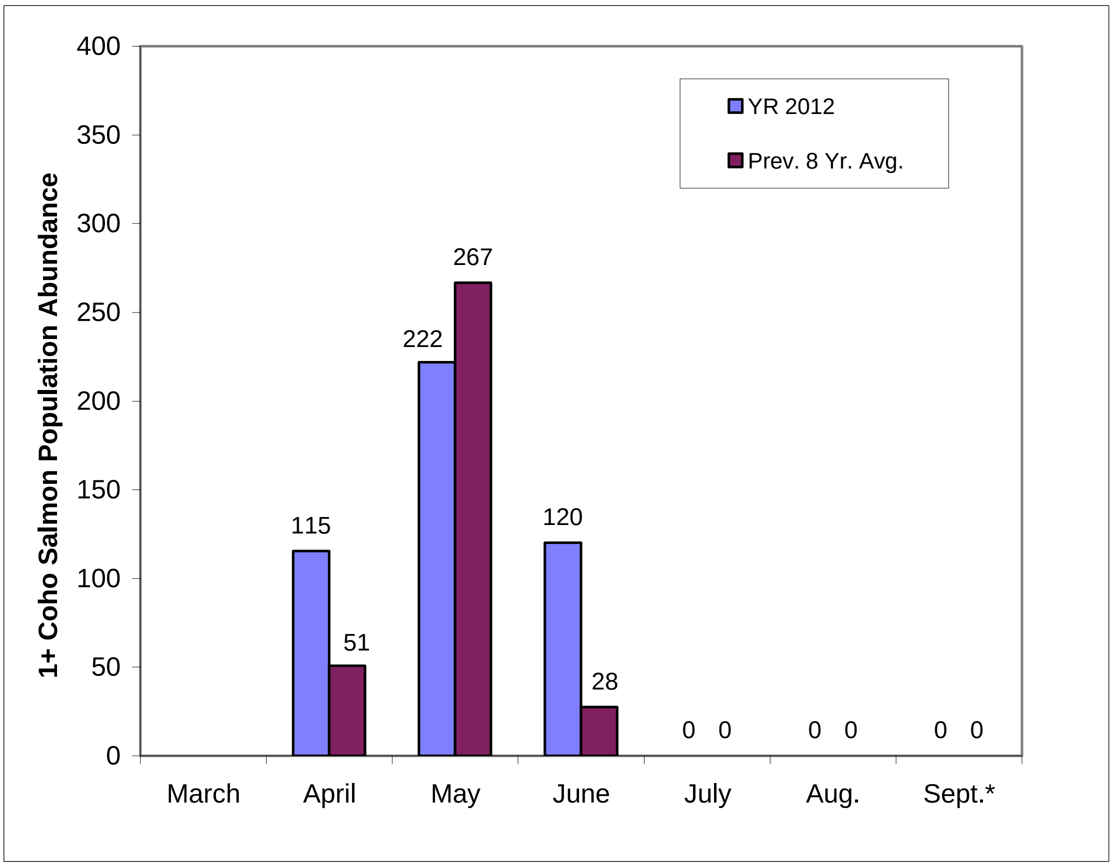


**Figure 14. Comparison of 1+ coho salmon population abundance by month in YR 2012 with the previous eight year average (* denotes monthly average of years 2010-2011), lower Redwood Creek, Humboldt County, CA.**

The peak in weekly abundance in YR 2012 occurred 4/23 – 4/29 (Table 9). For the nine study years, one peak occurred in late April, two peaks occurred in late April/early May, two peaks occurred in early-mid May, one peak occurred in mid May, two peaks occurred in late May, and one peak occurred in early-mid June (Table 9).

Population emigration ended during the week of 6/25 – 7/01 in YR 2012, 6/18 – 6/24 in YR 2011, 6/11 – 6/17 in YR 2010, 6/11 – 6/17 in YR 2009, 6/25 – 7/1 in YR 2008, 6/11

– 6/17 in YR 2007, 6/25 – 7/01 in YR 2006, 5/28 – 6/3 in YR 2005, and 6/4 – 6/10 in YR 2004.

**Table 9. Date of peak weekly 1+ coho salmon population emigration by study year (number of individuals in parentheses), lower Redwood Creek, Humboldt County, CA.**

| Study Year | Date of peak in weekly out-migration (number in parentheses) |
|---|---|
| 2004 | 4/30 - 5/06 (182) |
| 2005 | 5/07 - 5/13 (80) |
| 2006 | 6/04 - 6/10 (135) |
| 2007 | 5/21 - 5/27 (32) |
| 2008 | 5/21 - 5/27 (398) |
| 2009 | 5/14 - 5/20 (217) |
| 2010 | 4/30 - 5/06 (12) |
| 2011 | 5/07 - 5/13 (85) |
| 2012 | 4/23 - 4/29 (105) |

**<u>Cutthroat Trout</u>**

The population estimate of cutthroat trout emigrating past the trap site in lower Redwood Creek in YR 2012 equaled 201 individuals with a 95% CI of 135 – 266 individuals (Figure 15). Population estimate error (or uncertainty) equaled $\pm$ 33% or 66 individuals. Population abundance in YR 2012 was the second highest of record. The average population abundance in YRS 2006 – 2008, and 2010 - 2012 equaled 135 (SD = 77; SEM = 32).

Correlation of time (study year) on yearly population estimates indicated a non-significant, positive relationship (n = 6, p = 0.18, r = 0.63, power = 0.25) (Figure 15).

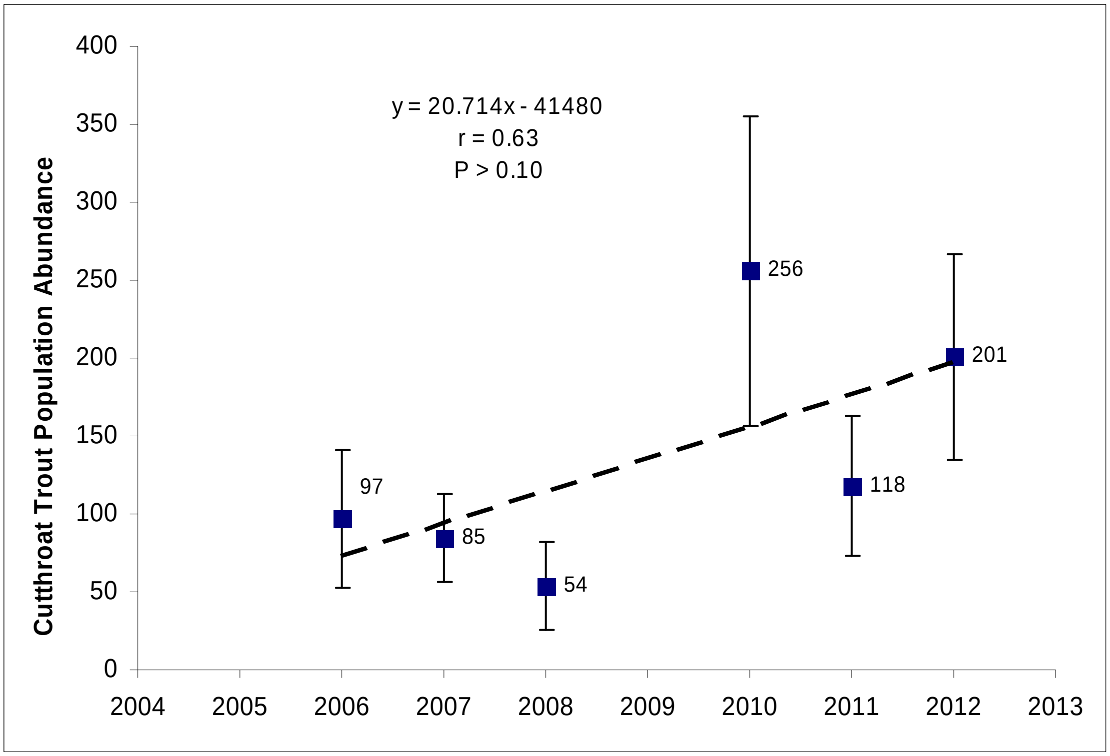


**Figure 15. Cutthroat trout population abundance estimates in YRS 2006 – 2008 and YRS 2010 - 2012 (error bars are 95% confidence intervals). Numeric values next to box represent number of individuals. Line of best fit is a regression line (dashed line indicates non-significance), with corresponding equation, correlation value (r), and p value, lower Redwood Creek, Humboldt County, CA.**

Monthly population emigration peaked in June in YR (N = 68 or 34% of total) in YR 2012, compared to July (N =  or 27% of total) for the average of YRS 2006 – 2008, and 2010 - 2011 (Figure 16).  In YR 2011, monthly emigration peaked in August (N = 76 or 64% of total).  The two most important months were June and July (65% of total) in YR 2012, compared to July and August (53% of total) for the average of years 2006 - 2008 and 2010 - 2011.  In YR 2011, July and August were the two most important months (79% of total).

The peak in weekly abundance in YR 2012 occurred 6/25 – 7/01, and was much earlier than peaks in YRS 2010 and 2011 (Table 10).  For the six study years when population abundances were determined, two peaks occurred in late June/early July, two peaks occurred in July, one peak occurred in August, and one peak occurred in September (Table 10).

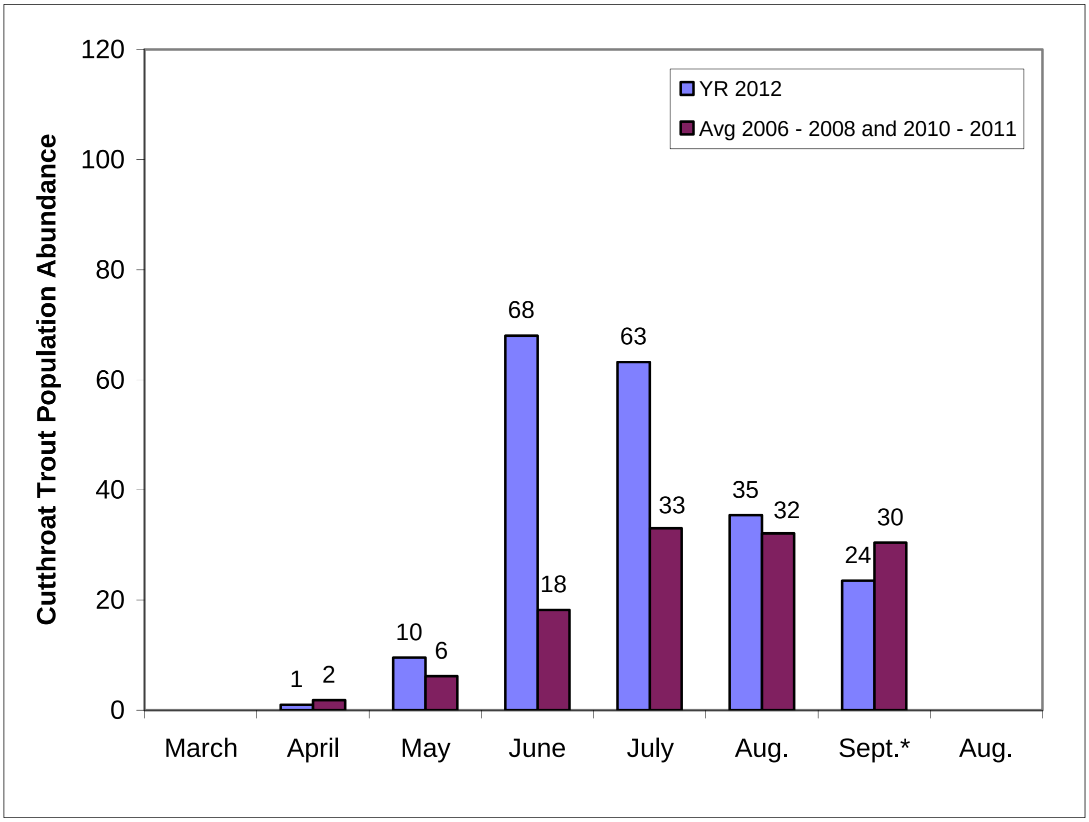


**Figure 16. Comparison of cutthroat trout population abundance by month in YR 2012 with the average of YRS 2006 – 2008 and 2010 (* denotes monthly average of years 2010-2011), lower Redwood Creek, Humboldt County, CA.**

**Table 10. Date of peak weekly cutthroat trout population emigration by study year (number of individuals in parentheses), lower Redwood Creek, Humboldt County, CA.**

| Study Year | Date of peak in weekly out-migration (number in parentheses) | |
|---|---|---|
| 2004 | | |
| 2005 | | |
| 2006 | 7/23 – 7/29 | (18) |
| 2007 | 7/09 – 7/15 | (15) |
| 2008 | 6/25 – 7/01 | (20) |
| 2009 | | |
| 2010 | 9/03 – 9/09 | (63) |
| 2011 | 8/13 – 8/19 | (46) |
| 2012 | 6/25 – 7/01 | (40) |

## 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 (i.e. the actual catches of 0+ steelhead trout are less than expected 0+ steelhead trout population migration). Far more 1+ steelhead trout migrated downstream than either 0+ or 2+ steelhead trout in YR 2012, and for all years combined (Table 11).

Using catch and population data, the ratio of 0+ steelhead trout to 1+ steelhead trout to 2+ steelhead trout equaled 1.9:9.4:1 in YR 2012, 2:3.7:1 in YR 2011, 0.8:4.5:1 in YR 2010, 1:23:1 in YR 2009, 4:5:1 in YR 2008, 3:3:1 in YR 2007, 3:4:1 in YR 2006, 0.2:4:1 in YR 2005, and 1:4:1 in YR 2004.

The ratio of 1+ steelhead trout to 2+ steelhead trout equaled 9.4:1 in YR 2012, 3.7:1 in YR 2011, 4.5:1 in YR 2010, 23:1 in YR 2009, 5:1 in YR 2008, 3:1 in YR 2007, and close to 4:1 in YRS 2004 - 2006.

**Table 11. Comparison of 0+ steelhead trout, 1+ steelhead trout, and 2+ steelhead trout percent composition of total juvenile steelhead trout downstream migration in YR 2012 with the previous eight year average, lower Redwood Creek, Humboldt County, CA.**

| | Percent composition of total juvenile steelhead trout out-migration | | |
|---|---|---|---|
| Study Year | 0+ steelhead* | 1+ steelhead | 2+ steelhead |
| 2012 | 15.8 | 76.1 | 8.1 |
| Prev. 8 Yr. Avg. | 23.6 | 62.7 | 13.7 |
| All years combined | 26.4 | 60.3 | 13.3 |

* Uses actual catches instead of population estimate.

## Fork Lengths and Weights

### 0+ Chinook Salmon

We measured (FL mm) 3,707 and weighed (g) 2,400 0+ Chinook salmon in YR 2012 (Table 12). Average FL (71 mm) and Wt (4.5 g) in YR 2012 were greater than the previous eight year average (Table 12). The average FL over nine study years equaled 67.5 mm (SD = 5.2 mm; SEM = 1.8 mm), and for Wt equaled 3.76 g (SD = 0.90 g mm;

SEM = 0.30 g). Average FL's (mm) by year were negatively related to yearly population abundances (Regression, p = 0.06, $R^2$ = 0.43, negative slope, power = 0.51, alpha = 0.10). Average Wt's (g) by year were not significantly related to yearly population abundances (Regression, p = 0.10, $R^2$ = 0.33, negative slope, power = 0.37, alpha = 0.10).

**Table 12. 0+ Chinook salmon average and median fork length (mm) and weight (g) in YRS 2004 - 2012, lower Redwood Creek, Humboldt County, CA.**

| | 0+ Chinook Salmon | | | | | | |
|---|---|---|---|---|---|---|---|
| | | Fork Length (mm) | | | Weight (g) | | |
| YR | (N) | n | Avg. | Median | n | Avg. | Median |
| 2004 | 554,890 | 3,192 | 59.8 | 61.0 | 1,429 | 2.55 | 2.40 |
| 2005 | 131,164 | 2,723 | 74.3 | 80.0 | 1,284 | 5.17 | 5.60 |
| 2006 | 85,149 | 2,058 | 76.2 | 78.0 | 1,715 | 4.96 | 5.10 |
| 2007 | 141,059 | 2,666 | 66.6 | 70.0 | 2,031 | 3.28 | 3.20 |
| 2008 | 173,758 | 3,113 | 64.5 | 67.0 | 2,099 | 3.04 | 3.10 |
| 2009 | 208,819 | 3,294 | 64.9 | 66.0 | 2,159 | 3.34 | 3.10 |
| 2010 | 132,733 | 3,543 | 66.8 | 71.0 | 2,125 | 3.71 | 3.50 |
| 2011 | 147,719 | 3,511 | 64.1 | 69.0 | 2,135 | 3.29 | 3.30 |
| Avg. | | | 67.2 | | | 3.67 | |
| 2012 | 210,370 | 3,707 | 70.6 | 75.0 | 2,400 | 4.46 | 4.50 |

## 1+ Chinook Salmon

We measured 18 1+ Chinook salmon for FL (mm) and 18 1+ Chinook salmon for Wt (g) in YR 2012 (Table 13). Average FL (114.2 mm) and Wt (16.56 g) in YR 2012 were close to the average of years 2005, 2008 - 2011 (Table 13). The average seasonal FL using all year's data equaled 114.3 mm (SD = 6.0 mm; SEM = 2.5 mm), and for Wt equaled 16.61 g (SD = 3.04 g mm; SEM = 1.24 g).

## 0+ Steelhead Trout

We measured (FL mm) 2,686 0+ steelhead trout in YR 2012 (Table 14). Average FL (59.3 mm) in YR 2012 was greater than previous study years (Table 14). The average FL using all year's data equaled 54.8 mm (SD = 3.2 mm; SEM = 1.1 mm). Average FL's (mm) by year were not related to catches by year (Regression, p = 0.44, R2 = 0.09, negative slope, power = 0.11, alpha = 0.10).

**Table 13. 1+ Chinook salmon average and median fork length (mm) and weight (g) in YRS 2005, 2008 - 2012, lower Redwood Creek, Humboldt County, CA.**

| | | 1+ Chinook Salmon | | | | | |
|---|---|---|---|---|---|---|---|
| | | Fork Length (mm) | | | Weight (g) | | |
| YR | N | n | Avg. | Median | n | Avg. | Median |
| 2004 | >2 | 2 | - | - | - | - | - |
| 2005 | >11 | 11 | 109.2 | 111.0 | 11 | 13.60 | 13.50 |
| 2006 | 0 | - | - | - | - | - | - |
| 2007 | 0 | - | - | - | - | - | - |
| 2008 | >10 | 10 | 113.4 | 113.0 | 9 | 15.80 | 14.2 |
| 2009* | 310 | 57 | 108.8 | 110.0 | 57 | 14.08 | 14.0 |
| 2010* | 22 | 10 | 125.4 | 126.0 | 10 | 22.00 | 21.9 |
| 2011* | 15 | 11 | 114.5 | 117.0 | 10 | 17.64 | 19.25 |
| Avg. | | | 114.3 | | | 16.62 | |
| 2012* | 64 | 18 | 114.2 | 114.0 | 18 | 16.56 | 16.80 |

* Denotes year when population abundance was determined.

**Table 14. 0+ steelhead trout average and median fork length in YRS 2004 - 2012, lower Redwood Creek, Humboldt County, CA.**

| | | 0+ Steelhead Trout* | | | | | |
|---|---|---|---|---|---|---|---|
| | | Fork Length (mm) | | | Weight (g) | | |
| YR | (N) | n | Avg. | Median | n | Avg. | Median |
| 2004 | > 18,642 | 2,939 | 49.6 | 52.0 | - | - | - |
| 2005 | > 1,345 | 1,099 | 51.1 | 53.5 | - | - | - |
| 2006 | > 29,957 | 2,757 | 55.8 | 58.0 | - | - | - |
| 2007 | > 42,827 | 3,355 | 53.8 | 56.0 | - | - | - |
| 2008 | > 39,892 | 2,787 | 52.9 | 56.0 | - | - | - |
| 2009 | > 2,489 | 1,557 | 56.7 | 60.0 | - | - | - |
| 2010 | > 4,566 | 2,275 | 56.9 | 63.0 | | | |
| 2011 | > 9,864 | 2,354 | 57.5 | 58.0 | | | |
| Avg. | | | 54.3 | | - | - | - |
| 2012 | > 7,301 | 2,686 | 59.3 | 61.0 | | | |

* Includes a small, but unknown number of cutthroat trout.

## 1+ Steelhead Trout

We measured (FL mm) 2,238 and weighed (g) 1,829 1+ steelhead trout in YR 2012 (Table 15). Average FL and Wt in YR 2012 were greater than previous study years (Table 15). The average seasonal FL over nine study years equaled 89.7 mm (SD = 3.7 mm; SEM = 1.2 mm), and for Wt equaled 8.36 g (SD = 1.16 g mm; SEM = 0.39 g). Average FL's (mm) by year were negatively related to yearly population abundances (Regression, p = 0.02, $R^2$ = 0.56, negative slope, power = 0.72, alpha = 0.10). Average Wt's (g) by year were also negatively related to yearly population abundances (Regression, p = 0.05, $R^2$ = 0.45, negative slope, power = 0.53, alpha = 0.10).

**Table 15. 1+ steelhead trout average and median fork length (mm) and weight (g) in YRS 2004 - 2012, lower Redwood Creek, Humboldt County, CA.**

| | 1+ Steelhead Trout | | | | | | |
|---|---|---|---|---|---|---|---|
| | | Fork Length (mm) | | | Weight (g) | | |
| YR | (N) | n | Avg. | Median | n | Avg. | Median |
| 2004 | 77,221 | 2,713 | 84.4 | 81.0 | 1,201 | 7.04 | 5.80 |
| 2005 | 32,901 | 1,442 | 90.8 | 89.0 | 919 | 8.31 | 7.40 |
| 2006 | 44,937 | 2,449 | 87.0 | 84.0 | 2,150 | 7.73 | 6.50 |
| 2007 | 37,683 | 2,761 | 88.6 | 87.0 | 2,146 | 7.88 | 7.00 |
| 2008 | 42,068 | 2,875 | 87.0 | 85.0 | 2,025 | 7.48 | 6.60 |
| 2009 | 40,728 | 2,349 | 87.6 | 86.0 | 1,673 | 7.59 | 6.80 |
| 2010 | 27,071 | 2,315 | 92.1 | 91.0 | 1,505 | 8.94 | 8.00 |
| 2011 | 20,501 | 1,945 | 93.2 | 92.0 | 1,168 | 9.77 | 8.85 |
| Avg. | | | 88.8 | | | 8.09 | |
| 2012 | 35,174 | 2,238 | 96.2 | 95.0 | 1,829 | 10.51 | 9.70 |

## 2+ Steelhead Trout

We measured (FL mm) 474 and weighed (g) 424 2+ steelhead trout in YR 2012 (Table 16). Average FL (142.8 mm) and Wt (31.45 g) in YR 2012 were slightly greater than the previous eight year average (Table 16). The average seasonal FL over nine study years equaled 142.2 mm (SD = 2.1 mm; SEM = 0.7 mm), and for Wt equaled 30.94 g (SD = 1.75 g mm; SEM = 0.58 g). Average FL's (mm) by year were not significantly related to yearly population abundances (Regression, p = 0.59, $R^2$ = 0.04, negative slope, power = 0.08, alpha = 0.10). Average Wt's (g) by year were not significantly related to yearly population abundances (Regression, p = 0.79, $R^2$ = 0.01, negative slope, power = 0.06, alpha = 0.10).

**Table 16. 2+ steelhead trout average and median fork length (mm) and weight (g) in YRS 2004 - 2012, lower Redwood Creek, Humboldt County, CA.**

| | | 2+ Steelhead Trout | | | | | |
|---|---|---|---|---|---|---|---|
| | | Fork Length (mm) | | | Weight (g) | | |
| YR | (N) | n | Avg. | Median | n | Avg. | Median |
| 2004 | 19,353 | 886 | 141.9 | 135.0 | 864 | 30.69 | 26.00 |
| 2005 | 8,754 | 413 | 143.2 | 139.0 | 412 | 31.25 | 27.05 |
| 2006 | 12,091 | 1,056 | 139.1 | 133.0 | 1,020 | 28.49 | 24.70 |
| 2007 | 12,607 | 1,148 | 141.7 | 134.0 | 1,098 | 31.15 | 25.60 |
| 2008 | 9,021 | 1,134 | 142.6 | 132.0 | 1,099 | 31.27 | 24.30 |
| 2009 | 1,743 | 234 | 140.4 | 133.0 | 219 | 28.65 | 23.90 |
| 2010 | 6,033 | 589 | 141.8 | 139.0 | 581 | 31.02 | 28.20 |
| 2011 | 5,587 | 653 | 146.6 | 145.0 | 638 | 34.49 | 31.65 |
| Avg. | | | 142.2 | | | 30.88 | |
| 2012 | 3,748 | 474 | 142.8 | 138.0 | 424 | 31.45 | 28.10 |

**<u>0+ Coho Salmon</u>**

We measured (FL mm) 77 and weighed (g) 75 0+ coho salmon in YR 2012 (Table 17). Average FL and Wt in YR 2012 were slightly greater than the previous eight year average (Table 17). The average FL over nine study years equaled 67.7 mm (SD = 6.9 mm; SEM = 2.3 mm), and for Wt equaled 4.08 g (SD = 1.24 g mm; SEM = 0.41 g). Average FL's (mm) by year were not significantly related to yearly population abundances (Regression, n = 7, p = 0.15, $R^2$ = 0.37, negative slope, power = 0.28, alpha = 0.10). Average Wt's (g) by year were not significantly related to yearly population abundances (Regression, n = 7, p = 0.22, $R^2$ = 0.29, negative slope, power = 0.21, alpha = 0.10).

**<u>1+ Coho Salmon</u>**

We measured (FL mm) 79 and weighed (g) 77 1+ coho salmon in YR 2012 (Table 18). Average FL (104.6 mm) and Wt (12.58) in YR 2012 were slightly less than the previous eight year average (Table 18). The average seasonal FL over nine study years equaled 106.3 mm (SD = 3.3 mm; SEM = 1.1 mm), and for Wt equaled 13.02 g (SD = 1.14 g mm; SEM = 0.38 g). Average FL's (mm) by year were not significantly related to yearly population abundances (Regression, p = 0.58, $R^2$ = 0.05, negative slope, power = 0.08, alpha = 0.10). Average Wt's (g) by year were also not significantly related to yearly population abundances (Regression, p = 0.54, $R^2$ = 0.06, negative slope, power = 0.09, alpha = 0.10).

**Table 17. 0+ coho salmon average and median fork length (mm) and weight (g) in YRS 2004 - 2012, lower Redwood Creek, Humboldt County, CA.**

| | 0+ Coho Salmon | | | | | | |
|---|---|---|---|---|---|---|---|
| | | Fork Length (mm) | | | Weight (g) | | |
| YR | (N) | n | Avg. | Median | n | Avg. | Median |
| 2004 | > 202 | 202 | 66.2 | 66.0 | 198 | 3.76 | 3.50 |
| 2005 | > 53 | 53 | 61.8 | 63.0 | 50 | 3.38 | 3.15 |
| 2006* | 508 | 106 | 64.6 | 67.0 | 106 | 3.40 | 3.50 |
| 2007* | 1,057 | 290 | 67.4 | 67.0 | 276 | 3.83 | 3.60 |
| 2008* | 1,886 | 391 | 61.1 | 64.0 | 383 | 3.04 | 3.00 |
| 2009* | 63 | 32 | 66.2 | 68.0 | 32 | 3.48 | 3.50 |
| 2010* | 10 | 6 | 84.5 | 84.0 | 6 | 7.20 | 6.90 |
| 2011* | 884 | 230 | 68.5 | 68.0 | 227 | 4.27 | 3.90 |
| Avg. | | | 67.5 | | | 4.04 | |
| 2012* | 201 | 77 | 69.2 | 67.0 | 75 | 4.33 | 3.30 |

* Denotes study year when population abundance was determined.

**Table 18. 1+ coho salmon average and median fork length (mm) and weight (g) in YRS 2004 - 2012, lower Redwood Creek, Humboldt County, CA.**

| | 1+ Coho Salmon | | | | | | |
|---|---|---|---|---|---|---|---|
| | | Fork Length (mm) | | | Weight (g) | | |
| YR | (N) | n | Avg. | Median | n | Avg. | Median |
| 2004 | 535 | 69 | 105.3 | 105.0 | 67 | 13.09 | 12.09 |
| 2005 | 183 | 39 | 109.4 | 110.0 | 39 | 13.71 | 13.40 |
| 2006 | 427 | 69 | 105.7 | 105.0 | 69 | 12.77 | 12.50 |
| 2007 | 102 | 34 | 104.9 | 107.0 | 34 | 12.36 | 12.30 |
| 2008 | 879 | 242 | 109.1 | 110.0 | 229 | 13.73 | 13.70 |
| 2009 | 482 | 101 | 100.0 | 100.0 | 100 | 10.70 | 10.40 |
| 2010 | 33 | 11 | 111.0 | 111.0 | 11 | 14.80 | 14.70 |
| 2011 | 113 | 24 | 106.7 | 106.5 | 23 | 13.40 | 12.90 |
| Avg. | | | 106.5 | | | 13.07 | |
| 2012 | 458 | 79 | 104.6 | 103.0 | 77 | 12.58 | 12.0 |

## Cutthroat Trout

We measured 70 (FL mm) and weighed (g) 64 cutthroat trout in YR 2012 (Table 19). Average FL and Wt in YR 2012 were less than the previous eight year average (Table 19). The average seasonal FL over nine study years equaled 194.0 mm (SD = 17.7 mm; SEM = 5.9 mm), and for Wt equaled 78.62 g (SD = 14.99 g mm; SEM = 5.00 g).

**Table 19. Cutthroat trout average and median fork length (mm) and weight (g) in YRS 2004 - 2012, lower Redwood Creek, Humboldt County, CA.**

| | Cutthroat Trout | | | | | | |
|---|---|---|---|---|---|---|---|
| | | Fork Length (mm) | | | Weight (g) | | |
| YR | (N) | n | Avg. | Median | n | Avg. | Median |
| 2004 | > 37 | 36 | 171.0 | 161.5 | 36 | 61.28 | 43.15 |
| 2005 | > 9 | 9 | 228.7 | 185.0 | 7 | 70.14 | 64.80 |
| 2006* | 97 | 36 | 193.4 | 182.0 | 35 | 89.80 | 65.60 |
| 2007* | 85 | 44 | 201.7 | 199.0 | 44 | 97.09 | 84.55 |
| 2008* | 54 | 22 | 178.9 | 163.5 | 21 | 65.87 | 45.10 |
| 2009 | > 8 | 8 | 200.0 | 156.0 | 7 | 93.29 | 33.10 |
| 2010* | 256 | 82 | 191.1 | 189.5 | 80 | 75.81 | 64.40 |
| 2011* | 118 | 57 | 204.7 | 199.0 | 54 | 94.01 | 79.95 |
| Avg. | | | 196.2 | | | 80.91 | |
| 2012* | 201 | 70 | 176.1 | 176.5 | 64 | 60.26 | 57.8 |

* Denotes study year when population abundance was determined.

### 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 each study year (Table 20). A totally random distribution would equal 33.3% for each designation (parr, pre-smolt, smolt). The combined percentage of pre-smolts and smolts in YR 2012 for 1+ steelhead trout was nearly 100%, and for 2+ steelhead trout equaled 100% (Table 20).

**Table 20. Developmental stages of captured 1+ and 2+ steelhead trout in YRS 2004 - 2012, lower 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 |
| 2004 | 0.2 | 31.5 | 68.3 | 0.0 | 5.7 | 94.3 |
| 2005 | 0.2 | 13.6 | 86.2 | 0.0 | 1.7 | 98.3 |
| 2006 | 0.1 | 25.1 | 74.8 | 0.0 | 2.1 | 97.9 |
| 2007 | 0.5 | 22.4 | 77.1 | 0.0 | 6.1 | 93.9 |
| 2008 | 0.6 | 15.3 | 84.1 | 0.0 | 1.5 | 98.5 |
| 2009 | 0.0 | 12.1 | 87.9 | 0.0 | 0.8 | 99.2 |
| 2010 | 0.1 | 11.1 | 88.8 | 0.0 | 0.5 | 99.5 |
| 2011 | 0.1 | 17.0 | 82.9 | 0.0 | 0.7 | 99.3 |
| Avg. | 0.2 | 18.5 | 81.3 | 0.0 | 2.4 | 97.6 |
| 2012 | 0.2 | 19.2 | 80.6 | 0.0 | 1.9 | 98.1 |

## 1+ Chinook Salmon, 1+ Coho Salmon, and Cutthroat Trout

All 1+ Chinook salmon and 1+ coho salmon captured in YR 2012 were in a smolt stage. Cutthroat trout catches consisted of 1% parr, 7% pre-smolt, and 92% smolt.

## Trapping Mortality

The mortality of fish that were captured in the trap and subsequently handled was closely monitored over the course of each trapping period. The trap mortality (includes handling mortality) for a given species at age in YR 2012 ranged from 0.00 – 1.43%, and using all data (pooling) equaled 0.19% of the total captured and handled (Table 21). Mortality in YR 2012 was less than average (Table 22). 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 21. Trapping mortality for juvenile salmonids captured in YR 2012, lower Redwood Creek, Humboldt County, CA.**

| | Trapping Mortality in YR 2012 | | |
|---|---|---|---|
| Age/spp. | No. captured* | No. of mortalities | Percent mortality |
| 0+ Chinook | 76,404 | 147 | 0.19 |
| 1+ Chinook | 18 | 0 | 0.00 |
| 0+ Steelhead | 7,211 | 14 | 0.19 |
| 1+ Steelhead | 3,287 | 3 | 0.09 |
| 2+ Steelhead | 472 | 0 | 0.00 |
| Cutthroat Trout | 70 | 1 | 1.43 |
| 0+ Coho | 78 | 0 | 0.00 |
| 1+ Coho | 82 | 1 | 1.30 |
| Overall: | 87,632 | 166 | 0.19 |

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

**Table 22. Comparison of trapping mortality of juvenile salmonids in nine consecutive study years, lower Redwood Creek, Humboldt County, CA.**

| | Trapping Mortality | | |
|---|---|---|---|
| Study Year | No. captured* | No. of mortalities | Percent mortality |
| 2004 | 88,088 | 167 | 0.19 |
| 2005 | 14,736 | 143 | 0.97 |
| 2006 | 55,671 | 93 | 0.17 |
| 2007 | 92,165 | 57 | 0.06 |
| 2008 | 126,201 | 140 | 0.11 |
| 2009 | 59,655 | 1,064 | 1.78 |
| 2010 | 52,649 | 113 | 0.21 |
| 2011 | 70,187 | 148 | 0.21 |
| 2012 | 87,632 | 166 | 0.19 |
| Avg. | 71,887 | 233 | 0.46 |
| Pooled | 646,984 | 2,093 | 0.32 |

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

## Stream Temperatures

The average daily (24 hr period) stream temperature from 4/18/12 – 9/24/12 was 15.4 $^{o}$C (or 59.8 $^{o}$F) (95% CI = 15.1 – 15.8 $^{o}$C), with daily averages ranging from 10.0 – 18.1 $^{o}$C (50.0 – 64.6 $^{o}$F). Median daily stream temperature in YR 2012 equaled 16.2 $^{o}$C (or 61.2 $^{o}$F). Average stream temperatures during the trapping periods in YRS 2004 – 2012 were similar, with the largest difference among years equaling 1.4 $^{o}$C (Table 23). With inclusion of data from YR 2012, average daily stream temperature (during the trapping period) over study years did not significantly change over time (Correlation, $p = 0.16$, $r = 0.51$, slope is negative, power = 0.28, alpha = 0.10). Similar to past data, average daily stream temperatures during the trapping period in YR 2012 were inversely related to the average daily stream discharge during the trapping period (Regression, $p < 0.000001$, $R^2 = 0.73$, slope is negative, power = 1.0). The minimum stream temperature in YR 2012 equaled 9.6 $^{o}$C (49.3 $^{o}$F) and occurred on 4/27/12; the maximum stream temperature equaled 21.0 $^{o}$C (69.8 $^{o}$F) and occurred on 7/23/12, 7/24/12, and 8/08/12 (Table 23).

**Table 23. Average, minimum, and maximum stream temperatures ($^{o}$C) (standard error of mean in parentheses) at the trap site during the trapping periods in YRS 2004 – 2012, lower Redwood Creek, Humboldt County, CA.**

| | Stream Temperature | | | | | |
|---|---|---|---|---|---|---|
| | Celsius | | | Fahrenheit | | |
| Study Year | Avg. | Min. | Max. | Avg. | Min. | Max. |
| 2004 | 15.5 (0.2) | 9.3 | 22.6 | 60.0 (0.8) | 48.7 | 72.3 |
| 2005 | 15.6 (0.3) | 9.0 | 22.6 | 60.1 (0.5) | 48.2 | 72.3 |
| 2006 | 15.5 (0.3) | 7.1 | 23.1 | 60.0 (0.5) | 44.8 | 73.6 |
| 2007 | 15.3 (0.3) | 8.1 | 24.2 | 59.5 (0.6) | 46.6 | 75.6 |
| 2008 | 14.2 (0.3) | 6.9 | 21.8 | 57.6 (0.5) | 44.4 | 71.2 |
| 2009 | 14.7 (0.2) | 7.4 | 21.2 | 58.5 (0.4) | 45.3 | 70.2 |
| 2010 | 14.6 (0.2) | 8.2 | 21.3 | 58.3 (0.4) | 46.8 | 70.3 |
| 2011 | 14.5 (0.3) | 7.4 | 21.8 | 58.0 (0.5) | 45.3 | 71.2 |
| 2012 | 15.4 (0.2) | 9.6 | 21.0 | 59.8 (0.3) | 49.3 | 69.8 |
| Avg. | 15.0 (0.2) | | | 59.1 (0.3) | | |

Average monthly stream temperatures during the majority of the trapping season (April – July) in YR 2012 ranged from 11.5 – 17.2 $^{o}$C (52.7 – 63.0 $^{o}$F) (Table 24). Highest stream temperatures occurred in the later part of the trapping season (June and July) each study year. The MWAT during the trapping period in YR 2012 at the trap site was 18.0 $^{o}$C (64.4 $^{o}$F); and occurred on 8/11/12 (Table 25). MWMT in YR 2012 was 20.7 $^{o}$C (69.3 $^{o}$F) and occurred on 8/11/12 as well (Table 25). MWAT and MWMT in YR 2012 were similar to previous study years (Table 25). The average daily stream temperature (transformed) significantly increased over the study period (days, transformed) in YR 2012 (Correlation, $p < 0.000001$, $r = 0.89$, slope is positive, power = 1.0) (Figure 16), as well as in past study years (Figure 17).

**Table 24. Average monthly stream temperature (°C) (°F in parentheses) at the trapping site in study years 2004 - 2012, lower Redwood Creek, Humboldt County, CA.**

| | Average stream temperature in Celsius (°F in parentheses) | | | | |
|---|---|---|---|---|---|
| Study Year | April | May | June | July | Avg. |
| 2004 | 11.9 (53.4) | 14.7 (58.5) | 16.8 (62.2) | 18.6 (65.5) | 15.5 (59.9) |
| 2005 | 11.5 (52.7) | 12.8 (55.0) | 14.6 (58.3) | 18.5 (65.3) | 14.3 (57.7) |
| 2006 | 10.4 (50.7) | 13.9 (57.0) | 16.7 (62.1) | 18.2 (64.8) | 14.8 (58.6) |
| 2007 | 10.7 (51.3) | 13.4 (56.1) | 16.4 (61.5) | 18.5 (65.3) | 14.8 (58.6) |
| 2008 | 9.8 (49.6) | 13.5 (56.3) | 15.6 (60.1) | 17.4 (63.3) | 14.1 (57.4)) |
| 2009 | 10.7 (51.3) | 12.9 (55.2) | 15.7 (60.3) | 17.3 (63.1) | 14.2 (57.6) |
| 2010 | 10.1 (50.2) | 11.1 (52.0) | 13.8 (56.8) | 17.2 (63.0) | 13.1 (55.6) |
| 2011 | 9.2 (48.6) | 11.3 (52.3) | 14.5 (58.1) | 17.4 (63.3) | 13.1 (55.6) |
| 2012 | 11.5 (52.7) | 12.8 (55.0) | 15.2 (59.4) | 17.2 (63.0) | 14.1 (57.4) |
| Avg. | 10.6 (51.1) | 12.9 (55.2) | 15.5 (59.9) | 17.8 (64.0) | |

**Table 25. Maximum weekly average temperature (MWAT) and maximum weekly maximum temperature (MWMT) for stream temperatures °C (°F in parentheses) at the trap site in lower Redwood Creek, Humboldt County, CA., study years 2004 – 2012.**

| | MWAT | | MWMT | |
|---|---|---|---|---|
| Study Year | Date of Occurrence | °C (°F) | Date of Occurrence | °C (°F) |
| 2004 | 7/22/04 | 19.3 (66.7) | 7/18/04 | 22.2 (72.0) |
| 2005 | 7/17/05 | 19.2 (66.6) | 7/17/05 | 22.1 (71.8) |
| 2006 | 7/25/06 | 19.2 (66.6) | 7/25/06 | 22.7 (72.9) |
| 2007 | 7/21/07 | 19.2 (66.6) | 7/31/07 | 22.4 (72.3) |
| 2008 | 7/07/08 | 18.2 (64.8) | 7/07/08 | 21.1 (69.8) |
| 2009 | 8/11/09 | 18.3 (64.9) | 8/11/09 | 20.9 (69.7) |
| 2010 | 7/14/10 | 17.9 (64.3) | 7/17/10 | 20.8 (69.4) |
| 2011 | 7/29/11 | 18.1 (64.6) | 7/29/11 | 21.2 (70.2) |
| 2012 | 8/11/12 | 18.0 (64.4) | 8/11/12 | 20.7 (69.3) |

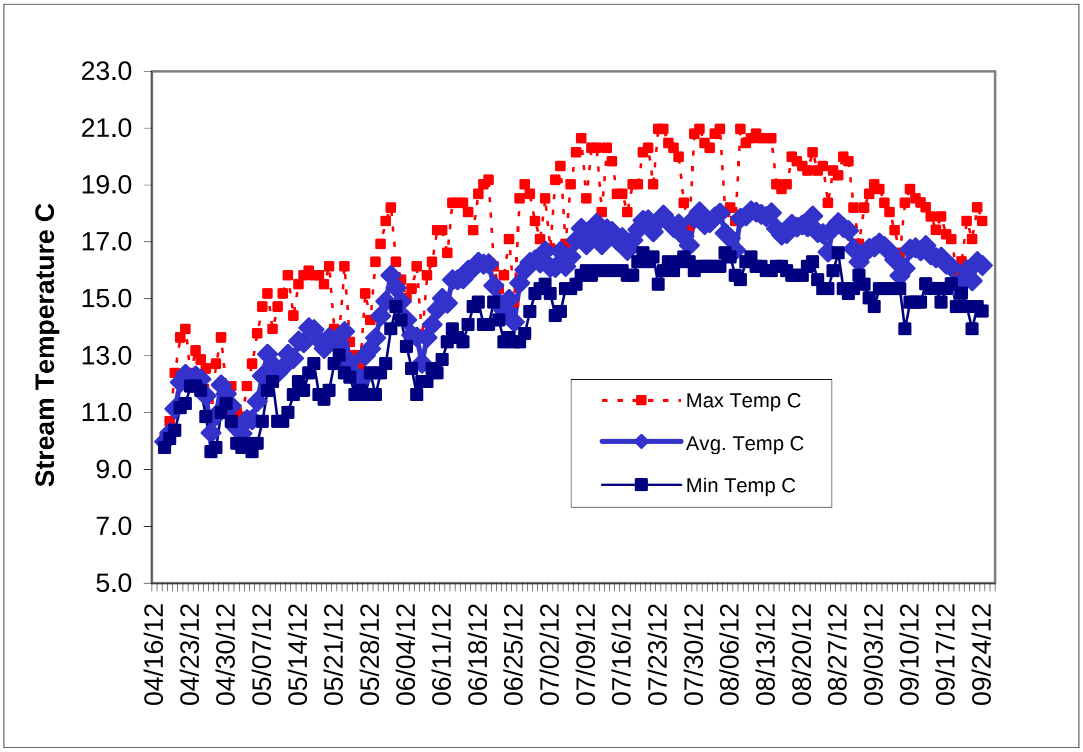


**Figure 17. Average, minimum, and maximum stream temperatures ($^{o}C$) in lower Redwood Creek, Humboldt County, CA., 2012.**

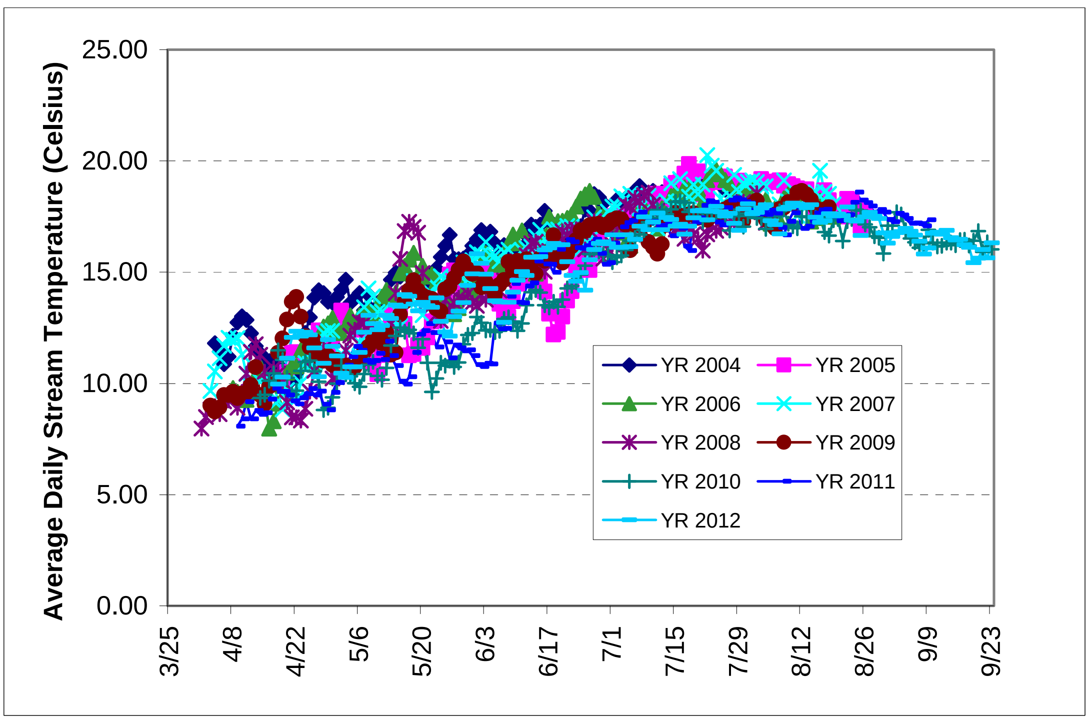


**Figure 18. Average daily stream temperatures ($^{o}C$) in YRS 2004 – 2012, lower Redwood Creek, Humboldt County, CA.**

## DISCUSSION

The main goal of our downstream migration study in lower Redwood Creek is to estimate and monitor the production of Chinook salmon, steelhead trout, coho salmon, and cutthroat trout from the majority of the Redwood Creek watershed in a reliable, long-term manner. The long term goal is to monitor trends in smolt abundance and smolt size, and to detect positive or negative changes due to watershed conditions and restoration activities in the basin. Redwood Creek is a difficult stream to monitor adult salmon and steelhead populations on a long term basis using traditional techniques (weirs and spawning ground surveys) due to adult salmon and steelhead run timing, water depth, precipitation, hydrology, and stream turbidity. However, "quantifying juvenile anadromous salmonid populations as they migrate seaward is the most direct assessment of stock performance in freshwater" (Seiler et al. 2004). 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 ninth consecutive year of trapping in lower Redwood Creek occurred during a WY with a 14% decrease in streamflow compared to the historic value, however, the average monthly stream discharge during the majority of the trapping season (April – July) in YR 2012 was 1.5 times greater than the historic average. The environmental conditions for downstream migrant trapping in YR 2012 were less difficult to operate the trap in compared to most study years, and we only missed one day of trapping due to high flow events and potentially, high debris loading in the trap's livebox. The estimates for catch and subsequent expansions to the population level, based on the missed trapping day, were negligible for each species at age; the greatest impact on a population estimate was estimated at 5%, and the adjusted point value easily fell within the 95% confidence interval of the un-adjusted point estimate. The number of fish missed when the trap was inoperable would not have greatly impacted population estimates. Thus, this season's trapping resulted in very good estimates of wild Chinook salmon, steelhead trout, cutthroat trout, and coho salmon smolt abundances from areas upstream of the trapping site. The abundance estimates for 1+ Chinook salmon smolts (+ or – 88%) and 1+ coho salmon smolts (+ or – 44%) were not as precise as for other species at age, yet sample sizes for marking these fish were much lower. The decrease in precision should not preclude the fact that yearling Chinook salmon smolts (N = 64) and coho salmon smolts (N = 458) were in low abundance in YR 2012.

### 0+ Chinook Salmon

0+ Chinook salmon (ocean-type) were the most numerous migrant captured in eight of nine consecutive study years. The correlation of 0+ Chinook salmon trap catches, study years, and whether or not there were flood type flows in the upper basin during egg incubation/embryogenesis with study years was significantly negative ($p = 0.02$). However, the best model to describe the variation in trap catches over years included the single variable of flood type flows in the upper basin ($p = 0.004$). Inference from these models suggest that the trap catches in lower Redwood Creek were strongly tied to Chinook salmon in the mid to upper basin, and to environmental conditions in the mid to upper basin with respect to stream flow, redd formation, and survival to emergence from redds.

On a population basis, 0+ Chinook salmon smolts were 1.5 – 5.7 times more abundant than 1+ and 2+ steelhead trout smolts combined over the nine years of study. The population abundance of 0+ Chinook salmon in YR 2012 (N = 210,370) was the second highest of record, 1.42 times greater than abundance in YR 2011, 62% less than the highest abundance measured in YR 2004 (N = 554,890), and 1.1 times greater than abundance for the average of the previous eight years. The overall trend in abundance over nine consecutive study years was negative; however, statistical significance was not detected, most likely due to the observed variation in population abundances and low sample sizes (n = 9 data points). Testing trends in abundance often requires numerous years of data to determine a statistically, reliable trend. Trends with low sample sizes not only preclude statistical significance, but the slope of the trend line can also change with the addition or omission of a single data point. For example, the slope of the trend line in Chinook salmon smolt abundance over nine years was greatly influenced by the high abundance determined in YR 2004; if we removed YR 2004 data, the slope would be positive instead of negative. The abundance in YR 2004 could be considered an outlier, however, we did catch more fish in that year than all years except for YRS 2008 and 2012, even though the stream gradient in YR 2004 was much less than the gradient in YRS 2006 - 2010. At this trapping site, trapping efficiencies are positively related to the stream gradient. In addition, population abundance in upper Redwood Creek peaked at about 630,000 individuals in YR 2004, which was much higher than other study years in that data set. Thus, I did not consider YR 2004 data in lower Redwood Creek to be unreasonable, or an outlier. Based upon data collected in upper Redwood Creek, it may take nine plus years to determine a significant trend in 0+ Chinook salmon population abundance passing through lower Redwood Creek (Sparkman 2013). Although the trend in abundance in lower Redwood Creek was non-significant, there was a significant, negative relationship in abundance when flood type flows in the upper basin were added as a dummy variable to the regression model ($p < 0.10$). This did not come as a surprise because there is a direct relationship between population abundances in the upper basin with that of the lower basin, and population abundances in the upper basin are strongly affected by flood type flows during adult spawning and the redd incubation period (Sparkman 2013).

The overall reduction in population abundance we observed from YRS 2004 – 2012 in lower Redwood Creek could be due to: 1) decrease in the total number of spawners upstream of the trap site, 2) high bedload mobilizing flows during and after reproduction which scoured or jostled redd gravels in the mid to upper basin, or 3) some combination of factors 1 and 2. Changes in spawner distributions within the Redwood Creek basin are not likely responsible for the decrease because Chinook salmon do not generally spawn in mainstem areas below the trap site in lower Redwood Creek, and the number of spawners in Prairie Creek in YR 2012 was near average (Duffy, pers. comm. 2012). Currently, we cannot separate effects of lower adult population abundance during years with high, bedload mobilizing flows on the subsequent production of juveniles because: 1) adult counts are only recently being conducted, 2) peak flows capable of redd scour in lower Redwood Creek occurred nearly each study year (YRS 2004 – 2009, 2011 - 2012), and 3) peak flows capable of redd scour in mid to upper Redwood Creek occurred in YRS 2005 and 2006. 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). Since each study year peaks in streamflow ($11,000^+$ cfs) capable of redd scour occurred in lower Redwood Creek with exception to YR 2010, and no peaks capable of redd scour occurred in the upper basin in YR 2012, the most plausible reason for the increase in abundance in YR 2012 is a simple increase in the number of returning adults. Although adult harvest is not allowed in Redwood Creek, the ocean salmon sport fishery does harvest an unknown number of adult Chinook salmon that belong to Redwood Creek. Roper and Scarnecchia (1999) reported that the abundance of 0+ Chinook salmon in the South Umpqua River, Oregon was positively related to the number of returning adults.

Subsequent to winter flows and emergence from redds, 0+ Chinook salmon migrated downstream nearly each day during the trapping period in YR 2012. Weekly peaks in abundance during a given study year were relatively large, ranging from 27,057 – 111,000 individuals. In YR 2012 the peak in weekly abundance equaled about 38,000 individuals, and occurred in mid to late June. The pattern in population abundance by month in YR 2012 compared to the previous eight year average showed the temporal delay in migration in YR 2012 (similar to YRS 2010 and 2011). Emigration in July, August, and September in YR 2012 was much greater than emigration for the previous eight year average. Peak monthly emigration occurred in June in YR 2012, as did the peak for the previous eight year average. The two most important months in YR 2012 were June and July which was also the two most important months for the previous eight year average. The temporally extended migration in YR 2012 was most likely attributable to higher than average stream flows during the trapping period. Population emigration during a given month can be quite large, reaching values up to 292,000 (June 2004), and in June 2012 population abundance equaled 91,525 individuals.

Each study year 0+ Chinook salmon (ocean-type) emigrating from Redwood Creek exhibit two different juvenile life histories (fry and fingerling) based on size and time of downstream migration. The fry (Avg. FL = 40 mm in YR 2012) are migrating shortly after emergence from spawning redds, and therefore are much smaller than the fingerlings (or smolts) (Avg. FL = 75 mm in YR 2012) which have reared in the stream for a longer period of time prior to passing the trap site. Although there is overlap in downstream migration, temporal differences are evident by three peaks in migration when data for fry abundance and fingerling abundance are plotted using two 'y' axes (data not given). For example, the first weekly peak (albeit relatively small, N = 2,520) in population emigration in YR 2012 occurred during 4/23 – 4/29, and consisted of 98% fry and 2% fingerlings. The average size of fry during this time period equaled 40 mm. Weeks later, the largest peaks in abundance (6/18 – 6/24, N = 37,818; 7/09 – 7/15, N = 35,056) consisted solely of fingerlings with an average FL of 68 and 77 mm, respectively. Fry and fingerlings that are marked for efficiency trials in the upper basin are captured each year by the trap in lower Redwood Creek. Factors that can influence the temporal component to fry and fingerling migration are: 1) time of adult spawning, 2) how far upstream of the trap site the adults spawned, 3) time from egg deposition to fry emergence from redds, and 4) travel rate, among other factors.

Small numbers of fry relative to the number of fingerlings migrated downstream through lower Redwood Creek each study year, with exception to YRS 2004 and 2011. The greatest number of fry migrating downstream towards the estuary and ocean occurred in YR 2004 (N = 82,584), and in YR 2012, 5% (or 10,259 individuals) of the population consisted of fry. The percentages of fry in the 0+ Chinook salmon population over the current nine years ranged from 0.1 – 19%, and averaged 6%. 0+ Chinook salmon fingerlings comprised the majority of the population each year, with percentages ranging from 81 – 99.9% of the total abundance; the greatest number of fingerlings (N = 472,306) migrating downstream occurred in YR 2004 as well. In YR 2012, 95% (or 200,111) of the 0+ Chinook salmon population consisted of fingerlings. In contrast, the 0+ Chinook salmon population emigrating from upper Redwood Creek consisted of nearly equal numbers of fry (105,487 or 44%) and fingerlings (98,864 or 56%) when averaged over a thirteen year period (YRS 2000 – 12). In YR 2012, 34% of the 0+ Chinook salmon emigrant population passing through upper Redwood Creek consisted of fry (Sparkman, 2013). 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.

The average size (FL = 71 mm; Wt = 4.5 g) of 0+ Chinook salmon migrants in YR 2012 was the third highest of record, and greater than the previous eight year average. Average and median FL's (mm) over years were negatively related to population abundances, thus density dependence was detected with size and population abundances. Given successful stream restoration, a reversal of this relationship would be very beneficial for increasing smolt to adult survival since larger smolts are considered to have greater survival than smaller smolts.

## 1+ Chinook Salmon

One year old juvenile Chinook salmon (stream-type) in Redwood Creek represent the third juvenile Chinook salmon life history. Stream-type juvenile Chinook salmon are easily differentiated from ocean-type by size at time of downstream migration, and general appearance. The average size (FL mm) in April/May 2012, for example, was 113 mm for 1+ Chinook salmon and 45 mm for 0+ Chinook salmon.

1+ Chinook salmon in Redwood Creek appear to be in very low abundance as evidenced by trap catches totaling 122 individuals over nine consecutive study years. In YR 2012 we captured 18 1+ Chinook salmon, and for the fourth consecutive year determined a mark/recapture population estimate (N = 64 in YR 2012). The population estimate was 310 in YR 2009, 22 in YR 2010, and 15 in YR 2011. Average abundance over YRS 2009 – 2012 equaled 103 individuals. The majority of 1+ Chinook salmon migrated downstream during May in YRS 2009 - 2012.

When present, 1+ Chinook salmon in Redwood Creek are more likely to be progeny of fall/winter-run Chinook salmon adults than from spring-run adults because few if any spring-run Chinook salmon are observed during spring and summer snorkel surveys in Redwood Creek (Dave Anderson, pers. comm. 2012). For example, in $25^{+}$ 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) (Dave Anderson, pers. comm. 2012). Additionally, streamflows 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) may also prevent any adult spring-run Chinook salmon migration into upper Redwood Creek, or inhibit their ability to over-summer in pools. The sedimentation in Redwood Creek and subsequent decrease in pool depths and other stream habitats may also limit the ability to over-summer as well.

Thus, a spring run of Chinook salmon adults was probably not responsible for the production of yearling Chinook salmon juveniles in Redwood Creek. Bendock (1995) also found both stream-type and ocean-type juvenile Chinook salmon in an Alaskan stream which only has one adult Chinook salmon race; and Conner 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 conclude 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, is whether the one year old life history for juvenile Chinook salmon in Redwood Creek was more prevalent prior to the changes in the watershed associated with land use activities, flood events, and natural geologic processes. Perhaps with continued stream restoration and maturation of the riparian zone in Redwood Creek, we will see an increase in the numbers of stream-type Chinook salmon smolts. The 1+ Chinook salmon life history may be important for increased ocean survival of Chinook salmon juveniles, and general species diversity (author, Don Chapman pers. comm. 2003).

## 0+ Steelhead Trout

The number of 0+ steelhead trout that can remain upstream of the trap site is considered to be some function of a fish's disposition to out-migrate (or not out-migrate) and habitat carrying capacity. Meehan and Bjornn (1991) comment that juvenile steelhead trout have a variety of migration patterns that can vary with local conditions, and that the trigger for out-migration can be genetic or environmental. They further state that some steelhead populations normally out-migrate soon after emergence from redds to occupy other rearing areas (we observe this as well in both upper and lower Redwood Creek). Habitat carrying capacity is generally thought to be related to environmental (hydrology, geomorphology, stream depth and discharge, stream temperatures, cover, sedimentation, etc.) and biological variables (food availability, predation, salmonid behavior), and any interactions between the two (Murphy and Meehan 1991). The general idea is that when habitat carrying capacity is exceeded (e.g. over-seeding, surplus production), the juvenile fish emigrate to find other areas to rear. A problem with the view of habitat carrying capacity's affect on migration is that it fails to explain why juvenile salmonids (e.g. 0+ SH, 0+ CO) emigrate at low, upstream densities or low, upstream population levels.

Young-of-year steelhead trout downstream migration in Redwood Creek is considered to be stream redistribution (passive and active) because juvenile steelhead trout in California normally smolt and enter the ocean at one to two years old, with lesser numbers out-migrating at an age of $3^+$ years (Busby et al. 1996, Sparkman 2013). Perhaps the most important finding with respect to 0+ steelhead trout movements in Redwood Creek were from experiments conducted in YRS 2006, 2007, 2010, and 2011 in which we marked 0+ steelhead trout (FL 40 – 60 mm) in the upper basin to later see if we would recapture a given percentage at the trap in lower Redwood Creek. Recaptures occurred within each study year of the experiments, and in YR 2010 we recaptured six out of 100 marked with a upper caudal fin clip (snip). In YR 2011 we only recaptured 1 out of 100 that were marked and released at the trap in upper Redwood Creek. To the best of my knowledge, these were the first experiments to show 0+ steelhead trout may cover considerable distances (e.g. 29 mi.) while moving downstream in search of rearing areas.

Trap catches of 0+ steelhead trout in YR 2012 (n = 7,301) in lower Redwood Creek were greater than catches for 1+ steelhead trout in YR 2012, and much greater than catches of 2+ steelhead trout in YR 2012. Trap catches of 0+ steelhead trout in YRS 2004 – 2012 ranged from 1,345 – 42,827 individuals, and averaged 17,431. In comparison to population abundances of 1+ and 2+ steelhead trout, 0+ steelhead trout comprised 26% of the total juvenile steelhead trout out-migration over the current, nine year period. With respect to 2+ steelhead trout, the ratio of 0+ steelhead trout catches to 2+ steelhead trout population abundances over the nine year period ranged from 0.8:1 to 4.4:1, and averaged 1.9:1. Relatively high catches of young-of-year steelhead trout by downstream migrant traps in small and large streams is not uncommon (USFWS 2001, Rowe 2003, Johnson 2004, Don Chapman pers. comm. 2004, Sparkman 2013). For example, 0+ steelhead trout catches in upper Redwood Creek from YRS 2000 – 2012 ranged from 32,585 - 128,885 and averaged 67,194 per year (Sparkman 2013). In YR 2012, a total of 39,997

0+ steelhead trout were captured moving downstream in upper Redwood Creek (Sparkman 2013). Similar to 0+ Chinook salmon, mid to upper Redwood Creek is important for adult steelhead trout spawning.

The 0+ steelhead trout captured by the trap in lower Redwood Creek indicate these fish are going to rear for some time period in lower Redwood Creek (including the estuary), or Prairie Creek. Dave Anderson (pers. comm. 2012), for example, routinely captures young-of-year steelhead trout (and coho salmon) in the estuary during summer and early fall sampling. Although relatively few 0+ steelhead trout migrated downstream past the trap site in YR 2012, the condition of lower Redwood Creek and estuary can impact the survival and growth of 0+ steelhead trout, which in turn could influence the number of older, juvenile steelhead trout in following years.

## 1+ Steelhead Trout

One-year-old steelhead trout smolts were the most numerous juvenile steelhead trout, on a population basis, migrating downstream through lower Redwood Creek in at least six of eight consecutive study years. In YR 2012, 1+ steelhead trout outnumbered 0+ and 2+ steelhead trout, with the corresponding ratio of 4.8:1 for 1+ steelhead trout to 0+ steelhead trout; and 9.4:1 for 1+ steelhead trout to 2+ steelhead trout. The ratio of 1+ steelhead trout to 0+ steelhead trout averaged 6.8:1 over the current nine years, and for 1+ to 2+ steelhead trout populations averaged 6.7:1. On a percentage basis, 1+ steelhead trout comprised 79 – 96% of the total juvenile steelhead trout age 1 and older population abundance each study year. In YR 2012, 1+ steelhead trout comprised 90% of the total juvenile steelhead trout age 1 and older population abundance each study year. Obviously, 1+ steelhead trout comprise the majority of steelhead trout smolts passing the trap site.

Population abundance in YR 2012 (N = 35,174 $\pm$ 18%) was the fourth lowest of record, and 13% less than the previous eight year average. With inclusion of data from YRS 2011 and 2012, the trend in abundance over the nine year period was statistically negative ($p = 0.04$), and on average, we are seeing about 3,968 less individuals each study year. The high abundance in the first year (YR 2004, N = 77,221) may appear to ‘drive’ the regression, however, the slope is still negative when YR 2004 data is omitted. The model describing population abundances with study year and whether or not there were flood type flows in the upper basin was also significantly negative, however the correlation value was only 0.06 points greater than the simpler model, and the power was also lower. The negative relationship with flood type flows 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 probably 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 overwintering habitat.

In addition to differences in population abundance among study years, there were temporal differences in monthly emigration in YR 2012 compared to the previous eight year average. Although the most important month for migration was June in YR 2012, and for the previous nine year average, migration in May 2012 was much less than average, and migration in July 2012 was much greater than average. The two most important months for migration were June and July in YR 2012, compared to May and June for the previous eight year average. In addition, migration in YR 2012 continued into September, when normally migration is over by early to mid August. The prolonged migration observed in YR 2012 (and YRS 2010 - 2011) was most likely due to higher than average streamflow during the study period, compared to historic values and previous study years. Population emigration during a given month can be quite large, reaching values up to 33,000 (May 2004), and in June 2012 population abundance peaked at 16,843 individuals.

The average size of 1+ steelhead trout migrants in YR 2012 (96 mm, 10.5 g) was greater than previous study years, and may be attributable to the prolonged migration and higher than average stream flows observed in YR 2012. Previous travel time and growth studies on pit tagged 1+ steelhead trout emigrating from the upper basin to be recaptured at the trap in lower Redwood Creek showed that 1+ steelhead trout grew more as travel time increased (Sparkman 2010). However, the regression of population abundances on average size showed a negative relationship, such that with higher abundances the size of smolts decreased. Similar to 0+ Chinook salmon, successful stream restoration and improvements in stream habitat quality could reverse this apparent trend.

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 very low each study year (0.0 - 0.6%), and indicated that few 1+ steelhead trout migrated downstream in a stream-residence form (parr). In contrast, the majority of 1+ steelhead trout (68 – 89%) in a given study year were emigrating in a smolt stage. Given more data years, we may 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 2000-09) in upper Redwood Creek were negatively related to water temperatures ($n = 10$, $p < 0.05$) (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. 2012) 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), 2010 (n = 260), and 2011 (n = 26). 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).

As previously mentioned, far more 1+ steelhead trout emigrated past the lower trap than older, juvenile steelhead trout age-classes (2+). The ratio of 1+ steelhead trout:2+ steelhead trout in YR 2012 equaled 9.4:1 in lower Redwood Creek, 28:1 in upper Redwood Creek, and 10:1 in Prairie Creek. The ratio of 1+ steelhead trout downstream migration is not unique to Redwood Creek, and other downstream migration studies have routinely documented 1+ steelhead trout emigration (USWFW 2001, Ward et al. 2002, Johnson 2004; B. Chesney pers. comm. 2011, among many others). However, the ratio of 1+ steelhead trout to 2+ steelhead trout (range of 3:1 to 24:1) passing through lower Redwood Creek was much different than that determined in a nearby river (Mad River), which equaled 1:6 in YR 2001 and 1:3 in YR 2002 (Sparkman 2002). Whether these differences are indicative of stream conditions or attributable to the different stock in each stream is unknown. In the Keogh River, about 20% of the total steelhead trout smolt yield consisted of 1+ steelhead trout parr (McCubbing and Ward 2003).

Based upon studies in other streams, the number of returning adult steelhead trout that migrated to the ocean as one-year-old smolts is relatively low, and usually less than 29% (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 collected in Redwood Creek, 50% of the adults entered the ocean as one-year-old juveniles in YR 2008; the most successful juvenile steelhead migrants to reach adulthood were 2+ steelhead trout (author). More recently, the percentage of adults showing the one year old smolt life history equaled 40% in YR 2009, 33% in YR 2010, and 40% in YR 2012. CDFW AFRAMP is currently collecting scale samples from adult steelhead trout in Redwood Creek 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 2013). In addition, streamflow 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, 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, McCubbing and Ward 2003). Pautzke and Meigs (1941), for example, reported that 84% of returning adult steelhead trout 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 Redwood Creek is that they were far less abundant (by about 67 - 96%) 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 4 – 25% of the population. In YR 2012, 2+ steelhead trout comprised 9.6% of the combined population of age 1 and older steelhead trout smolts.

The population abundance of 2+ steelhead trout in YR 2012 was the second lowest of record, and about 60% less than the average abundance over the previous eight years. The sharp decline in YR 2009 caused the previously non-significant negative trend to become a statistically significant negative trend, and with inclusion of YRS 2010 - 2012 data, the trend remained significantly negative. On average, there were 1,582 less individuals each study year. The inclusion of flood type flows in the linear model was significantly negative, however, the best model included population abundance and time (years). As discussed in the section for 0+ Chinook salmon, testing trends in abundance often requires numerous, consecutive years of data to determine a reliable trend. For example, the slope of the trend line for 2+ steelhead trout emigrating through lower Redwood Creek was greatly influenced by the high population abundance measured in YR 2004. However, if we considered YR 2004 data an outlier and removed YR 2004 data from the correlation test, we would still have a negative relationship, albeit non-significant. The negative trend in abundance for 2+ steelhead trout emigrating from upper Redwood Cr was first detected at year four, and statistically determined at year eight. The 2+ steelhead trout population emigrating from upper Redwood Creek during study years 2000 – 2012 are currently showing a significant, negative trend (Sparkman, 2013). Whether the populations of 2+ steelhead trout smolts passing through lower Redwood Creek are showing a true negative trend will take more study years to determine.

Confidence intervals (and percent error) for the population abundance estimate of 2+ steelhead trout passing through lower Redwood Creek each year were larger than the 95% confidence intervals for 1+ steelhead trout because: 1) 2+ steelhead trout are typically harder to catch than younger age-classes of steelhead trout, and 2) sample sizes for marking and subsequent recapture were lower. During the trapping period we routinely adjusted the trap configuration and installed weir panels to increase the capture efficiency of 2+ steelhead trout. Additionally, we performed numerous mark/recapture trials in a given week, and when combined with altering trap configuration and paneling, were then able to produce a reliable population estimate with a low to moderate error term (e.g. $\pm$ 31% observed in YR 2012).

In addition to differences in population abundance among study years, there were temporal differences in monthly emigration. Migration in YR 2012 was skewed to the left, compare to the right for the previous eight year average. The most important month for abundance in YR 2012 was June, compared to May for the previous eight year average. Similar to 1+ steelhead trout in YR 2012, 2+ steelhead trout migration in May was drastically reduced compare to the previous eight year average. The two most important months were June and July in YR 2012, compared to May and June for the previous eight year average. The weekly peak in emigration in YR 2012 was also later than previous study years, with exception to YRS 2010 and 2011. The peak in weekly abundance in YR 2011 occurred during the same Julian week as YR 2012 (6/25 – 7/01). Similar to 1+ steelhead trout, the delay in migration of 2+ steelhead trout in YR 2012 was most likely due to higher than normal stream discharge during the trapping period.

Average FL and Wt for 2+ steelhead trout in YR 2012 were slightly greater than the average size of previous study years. However, average FL and Wt of 2+ steelhead smolts showed little variation among study years; the greatest difference between any two years was 7.5 mm and 6.0 g. Such differences are unlikely to have biological meaning unless they affect survival to adulthood, which seems doubtful. 2+ steelhead trout are also expected to gain additional length and weight when residing in the estuary prior to ocean entry. The size of 2+ steelhead trout smolts over nine years was not related to population abundances, thus density dependence was not detected.

The percentage of 2+ steelhead trout showing parr characteristics was zero each study year, and indicated 2+ steelhead trout do not emigrate through lower 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 2012 (98.1%) was greater than three of the previous study years, however the greatest differences among study years was only six percentage points. In YR 2012, 1.9% of the smolts were classified as pre-smolts, compared to 2.4% for the previous eight year average. Analysis of trapping data (n = 10 years) in upper Redwood Creek during YRS 2000 – 2009 showed that smolt percentages in a given study year were negatively related to 2+ steelhead trout population abundances, and negatively related to stream temperatures (Sparkman 2010). 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 54% of the variation in smolt percentages over ten study years can be attributed to the variation in stream temperatures (Sparkman 2010). Whether this will be true for 2+ steelhead trout populations emigrating through lower Redwood Creek remains to be tested.

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 from upper Redwood Creek 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. 2012). 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. Future trapping efforts will try to increase the sample size of recaptured 2+ steelhead trout for travel time and growth information by increasing the sample size of releases from upper Redwood Creek. The lack of large numbers of 3+ steelhead trout captured 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 are 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 in the Keogh River 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 Redwood Creek steelhead 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 relate to future adults (and watershed conditions) is hard to dismiss or invalidate.

With respect to younger juvenile stages (0+ and 1+), the 2+ steelhead trout smolt is the best candidate for assessing steelhead status, trends, and abundance when information on adult steelhead is unavailable or un-attainable. 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 trout 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 prior to ocean entry. 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.

## Cutthroat Trout

A very low number of cutthroat trout were captured in each study year relative to other juvenile salmonids, and over the current nine years a total of 362 individuals were captured passing through lower Redwood Creek. The total catch of cutthroat trout over nine years was about 99.3% less than the total catch of 1+ and 2+ steelhead trout. The population abundance of cutthroat trout passing through lower Redwood Creek also shows that relatively few cutthroat trout emigrated from the majority of the Redwood Creek basin. The lowest abundance occurred in YR 2008 (N = 54), the highest abundance occurred in YR 2010 (N = 256), and abundance in YR 2012 (N = 201) was the second highest of record. The average abundance over the six years when we determined population abundances equaled 135 individuals. Currently the trend in abundance is non-significantly positive. Low catches and low population abundances does support our hypothesis that few cutthroat trout are emigrating from the majority of the Redwood Creek basin, upstream of the confluence with Prairie Creek. Trap catches in upper Redwood Creek over a thirteen year period were even lower, and in YR 2012 only two were captured (Sparkman 2013). Similar to juvenile coho salmon, the Prairie Creek watershed is probably the biggest contributor to cutthroat trout populations in the Redwood Creek basin based upon this study, the study in upper Redwood Creek, and various studies in Prairie Creek (Walter Duffy, pers. comm. 2011, Duffy and Sparkman, In progress). For example, the smolt trap in lower Prairie Creek (Rm 0.25) in YR 2012 captured 1,793 cutthroat trout smolts, and the resulting population estimate equaled 5,043 individuals (Duffy and Sparkman, In progress).

Unlike other species at age in YR 2012, monthly population emigration through lower Redwood Creek peaked earlier (June) than the average of previous study years (July). The two most important months were June and July in YR 2012, compared to July and August for the average of previous years. In Prairie Creek, April was the most important month for population emigration in YR 2012 (Duff and Sparkman, In progress).
The majority of cutthroat trout captured in lower Redwood Creek in YR 2012 were in a smolt stage (92%), and only 1% were classified as parr. 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 (and population estimates) may not necessarily reflect a very low population size in Redwood Creek. However, if there were large numbers present within the Redwood Creek basin, 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, and more recently over 1,000, cutthroat trout during spring/early summer as they migrate downstream (Roelofs and Klatte 1996, Roelofs and Sparkman 1999, Walter Duffy, pers. comm. 2011) (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 age-1 and older cutthroat trout were captured in any given year. Far more age 1 and older juvenile steelhead trout (1+ and 2+) migrated through lower Redwood Creek than cutthroat trout as evidenced by trap catches. In nine study years, for example, the ratio of 1+ and 2+ steelhead trout combined catches to cutthroat trout catches each year ranged from 47:1 to 596:1, and averaged 226:1. In other words there was, on average, 226 times more 1+ and 2+ steelhead trout (combined) captured than cutthroat trout. Ratios would be even higher if population data were used instead of catch data; thus it seems very unlikely that low numbers of cutthroat trout could produce a significant portion of the young of year 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 also usually more abundant on coastal 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. We have observed less than six potential hybrids in the nine years of study, and based upon visual identification, the number of (potential) hybrids (age-1 and greater) is extremely rare in Redwood Creek. Similar findings occurred in upper Redwood Creek as well (Sparkman 2011b).

### 0+ Coho Salmon

Similar to 0+ steelhead trout, trap catches of 0+ coho salmon are not all inclusive because only a given percentage of the total number present upstream of the trapping site will migrate downstream, this also pertains to the population point estimate. Thus, catches and population estimates are for those fish that were migrating past the trapping site.

Trap catches of 0+ coho salmon moving downstream is typical for most streams, including relatively, pristine streams like Prairie Creek (Duffy and Sparkman, In progress). Koski (2009) called these migrating 0+ coho salmon 'nomads' and considered this life history strategy to be important for species resilience and diversity.

Few 0+ coho salmon were captured by the trap in lower Redwood Creek in eight consecutive study years (total catch = 1,390 individuals), and in YR 2012 only 78 individuals were captured. The low catches of 0+ coho salmon in lower Redwood Creek is contrasted by higher catches in Prairie Creek. For example, trap catches of 0+ coho salmon in mid to upper Prairie Creek from 1996 – 1998 ranged from a low of 372 to a high of 25,492, and averaged 9,659 per trapping season (Roelofs and Sparkman 1999). However, trap catches in lower Prairie Creek in YR 2012 equaled 384 individuals (Duffy and Sparkman, In progress).

In YR 2012 we determined the population abundance of emigrating 0+ coho salmon for the seventh time during our monitoring studies. Population abundances over years equaled 201 in YR 2012, 884 in YR 2011, 10 in YR 2010, 63 in YR 2009, 1,886 in YR 2008, 1,057 individuals in YR 2007, and 508 in YR 2006. The preliminary trend in abundance was significantly positive in YR 2008, and with addition of data in YRS 2009 - 2012, showed a non-significant, negative relationship. The current trend line is very susceptible to change due to low sample sizes (n = 7 years), as discussed in earlier sections. Although we may not have a reliable trend in abundance, the point estimates (of abundance) were low each study year, and indicate that relatively few young-of-year coho salmon emigrated through lower Redwood Creek, upstream of the confluence with Prairie Creek. Population emigration through lower Prairie Creek was also low in YR 2011 (N = 726) yet much higher in YR 2012 (N = 8,403) (Duffy and Sparkman, In progress).

The migration of 0+ coho salmon at the population level in YR 2012 primarily occurred in the later part of the trapping season, and may be attributable to the increase in stream discharge during the trapping period compared to previous study years. The most important month for migration was July in YR 2012, compared to June for the average of the previous years. Migration in September 2012 was over two times greater than the previous year's average for September. The temporal delay in migration in YR 2012 appeared to influence the average size of 0+ coho salmon. The average FL and Wt in YR 2012 was slightly greater than the average for the previous eight years. The size of 0+ coho salmon migrants was not related to population abundance, thus density dependence was not detected. The migration of 0+ coho salmon through lower Redwood Creek indicate that these fish were moving downstream to rear, or possibly to enter the ocean at age 0. If the young-of-year coho salmon do not move into Prairie Creek, then they must be moving downstream to the estuary. Thus, lower Redwood Creek and the estuary may serve as an important place for young-of-year coho salmon to rear. Madej et al. (2006) reported that large areas of the Redwood Creek mainstem may be inhospitable for juvenile coho salmon to rear because of high stream temperatures during summer months. Data from trapping efforts in the upper basin support this assertion because juvenile coho salmon were only captured in two of the thirteen consecutive study years

(Sparkman 2013). Therefore, determining the spatial distribution of 0+ coho salmon within the Redwood Creek basin is recommended. CDFW (AFRAMP) recently submitted a proposal to determine the spatial distribution within Redwood Creek.

### 1+ Coho Salmon

Low numbers of one plus-year-old coho salmon were caught at the lower trap each study year, with the total catch over nine years equaling 679 individuals. The highest catch occurred in YR 2008 (n = 242), and the lowest catch occurred in YR 2010 (n = 13). Similar to 0+ coho salmon, the low catches of 1+ coho salmon in lower Redwood Creek are contrasted by much higher catches in Prairie Creek. For example, trap catches of 1+ coho salmon in mid to upper Prairie Creek from 1996 – 1999 ranged from 1,475 – 2,302, and averaged 1,965 per trapping season (Roelofs and Sparkman 1999). More recently, 2,455 1+ coho salmon were captured in lower Prairie Creek in YR 2011, and 2,621 in YR 2012 (Duffy and Sparkman, In progress).

The population abundance of 1+ coho salmon in Redwood Creek in YR 2012 was the fourth highest of record (N = 458), and about 1.3 times greater than the previous eight year average abundance. The average population abundance over nine years of study was 358 individuals, and should be considered to be a very low number. The trend in abundance from YR 2004 - 2012 was non-significantly negative, and indicates more study years will be required to determine a reliable trend in abundance. Population estimates for 1+ coho salmon should be viewed cautiously (due to relatively large error terms for some estimates, 44 - 86%), and the proper context could be that we are 95% sure that the greatest population abundance during any given study year was less than 1,127 individuals (upper 95% CI for YR 2008 estimate). The population abundances we determined over the current, nine year period can be considered very low (alarmingly so), particularly for a stream the size of Redwood Creek. The low abundances observed in YR 2011 (N = 113), YR 2010 (N = 33), and YR 2007 (N = 102) may indicate year class failures. The population abundance of 1+ coho salmon smolts in Prairie Creek equaled 8,446 in YR 2011 and 20,141 in YR 2012; thus Prairie Creek is extremely important for production of coho salmon smolts, and an important refuge for coho salmon within the Redwood Creek watershed (Duffy and Sparkman, In progress).

1+ coho salmon in Redwood Creek had the most restricted temporal pattern to migration compared to other juvenile salmonids, with exception to 1+ Chinook salmon. The majority of the 1+ coho salmon population emigrated during May for any given study year, and in YR 2012 May accounted for 49% of the total. The two most important months are usually April and May, however, in YR 2012 May and June were the two most important months for migration. Migration in YR 2012 was also more spread out, with increased migration during April and June, compared to the previous eight year average. The weekly peak in migration in YR 2012 occurred earlier than previous study years (4/23 – 4/29). The migration of 1+ coho salmon smolts in Prairie Creek in YR 2012 (and YR 2011) was much more protracted compared to the smolt migration through lower Redwood Creek; the migratory period through lower Prairie Creek in YR 2012 ended on July 15th, compared to an end date of June 26th for lower Redwood Creek.

The average size of 1+ coho salmon smolts in YR 2012 (FL = 104.6 mm, Wt = 12.6 g) was slightly below average, and close in value to the average size in Prairie Creek in YR 2012 (FL = 102 mm, Wt = 12.07) (Duffy and Sparkman, In progress).
The reason(s) for the lack of sufficient numbers of 1+ coho salmon smolts emigrating from Redwood Creek warrants further study, as does their current distribution within the Redwood Creek basin.

### 0+ Pink Salmon

Pink salmon in California are recognized as a "Species of Special Concern", and California is recognized as the most southern border for the species (CDFW 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 (CDFW 1995). More recently, 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 lower Redwood Creek during the fall of YR 2010 (D. Anderson, pers. com. 2012).

I know of no historic records or anecdotal information documenting pink salmon presence in the mainstem of Redwood Creek prior to our downstream migration trapping efforts. The pink salmon in Redwood Creek are in very low numbers, and were only observed in lower Redwood Creek in YR 2005. In upper Redwood Creek we have captured small numbers of juvenile pink salmon in six out of twelve years, with the most recent capture occurring in YR 2011 (n = 1) (Sparkman 2012). 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. According to the Habitat Conservation Planning Branch (HCPB) of CDFW, pink salmon are considered to be "probably extinct" in California (CDFW 1995). However, the HCPB does state that "more efforts need to be conducted to prove (or disprove) that reproducing populations exist anywhere in California" (CDFW 1995). Based upon our trapping data in upper and lower Redwood Creek, pink salmon are present in Redwood Creek and reproducing, albeit in low numbers.

## CONCLUSIONS

The migration of juvenile salmonids through lower Redwood Creek consisted of juvenile Chinook salmon (ocean-type and to a much lesser degree stream-type), steelhead trout (at least three age classes), coho salmon (two age classes), and cutthroat trout (multiple age classes, including adults). The abundance of 0+ Chinook salmon in YR 2012 (N = 210,370) was the second highest of record, and 1.1 times greater than the previous eight year average. The nine year average equaled 198,407, with annual abundances ranging from 85,149 – 554,890. The abundance of 1+ Chinook salmon in YR 2012 equaled 64 individuals, and indicated for the fourth consecutive year that yearling Chinook salmon are relatively rare in Redwood Creek. Average abundance over YRS 2009 – 2012 equaled 103 individuals. The abundance of 1+ steelhead trout in YR 2012 (N = 35,174) was 13% below average, and for 2+ steelhead trout (N = 3,748) was the second lowest of record. Annual abundances for 1+ steelhead trout ranged from 20,501 – 77,221, and for 2+ steelhead trout ranged from 1,743 – 19,353. Far more 1+ steelhead trout emigrated from Redwood Creek than 2+ steelhead trout each year, and may indicate stream habitat conditions are limiting the abundance of the older age class (2 years); or favoring a change in life history to a younger smolt age (age 1). The abundance of 0+ coho salmon in YR 2012 was a low value of 201 individuals, and annual abundances ranged from 10 – 1,886. However, not all of the 0+ coho salmon within the Redwood Creek basin will migrate downstream. The 0+ coho salmon migrating through lower Redwood Creek (and Prairie Creek) are no longer considered 'lost or surplus production', and several studies are showing this life history can give resilience to populations (Koski 2009). The abundance of 1+ coho salmon smolts passing through lower Redwood Creek was a very low value of 458 individuals, and annual abundances ranged from 33 – 879. Population abundances in Redwood Creek contrasted the much higher abundance for 1+ coho salmon (N = 21,141) emigrating from Prairie Creek in YR 2012. The abundance of cutthroat trout in YR 2012 (N = 201) was the second highest of record, however, abundances across all years can be considered low (ranged from 54 – 256).

The trends in population abundances over the current nine years were non-significant for 0+ Chinook salmon, 0+ coho salmon, 1+ coho salmon, and cutthroat trout. The trends in abundance for 1+ steelhead trout smolts and 2+ steelhead trout smolts over time were significantly negative. The addition of whether or not there were flood type flows in the upper basin during winter months was an important, additional variable for analyzing the trends of 0+ Chinook salmon population abundance. The addition of flood type flows in the model for 0+ Chinook salmon caused the trend over time to became statistically significant. With respect to 0+ Chinook salmon, population abundances were negatively related to study year and flood type flows, and indicated that the 0+ Chinook salmon populations passing through lower Redwood Creek were strongly tied to abundances in upper Redwood Creek and flood type flows in the upper basin which occurred during the redd egg incubation/embryogenesis periods. For both 1+ steelhead trout and 2+ steelhead trout, abundances were also negatively related to study year and flood type flows in the upper basin, which may indicate that over winter conditions in the upper basin are limiting survival when flood type flows are present.

The patterns in monthly population abundances in YR 2012 showed a temporal delay in migration for several species at age which I attribute to increased stream discharge during the trapping period compared to previous study years. Trapping in YR 2012 was extended into September to account for delays in migration, and delays in migration were readily apparent for 0+ Chinook salmon, 1+ Chinook salmon, 1+ steelhead trout, 2+ steelhead trout, 0+ coho salmon, and 1+ coho salmon. The two most important months for migration in YR 2012 were June/July for 0+ Chinook salmon, 1+ steelhead trout, 2+ steelhead trout, 0+ coho salmon, and cutthroat trout; and May/June for 1+ Chinook salmon and 1+ coho salmon.

The trap catch of 0+ steelhead trout in YR 2012 (n = 7,301) was the fourth lowest of record, which could be attributable to: 1) an decrease in adult numbers upstream of the trap site, 2) lower trapping efficiencies, 3) difference in the percentage of the total 0+ steelhead trout population emigrating downstream each year, or 4) some combination of factors 1 – 3. Marked 0+ steelhead trout released at the upper trap in Redwood Valley in YRS 2006, 2007, 2010, and 2011 were recaptured at the lower trap in the same year as release, and indicated 0+ steelhead trout can migrate considerable distances in search of rearing areas. These experiment could be the first to document long range dispersal (29 mi.) of young of year steelhead trout from spawning to rearing areas. The 0+ steelhead trout and 0+ coho salmon that passed by the trap in lower Redwood Creek are probably rearing in reaches below RM 4 and in the estuary, thus lower Redwood Creek and the estuary are also important for young-of-year fish, in addition to older, juvenile salmonid age classes.

The overall study objectives in YR 2012 were successfully completed, and demonstrated that the smolts passing through lower Redwood Creek can be monitored, even under higher than average stream flows. During some years we may fail in obtaining population abundance estimates for cutthroat trout or 0+ coho salmon due to low sample sizes, however, we may be able to model the data using data from previous study years (i.e. modeling trapping efficiency with stream flow) or by using trapping efficiencies associated with fish of nearly equal size and age in the same study year.

Redwood Creek is currently classified as temperature and sediment impaired, and many scientists, resource managers, and members of the public also realize that the estuary is in need of restoration. Future fisheries work in Redwood Creek should be able to show any fish response to current and future watershed and stream conditions by combining data from this study, smolt trapping in upper Redwood Creek, adult and juvenile studies in Prairie Creek, and juvenile monitoring in the estuary (author, Walter Duffy pers. comm. 2011, and David Anderson, pers. comm. 2011). In addition, CDFW and USGS CA. Cooperative Fish and Wildlife Research Unit have begun monitoring adult salmon and steelhead populations in Redwood Creek; such information could be used to investigate smolt to adult, and adult to smolt relationships. The adult information would greatly compliment our studies on smolt populations within the Redwood Creek basin.

## RECOMMENDATIONS

This study is one of the few studies that is designed to document smolt abundances 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 and steelhead trout 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.

2. Cover multiple cohort life cycles over time.
3. Collect baseline data for future comparisons:

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

    b. Detect changes in population abundance which can be used to assess the status and trends of Chinook salmon, steelhead trout, coho salmon, and (possibly) cutthroat trout in Redwood Creek.

    c. Detect any fish response (population, fish size, age class composition, etc) to stream and watershed conditions and restoration activities in Redwood Creek.

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

5. Investigate relationships between the number of adults (via redd counts and adult counts using DIDSON technology) and smolt production.

This study, when combined with juvenile salmonid monitoring in the upper basin (RM 33, lower Prairie Creek, and estuary (Redwood National Park), will also help determine bottlenecks to anadromous salmonid production in Redwood Creek.

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# APPENDICES

**Appendix 1. Reasons for collecting genetic samples from Chinook salmon, steelhead trout smolts, and coho salmon fry, parr, and smolts.**

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 trap site and average daily streamflow (cfs) measured at Orick gaging station (USGS 2012) in YR 2012, lower Redwood Creek, Humboldt County, CA.**