State of California
The Resources Agency
DEPARTMENT OF FISH AND GAME

2007 ANNUAL REPORT

LOWER REDWOOD CREEK
JUVENILE SALMONID (SMOLT) DOWNSTREAM MIGRATION STUDY
2004 – 2007 Seasons
PROJECT 2a7

Fisheries Restoration Grant Program (P0610531)

FINAL

Prepared by

Michael D. Sparkman
Northern Region

Anadromous Fisheries Resource Assessment and Monitoring Program

October 2008

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF FIGURES CONTINUED

LIST OF FIGURES CONTINUED

LIST OF TABLES

LIST OF TABLES CONTINUED

LIST OF TABLES CONTINUED

LIST OF TABLES CONTINUED

LIST OF APPENDICES

2007 ANNUAL REPORT

LOWER REDWOOD CREEK
JUVENILE SALMONID (SMOLT) DOWNSTREAM MIGRATION STUDY
2004 - 2007 Seasons
PROJECT 2a7 [1/]

Prepared by

Michael D. Sparkman
Northern Region

ABSTRACT

Juvenile anadromous salmonid trapping was conducted for the fourth consecutive year in lower Redwood Creek, Humboldt County, California during the spring/summer emigration period (April – August). The purpose of the study was to describe juvenile salmonid out-migration and estimate smolt population abundances for wild 0+ 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 needed for Viable Salmonid Population (VSP) Analysis.

The trap operated 136 out of 137 days/nights possible, and captured 43,233 0+ Chinook salmon, zero 1+ Chinook salmon,42,827 0+ steelhead trout, 6,679 1+ steelhead trout, 1,198 2+ steelhead trout, 44 cutthroat trout, zero 0+ pink salmon, 293 0+ coho salmon, and 34 1+ coho salmon to total 94,308 juvenile salmonids. Trap catches of most juvenile salmonids in YR 2007 were greater than previous study years, due in part to increased trapping efficiencies after moving the trap 75 m downstream to a more favorable location in YRS 2006 and 2007. Average weekly trapping efficiency in YR 2007 was 30% for 0+ Chinook salmon, 14% for 1+ steelhead trout, 10% for 2+ steelhead trout, 34% for cutthroat trout, 23% for 0+ coho salmon, and 10% for 1+ coho salmon. The total 0+ Chinook salmon population estimate with 95% confidence intervals in YR 2007 equaled 141,059 (130,068 – 152,049), and was 45% less than the previous three year average. The observed decrease over years could be due to: 1) high bedload mobilizing flows during egg incubation in spawning redds (YRS 2004 - 2007), 2) large decrease in adult spawners upstream of the trap site, or 3) a combination of the two factors. Population estimates with 95% confidence intervals in YR 2007 equaled 37,683 (33,591 – 41,774) for 1+ steelhead trout; 12,067 (9,416 – 15,798) for 2+ steelhead trout; 1,057 (793 – 1,320) for 0+ coho salmon, 102 (53 – 150) for 1+ coho salmon, and 85 (58 – 113) for age-1 and older cutthroat trout. The population abundance of 0+ Chinook salmon, 1+ steelhead trout, 2+ steelhead trout, and 1+ coho salmon showed a (preliminary) non-significant negative trend over four study years. Monthly peaks in population emigration in YR 2007 occurred in June for 0+ Chinook salmon, 1+ steelhead trout, 2+ steelhead trout and 0+ coho salmon, May for 1+ coho salmon, and July for cutthroat trout. In general, the pattern in population abundances by week for a given species at age closely reflected trap catches by week.

[1/] This paper should be referenced as: Sparkman MD. 2008. Lower Redwood Creek juvenile salmonid (smolt) downstream migration study, study year 2007. CDFG AFRAMP, 2007 Annual Report 2a7: 135 p.

INTRODUCTION

This report presents results of the fourth consecutive year of juvenile salmonid downstream migrant trapping in lower Redwood Creek, Orick, California during the spring/summer emigration period. The study was conducted by the California Department of Fish and Game's Anadromous Fisheries Resource Assessment and Monitoring Program (CDFG AFRAMP) in YRS 2004 - 2007. 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 Grant Program (FRGP). Funding in YR 2006 was provided by CDFG AFRAMP and FRGP (Project No. P0510532), and YR 2007 by CDFG AFRAMP and FRGP (Project No. P0610531).

The initial impetus for this study was to determine how many wild salmon and steelhead 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. Prior to our trapping in lower Redwood Creek, Humboldt State University (YR 2001) and the United States Fish and Wildlife Service (USFWS) (YR 2003) operated a rotary screw trap in lower Redwood Creek nearby the present trapping site. Their efforts did not produce smolt population estimates but did collect data on species presence/absence, temporal distribution of out-migration, and fork lengths and weights of captured fish. In YR 2004, CDFG AFRAMP successfully determined juvenile Chinook salmon and steelhead trout smolt population estimates 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 estimates for juvenile Chinook salmon and steelhead trout emigrating from upper Redwood Creek for the past eight consecutive years (Sparkman 2008). 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 populations are difficult to monitor in Redwood Creek because the adult fish migrate upstream during fall or late fall (dependent upon streamflow and whether the mouth is open to the ocean or not), winter and early 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, the streamflow during this time period often carries large amounts of suspended sediments, which render visual observations of adult fish and redds (eg spawning surveys) unreliable and unlikely for long term monitoring. Scientific studies which focus on salmonids in tributaries to Redwood Creek are less affected by these processes, 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 spawn in the mainstem. A possible exception is the Prairie Creek watershed which probably accounts for a considerable amount of the coho salmon production in Redwood Creek. 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), 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), 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).

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 3,200 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 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).

Geology

The Redwood Creek watershed is situated in a tectonically active and geologically complex area, and is considered to have some of the highest uplift and seismic activity rates in North America (CDFG NCWAP 2004).

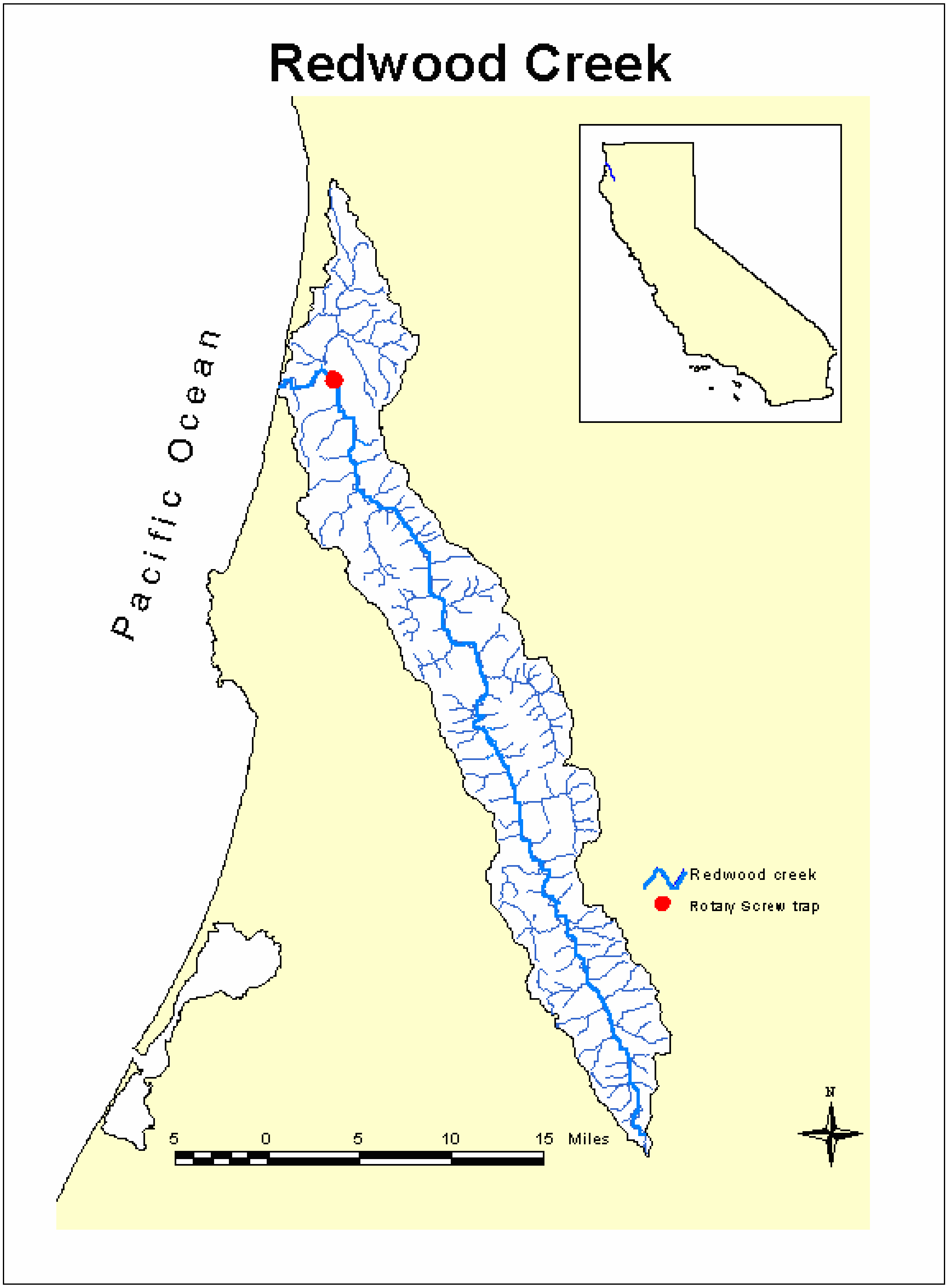


Figure 1. Redwood Creek basin with rotary screw trap location (RM 4), Humboldt County, CA. (scale is slightly inaccurate due to reproduction process, Charlotte Peters pers. com. 2001).

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 and Annual Precipitation

The climate of Redwood Creek basin varies dependent upon location within the watershed and season. Coastal areas have a moderate climate due to proximity to the ocean, and differ from inland areas (i.e. upper Redwood Creek) which experience higher and lower temperatures. Summers are typically cool and moist on the coast, and hot and dry inland. Snow fall is common during winter months in the upper basin and relatively rare in the lower basin.

The United States Geological Survey (USGS) operates a rain gage in lower Redwood Creek, about 850 m downstream of the current trapping site. Rainfall records cover the periods of 1987 – 2007 to total 21 years (Redwood National Park, in house data, 2007; Vicki Ozaki pers. comm. 2007). Annual precipitation ranges from 77 cm (30 in.) to 204 cm (80 in.), and averages 138 cm (54 in.). Most (91%) of the rainfall in Redwood Creek occurs from November through May, with peak monthly rainfall occurring in December and January (Appendix 1). However, in some years relatively large amounts of rainfall may occur in November, February, March (as in YR 2005), April, and May as well. Rainfall in WY 2007 (121 cm or 47.6 in.) was 12% less than the historic average (138 cm or 54 in.), 1.01 times the rainfall in WYS 2004 and 2005, and 30% less than rainfall in WY 2006 (Appendix 1). Thus, rainfall in WY 2007 was slightly below average.

The 21 year average monthly rainfall during the majority of the trapping season (April – July) totaled 23.7 cm (9.3 in.) (Table 1). Total monthly rainfall during this period of trapping in YR 2007 was about 26% less than the historic average, 1.7 times greater than YR 2004, 56% less than YR 2005, and 18% less than YR 2006 (Table 1). For each comparison, the month of April experienced the highest amount of rainfall (Table 1).

Table 1. Comparison of 21 year average monthly rainfall with average monthly rainfall in YRS 2004 - 2007 during the majority of the trapping period, lower Redwood Creek, Orick, California (USGS 2007).

	Monthly Precipitation during Trapping Period (cm)*				
Month	Historic	YR 2004	YR 2005	YR 2006	YR 2007
April	12.5	7.1	17.6	11.9	11.2
May	7.5	2.4	15.3	7.0	2.0
June	3.2	0.5	7.0	2.2	2.5
July	0.5	0.1	0.0	0.1	1.7
Total:	23.7	10.2	39.9	21.2	17.5
Average:	5.9	2.5	10.0	5.3	4.4

* Data courtesy of Redwood National Park, Vicki Ozaki pers. comm. 2007.

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 – 2007, and total 55 years (Chris O'Neil pers. comm. 2007; USGS 2007). High streamflows usually occur from November through May, and typically peak in January; in YR 2007 streamflow peaked in December (Appendix 2). However, the months of December, February, March, and April can experience high flows as well. Using all years' data (historic), mean monthly discharge was 1,016 cfs, and ranged from 36 – 2,526 cfs (Chris O'Neil pers. comm. 2007; USGS 2007) (Appendix 2). Average monthly discharge in WY 2007 equaled 933 cfs, ranged from 13 – 2,588 cfs, and peaked in December (Appendix 2). Average streamflow in WY 2007 was about 8% below the historic average, 1.1 times the average flow in WY 2004, 1.2 times the average flow in WY 2005, and 41% less than the average flow in WY 2006. Thus, average streamflow in WY 2007 was about average.

The 56 year average monthly flow during the majority of the trapping season (April – July) equaled 549 cfs, and ranged from 86 – 1,232 cfs (Chris O'Neil pers. comm. 2007; USGS 2007) (Table 2). Average monthly discharge from April – July, 2007 (437 cfs) was 21% less than the historic average, 1.7 times greater than the average for YR 2004, 60% less than the average for YR 2005, and 32% less than the average for YR 2006 (Table 2, data from USGS 2007).

The probability of the average flow during the trapping period in YR 2007 being greater than 437 cfs (based upon the 56 years of record) equaled 54%, and for being greater than 1,087 cfs (YR 2005) equaled 5.4% (USGS 2007).

Table 2. Comparison of 56 year average monthly discharge (historic) with average monthly discharge (Orick gaging station) during the majority of the trapping period in YRS 2004 – 07 (USGS 2007).

	Average Monthly Discharge (cfs)				
Month	Historic	YR 2004	YR 2005	YR 2006	YR 2007
April	1,232	602	2,138	1,741	1,094
May	630	271	1,400	472	449
June	251	109	613	184	138
July	86	41	195	61	65
Average:	549	256	1,087	615	437

<u>Overstory</u>

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.

<u>Understory</u>

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 aggredation, 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, 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+ (between 1 and 2 years old) 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 Viability (VSP) analysis. An additional goal is to document the presence or absence of 1+ Chinook salmon (Stream type). Specific study objectives were as follows:

1) Determine the species composition and temporal pattern of downstream migrating juvenile salmonids.
2) Determine population estimates for downstream migrating 0+ 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) Investigate 0+ Chinook salmon, 1+ steelhead trout, and 2+ steelhead trout travel time and growth as they migrate from the upper trap to the lower trap (or estuary) using passive integrated transponder tags (Pit Tags).
5) Collect genetic samples from 0+ Chinook salmon, 0+ steelhead trout, 1+ steelhead trout, 2+ steelhead trout and juvenile coho salmon (if present) for future analyses and comparisons (Appendix 3).
6) Collect and handle fish in a manner that minimizes mortality.
7) Statistically analyze data for significance and trends.
8) Compare data between study years.
9) Link data collected from the lower trap, upper trap, and estuary (Redwood National Park) to provide a more complete study on the life history and abundance of emigrating juvenile salmonids (smolts) in Redwood Creek.

METHODS AND MATERIALS

Trap Operations

A modified E.G. Solutions (5 foot diameter cone) rotary screw trap was deployed in lower Redwood Creek (RM 4) on April 2, 2007 at the same general location as previous study years (YRS 2004 - 2006). The trap in YR 2007 was set in the same location as YR 2006, which was about 75 m downstream of the location in YRS 2004 and 2005. The trap was set in a fairly steep run that during lower flows resembled a riffle habitat type; the channel configuration was more confined and had a steeper gradient compared to YRS 2004 and 2005.

The rotary screw trap was modified by using the larger pontoons normally equipped with the 8 foot cone so that a larger livebox could be used. The debris wheel of the E.G. solutions livebox was cut out, and aluminum was added to the livebox to increase the length nearly two-fold (L 218.4 cm x W 121.9 cm x H 55.9 cm). A framed perforated steel plate (L x W x H) with 2 mm holes was then used to close the downstream end where the debris wheel was once located. Perforated plates with 2 mm holes were also placed in the sides (n = 2, 56 x 31 cm) and bottom (n = 1, 89 x 41 cm) of the livebox to dissipate livebox water velocities. A 50 cm L x 55 cm H plywood board was placed on the outside of the back screen (perforated plate) to reduce the number of captured fry and amount of debris (sticks, leaves, etc) from being impinged on the screen during very high stream flow and debris periods. The board was placed on the right corner (looking downstream) and by providing a resistance to flow, allowed some of the water outside of the trap to enter the livebox. The water entering the livebox would then push most of the debris (leaves, sticks, etc) towards the middle of the livebox, thus preventing debris loading on the rear screen. Modifications to the livebox decreased livebox water velocities, allowed for less fish crowding during peak catches, and enabled the trap to continue trapping under higher flows as compared to the stock model. We operated the rotary screw trap continually (24 hrs/day, 7 days a week) from April 2nd through August 17th, except for one partially missed day on June 11, 2007 when a log jammed the trap's cone sometime in the early morning. Trapping methods were identical to previous years, and nearly identical to those used for the upper trap (RM 33) in YR 2007 (Sparkman 2008). Every attempt was made to maintain the trap's position in the thalweg.

During periods of lesser streamflows, weir panels were used with the rotary screw to: 1) keep the trap's cone revolutions relatively high, and 2) maintain good trap efficiencies by directing fish into the cone area. The weir panels were set to fall down under any unexpected peaks in streamflow. Weir panels were first installed on May 9, and positioned at an angle to each of the trap's pontoons. Additional weir panels were later added to increase the overall length, and by August 9, the weir panels were 110 ft long on the right bank side (includes rock weir), and 165 ft long on the left bank side. Rock weirs were built to join the weir panels to form a more complete weir configuration. Prior to the end of the study, plastic drop cloths were fastened to the weir panels to force more water into the cone area, which greatly increased the cone revolutions. The YR 2007 trapping season can be characterized with relatively few high flow events (n = 2; 4/12/07 and 4/22/07); however, during April 12 and 22 the stream rose 11 and 19 inches, respectively. Similar to past study years, we made frequent adjustments to the trap configuration to increase trapping efficiencies. Trapping in YR 2007 was much easier compared to most of the previous study years.

Biometric Data Collection

Fishery technicians frequently removed debris (e.g. alder cones, leaves, sticks, detritus, large amounts of filamentous green algae, etc) from within the livebox at night to reduce trap mortalities the following morning. The trap's livebox was emptied at 09:00 every morning by 2 - 4 technicians. 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 drain excess water. The water lines to the recovery buckets were elevated above the recovery buckets so that the fresh water would also provide increased aeration. 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. Marked fish from the upper trap were tallied separately from the marked fish used to determine trap efficiencies for the lower trap. All 1+ steelhead trout, 2+ steelhead trout, and 0+ Chinook salmon captured were scanned (interrogated) for pit tags. Fish with partial, upper caudal fin clips (secondary mark for the pit tag) were observed and recorded for how visible the scar (for pit tag insertion) and partial fin clip were (visible, partially visible, not visible); these data provided detailed information on the longevity and visibility of surgical scars and partial fin clips.

Fork Lengths/Weights

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 ($\pm$ 1 mm), and an Ohaus Scout ll digital scale ($\pm$ 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. 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 70 m downstream of the trap site and released in the margin of the stream; and aged 1 and older fish were transported 90 m downstream of the trap site and released near the middle of the stream.

Developmental Stages

We visually determined developmental stages (e.g. parr, pre-smolt, smolt) for every 1+ Chinook salmon, 1+ steelhead trout, 2+ steelhead trout, 1+ coho salmon, and 1+ (and greater) cutthroat trout captured using the following criteria:

- Parr designated fish that had obvious parr marks present and no silvering of scales.
- Pre-smolt designated individuals with less obvious parr marks, showed some blackening of the caudal fin, and were in the process of becoming silver colored smolts. Pre-smolt was considered in-between parr and smolt.
- Smolt designated fish that were very silver in coloration (i.e. smoltification), had little to no parr marks present, and had blackish colored caudal fins.

Discerning developmental stages is subjective; however, I attempted to minimize observer bias by individually training (and checking) each crew member and having crew members follow the same protocol. Only crew members who had worked in previous study years were allowed to identify the developmental stage in order to minimize learning curves. The most difficult stages to separate were for those fish which fell between smolt and pre-smolt. Negus (2003) reported that the level of ATPase activity (index of smoltification) increased when juvenile steelhead trout were more silvery in color, compared to the dark banded (parr) stage; and Haner et al. (1995) found that skin reflectance increased during smoltification, and correlated well with gill ATPase activity and skin guanine concentration.

Population Estimates

The number of fish captured by the trap represented only a portion of the total fish moving downstream in that time period. Total salmonid out-migration estimates (by age and species) were determined on a weekly basis for 0+ Chinook salmon, 1+ steelhead trout, 2+ steelhead trout, cutthroat trout, and 1+ coho salmon using mark-recapture methodology described by Carlson et al. (1998). The approximately unbiased estimate equation for a 1-site study was used to determine total population size (U_h) in a given capture and trapping efficiency period (h). Variance was computed, and the value was used to calculate 95% confidence intervals (CI) for each weekly population estimate. The weekly population estimate (U_h) does not include catches of marked releases in the

"C" component (or 'u_h') of the equation, and any short term handling mortality was subtracted (Carlson et al. 1998). Trap efficiency trials were conducted one to six times a week, depending upon sample sizes, for 0+ Chinook salmon, 1+ steelhead trout, 2+ steelhead trout, cutthroat trout, and 1+ coho salmon. Data was combined and run through the equation to determine the weekly estimate (for a complete description of estimation methods and model assumptions see Sparkman 2004a). The Carlson et al. (1998) model and my methods were (favorably) peer reviewed in YR 2003 by CDFG Biometrician Phil Law and Dr. Don Chapman.

Small, partial fin clips were used to identify trap efficiency trial fish by squaring the round edge (or tip) of a given fin (caudal, pectoral) with scissors. Fish used in efficiency trials were given partial fin clips while under anesthesia (MS-222), and recovered in 5 g buckets which received fresh stream water (via the plumbing system). Clip types for 0+ Chinook salmon, 1+ steelhead trout and 2+ steelhead trout were different than those used at the upper trap. Clips for 1+ coho salmon and 2+ steelhead trout were stratified by week such that marked fish of one group (or week) would not be included in the following weekly calculation (a relatively rare event). I did not stratify clips for 0+ Chinook salmon and 1+ steelhead trout because four years of data (when I did stratify clips) at the upper trap showed that nearly all of the recaptures (99.4%) occurred in the correct strata. The few fish that were recaptured out of strata had little to no effect on the weekly and total population estimates (Phil Law, personal comm. 2003). 0+ Chinook salmon, 0+ coho salmon, 1+ steelhead trout, and cutthroat trout were given lower caudal partial fin clips. 1+ coho salmon were given an upper or lower caudal fin clip, and 2+ steelhead trout were given right or left pectoral partial fin clips. Once recovered from anesthesia, the fish were placed in mesh cages in the stream for at least 1 - 2 hrs to test for short term delayed mortality (Carlson et al. 1998). Many of the fin clipped fish were held for up to five hours prior to release at night. Fin clipped 0+ Chinook salmon were released in fry habitat 183 m upstream of the trap, and clipped 1+ and 2+ steelhead trout, cutthroat trout, and 1+ coho salmon were released into a pool (with woody debris) 152 m upstream of the trap. Fin clipped fish were manually released upstream of the trap at night.

Additional Experiments

Re-Migration

In YR 2006 we pit tagged and released 38 2+ steelhead trout, 246 1+ steelhead trout, and 121 0+ Chinook salmon to investigate travel time between the upper trap (RM 33) and lower trap (RM 4) in Redwood Creek. These tags can also serve to show if any marked juveniles that migrated downstream in YR 2006 re-migrated back upstream of the upper trap to be later caught in YR 2007 as one, two or three year old fish. We have investigated re-migration in previous study years as well (YRS 2001 - 02, and 2004 - 2005). Every 2+ steelhead trout captured at the upper trap in YR 2007 was scanned for pit tags, as were the largest juvenile Chinook salmon smolts (potential 1+ smolts).

Travel Time and Growth

We did not use plastic elastomer in YR 2007 to investigate travel time from the upper to the lower trap (this study) because individual fish cannot be uniquely identified when elastomer marks are used for batches of fish, and the mark is rather difficult to apply for fish under 85 mm (FL). Pit tags (passive integrated transponder tags) offer the ability of individual recognition by using numbers unique to each tag (and marked fish). In YR 2007 (and YRS 2005 and 2006) we used Pit Tags to investigate both travel time and growth of tagged fish as they migrated downstream from Redwood Valley to be later caught at the lower trap (Sparkman 2008) or estuary (David Anderson, pers. comm. 2008). We found pit tagging to be easier and faster than applying elastomer. Pit tags used in the study were 11.5 mm long x 2 mm wide, and weighed 0.09 g (ALLFLEX USA, Inc., PO BOX 612266, Dallas/Ft Worth Airport, Texas). Pit tags were applied to randomly selected 1+ steelhead trout (n = 484), 2+ steelhead trout (n = 48) and 0+ Chinook salmon smolts (FL $\geq$ 67 mm**,** n = 696) using the same techniques as in previous study years. Fish were anesthetized with MS-222, and measured for FL (mm) and Wt (g) prior to tagging. A scalpel (sterilized with a 10:1 solution of water to Argentyne; Argent Chemical Laboratories, 8702 152nd Ave. N.E., Redmond, WA, 98052) was used to make a small incision (2 - 3 mm long) into the body cavity just posterior (about 3 - 5 mm) to a pectoral fin. The incision was dorsal to the ventral most region of the fish to help prevent the tag from exiting the incision. Tags were also sterilized with Argentyne, and then inserted by hand into the body cavity via the incision. Glue was not used to close the incision after tag placement because previous experience with tagging showed it was unnecessary, and in YR 2007 we found tag retention from 24 – 48 hrs post tagging to be 100%. Pit tagged 0+ Chinook salmon, and 1+ and 2+ steelhead trout were also given a small partial upper caudal fin clip to later aid in recognizing a tagged fish. Nevertheless, all fish (except 0+ steelhead trout) captured at the lower trap were scanned (interrogated) for pit tags while being processed. We also pit tagged some of the 0+ Chinook salmon recaptures (n = 77) from the trap efficiency trials at the upper trap to increase sample size, and to test if there were differences in capture probability between pit tagged fish that had been captured once at the upper trap, given a pit tag, and then released downstream vs. those that were captured twice at the upper trap (trap efficiency trial fish), given a pit tag, and released downstream. The recapture of pit tagged, trap efficiency recaptures at the lower trap site indicated that these fish probably did not ‘learn’ about avoiding rotary screw traps because the capture at the lower trap represented the third capture. Additionally, the percent recapture among the two groups was statistically the same (Chi-square, p = 0.74; 34% recapture for pit tagged, efficiency trial fish and 36% recapture for pit tagged fish that had been previously captured one time).

After initial tag application, fish were held in a livecar in the stream for a period of 10 - 60 hrs to test for delayed mortality; however, most pit tagged juveniles were held for a 34 hr period. 0+ Chinook salmon were kept separately from 1+ and 2+ steelhead trout. All pit tagged fish were released at night downstream of the trap site at the normal downstream release site. Field crews at the upper trap, lower trap, and estuary had hand held pit tag readers (ALLFLEX USA, Inc., PO BOX 612266, Dallas/Ft Worth Airport, Texas) so that they could scan and identify pit tagged fish; and perform necessary fork length and weight measurements. I assumed pit tags did not affect feeding or migration based upon findings by Newby et al. (2007). In addition, this study shows that the majority of recaptured pit tagged salmon and steelhead trout showed growth; if the tag had a negative impact upon juveniles we would expect more fish to not grow, or lose weight when compared to those that did grow.

For the second year in a row we investigated whether 0+ steelhead trout released at the upper trap site would travel the 29 miles downstream to the lower trap site. We performed two trials (6/28/07, n = 100; 7/20/07, n = 100) and used a partial, upper caudal fin clip on 6/28/07, and a partial, lower on 7/20/07. The 0+ steelhead trout used in the experiments ranged from 40 to 55 mm FL, and the first release group was held for a 24 hr period prior to release to assess any delayed mortality (0%).

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 from April 3rd – August 17th, 2007. The gage was read every morning at 0900 to the nearest one-hundredth of a foot prior to biometric data collection. A graphical representation of the data, along with average daily stream discharge data from the O'Kane gaging station (USGS 2007), is given in Appendix 4.

Stream temperatures were recorded with an Optic StowAway® Temp data logger (Onset Computer Corporation, 470 MacArthur Blvd. Bourne, MA 02532) placed behind the rotary screw trap. A second probe was deployed at the same location for comparison. Both probes gave similar results (Avg. = 15.3 and 15.4 ^{o}C), therefore only data from one probe is reported. The probes were placed into a PVC cylinder with holes to ensure adequate ventilation and to prevent influences from direct sunlight. Probes were set to record stream temperatures (^{o}C) every 30 minutes and recorded 6,672 measurements per probe over the course of the study. The shallowest stream depth during which measurements were taken (in August) was about 1.0 feet. The maximum weekly average temperature (MWAT) and maximum weekly maximum temperature (MWMT) for YRS 2004 - 2007 were determined following methods described by Madej et al. (2006). MWAT is defined as the maximum value of a 7-day moving average of daily average stream temperatures, and MWMT is the maximum value of a 7-day moving average of daily maximum stream temperatures (Madej et al. 2006).

Statistical Analyses

Numbers Cruncher Statistical System software (NCSS 97) (Hintze 1998) was used for linear correlation, regression/ANOVA output, single factor ANOVA, chi-square, 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 population abundance of a given species at age was increasing or decreasing over the four years of study. The tests are considered very preliminary, and more data will be required to detect the true trend in population abundance over years. With respect to 0+ Chinook salmon, peaks in stream flows were great enough to potentially mobilize redd gravels each study year. Flood type flows capable of gravel scour (and deposition) are generally thought to occur near 11,000 cfs (Randy Klein, Greg Bundros, Vicki Ozaki, Mary Ann Madej, pers. comm. 2003).

I partitioned the 0+ Chinook salmon population estimate into classes of fry (newly emerged and post-emergent fry, FL < 45 mm) and fingerlings (FL > 44 mm) each week of a given year using weekly FL data and weekly population estimates. The percentage of juvenile Chinook salmon per size class each week was multiplied by the corresponding weekly population estimate (which included marked recaptures of fry and fingerlings) to estimate the population of fry and fingerlings. The FL cutoff between fry and fingerlings was determined by examining FL histograms from seven years of downstream migrant trapping in upper Redwood Creek (FL nadir ranged from 42 – 45 mm, mean = 44 mm; nadir in YR 2007 was 44 mm), from four years of trapping in lower Redwood Creek (FL nadir was 43 mm in YR 2004, 45 mm in YR 2005, 42 mm in YR 2006, and 43 mm in YR 2007; Avg. = 43 mm), from trapping Chinook salmon redds in Prairie Creek (emergent fry fork length per redd ranged from 35 – 43, and averaged 39 mm, n = 4 redds; Sparkman 1997 and 2004b), and from information gathered in the literature (Allen and Hassler 1986, Healey 1991, Bendock 1995, Seiler et al. 2004). Allen and Hassler (1986) summarized that newly emerged Chinook salmon fry range from 35 – 44 mm FL, Healey (1991) reported that Chinook salmon fry FL's normally range from 30 – 45 mm, and Bendock (1995) and Seiler (2004) used a FL < 40 mm for fry. Therefore, the 45 mm FL cutoff for fry in Redwood Creek was similar to that used in other studies.

I determined a ' rough' estimate of growth rate in FL and Wt for 0+ Chinook salmon in YR 2007 generally following methods by Bendock (1995). I used the first weekly average in FL and Wt with a sample size ≥ 25 (week 4/02 – 4/08) and the last weekly average in the season (7/30 - 8/05) with a sample size ≥ 25. The first average was subtracted from the last average, and divided by the number of days from the first day after the first weekly average to the last day of the last weekly average. For the example above, the number of days used in the growth calculation equaled 119. The resultant growth rate is not an individual growth rate, but more of a 'group' growth rate. The calculated values were then compared to values put forth by Healey (1991) and Bendock (1995) for juvenile Chinook salmon in other streams. The growth rates for 0+ steelhead and 0+ coho salmon were also determined using this method.

Descriptive statistics were used to characterize the mean and median FL (mm) and Wt (g) of each species at age on a study year and weekly basis. Linear correlation was also used to test if the average weekly FL and Wt of each species at age (excluding 0+ steelhead weight) in each study year increased over the study period. The lack of data in any given week was due to: 1) differences in trap deployment time among study years, 2) no catches occurred, or 3) sample size was too low to generate a reliable average. Single factor ANOVA (or non-parametric equivalent, Kruskal-Wallis One-Way ANOVA on Ranks) was used to test for significant variation among weekly FLs and Wts in YRS 2004 – 07. Given significance, further testing was performed using multiple comparison procedures (Kruskal-Wallis Multiple-Comparison Z-Value Test with Bonferroni control) to determine which groups differed from one-another. Correction factors for alpha were applied when performing multiple hypothesis testing (NCSS 97).

Chi-square was used to test for differences in the proportions of parr, pre-smolt and smolt designations for captured 1+ steelhead trout and 2+ steelhead trout in YR 2007 compared to the previous three year average (YRS 2004 – 06). Parr stage was not included in the test for 2+ steelhead trout because none were classified as parr (NCSS 97). Chi-square was also used to test if the percentages of fry and fingerlings in YR 2007 were random by assuming that a random occurrence of the two designations would equal 50/50 or 1:1; and if fry and fingerling percentages in YR 2007 differed from the previous three year average.

Descriptive statistics were used to characterize FL, Wt, travel time (d), travel rate (mi per d), and various growth indices (Percent Change in Growth, Absolute Growth Rate, Specific Growth Rate, and Relative Growth Rate) for all pit tagged fish recaptured at the lower trap. The weight of the pit tag (0.09 g) was subtracted from the final recorded weight to obtain the true weight of the fish. Measurement uncertainties for FL and Wt were assumed to be $\pm$ 1 mm and $\pm$ 0.1 g, therefore final FL's and Wt's needed to be greater than the initial FL and Wt by this amount to constitute a real change in size.

Travel time is defined as the difference (in days) from the recapture date to initial release date, and equals the period of growth for recaptured individuals. Since pit tagged fish were released at night (eg 2100) and recaptured at some date in the morning by the lower trap (when the crew checks the trap at 0900) the earliest recorded travel time could be 0.5 days (or 12 hours). Travel rate is the travel time divided by 29 miles (the distance between the upper and lower traps).

Numerous growth indices (Percent Change in Growth, Absolute Growth Rate, Specific Growth Rate scaled, and Relative Growth Rate) were calculated to ensure comparisons of our data with data reported in the literature. Equations for growth indices are found in Busacker et al. (1990). Absolute growth rate is expressed as mm per day for FL or g per day for Wt. Specific growth rate (mm/d) is expressed as a scaled number (by multiplying specific growth rate by 100). Thus, if the specific growth rate scaled equaled 0.741% (mm per day), the un-scaled value would equal 0.00741 mm per day. Relative growth rate is a growth rate that is relative to the initial size of the fish, and units for FL are in mm/mm/d and for Wt, g/g/d. Therefore, if the relative growth rate equaled 0.003 mm/mm/d, then we would say that the fish grew 0.003 mm per mm of fish per day. Travel time, travel rate, and growth for recaptured pit tagged 0+ Chinook salmon (n = 245) and 1+ steelhead trout (n = 18) smolts in YR 2007 were modeled using linear regression. Travel and growth parameters for 2+ steelhead trout could not be modeled due to a single recapture. Independent variables for travel time and travel rate (dependent variables in this case) included fish size at time 1 or time 2, water temperature during a specific migration period (average of data from both traps), lunar phase (averaged across a specific migration period), and stream discharge during a specific migration period (average of data from O'Kane and Orick gages, USGS 2007).

Independent variables for modeling growth (dependent variable) included travel time, travel rate, average water temperature, average stream discharge, and average lunar phase. Physical variables were once again averaged across a specific migration period; and stream temperature and stream discharge were not included together in any regression models because they were highly correlated ($p < 0.001$). During the travel time and growth experiments (4/05 – 8/19), average daily stream temperatures at the upper trap site ranged from 7.3 - 22.7 ^{o}C (45.1 – 72.9 ^{o}F) and average daily stream discharge ranged from 5.8 - 547 cfs (O'Kane gage, USGS 2007). Average daily stream temperatures at the lower trap site ranged from 8.8 - 20.3 ^{o}C (47.8 - 68.5 ^{o}F) and average daily stream discharge ranged from 22 - 2,200 cfs (Orick gage, USGS 2007). Thus, the experiments were conducted over a fairly wide range of environmental variables.

Minimum, average, and maximum stream temperatures for each day during the trapping period were determined from data collected by temperature probes at the trapping site. Descriptive statistics were used to determine the average stream temperature during the course of the study. Single factor ANOVA was used to test for significant variation in monthly stream temperatures among study years. Correlations were used to test if the average daily (24 hour) stream temperature increased or decreased over the study period (March - August) in YR 2007; and regression was used to examine the relationship of the daily stream gage height and average daily stream discharge (cfs) on average daily stream temperature in YR 2007.

If data violated tests of statistical assumptions, data was transformed with Log (x+1) to approximate normality (Zar 1999). The term 'transformed' in this paper refers to the log(x+1) transformation. "X" could be the independent or dependent variable in linear regression, or the response variable for a given treatment using ANOVA. 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) for tests with less than five data points (eg. population trend analysis) was set at 0.10, and for tests with more than five data points, alpha was set at 0.05. When performing multiple comparison procedures, alpha was corrected by dividing the alpha value (eg 0.05) by the number of tests involved (NCSS 97; Zar 1999).

RESULTS

The rotary screw trap operated from 4/02/07 - 8/17/07 and trapped 136 days/nights out of a possible 137. The trapping rate in YR 2007 was 99%, compared to 97% in YR 2006, 91% in YR 2005 and 97% in YR 2004. The missed trapping day in YR 2007 occurred on June 11th.

Species Captured

Juvenile Salmonids

Species captured in YR 2007 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 94,308 juvenile salmonids were captured in YR 2007 (Figure 2).

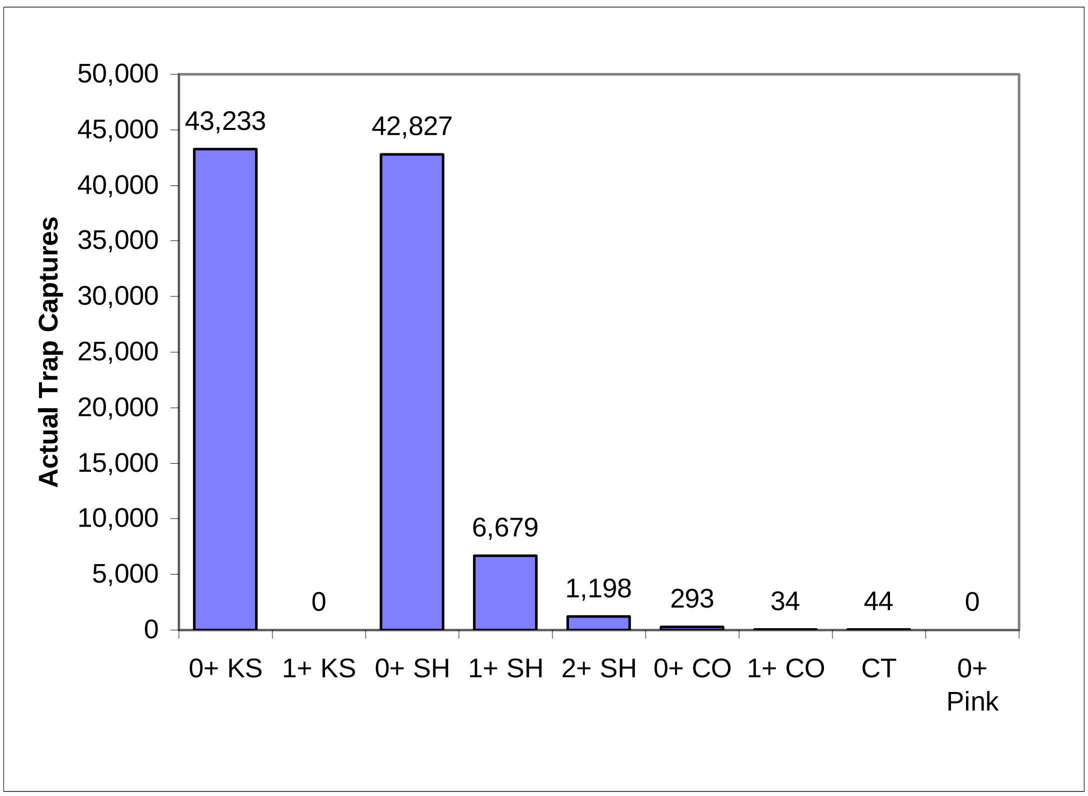


Figure 2. Total juvenile salmonid trap catches (n = 94,308) from April 3rd through August 17th, 2007, lower Redwood Creek, Humboldt County, CA. Numeric values above columns represent actual catches. 0+ KS = young-of-year Chinook salmon, 1+ KS = age 1 Chinook salmon, 0+ SH = young-of-year steelhead trout, 1+ SH = age 1 and older steelhead trout, 2+ SH = age 2 and older steelhead trout, CT = cutthroat trout, 0+ Pink = young-of-year pink salmon.

The total trap catch of juvenile salmonids in YR 2007 was considerably higher than two of the previous three study years (Table 3). Young-of-year juvenile salmonids comprised the majority of the total catch each study year, and accounted for 89% of the total captures over four study years. (Table 3). 0+ Chinook salmon accounted for 52% of the four year total catch (Table 3).

Table 3. Juvenile salmonid trap catches in YRS 2004 - 2007, lower Redwood Creek, Humboldt County, CA.

Age/species*	YR 2004	YR 2005	YR 2006	YR 2007
0+ KS	61,778	10,827	16,773	43,233
1+ KS	2	11	0	0
0+ SH**	18,642	1,345	29,957	42,827
1+ SH	6,371	2,033	7,660	6,679
2+ SH	907	417	1,111	1,198
0+ CO	202	53	108	293
1+ CO	69	39	72	34
CT	37	9	36	44
0+ Pink	NC***	2	0	0
Total:	88,088	14,736	55,717	94,308

* Age/species definitions are the same as in Figure 2.
** Includes a small, but unknown percentage of young-of-year cutthroat trout.
*** Denotes not counted.

Miscellaneous Species

The trap caught numerous species besides juvenile anadromous salmonids in YR 2007, 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 (*Entosphenus tridentatus*) (Table 4).

Table 4. Miscellaneous species captured in YRS 2004 - 2007, lower Redwood Creek, Humboldt County, CA.

Species Captured	YR 2004	YR 2005	YR 2006	YR 2007
Prickly Sculpin	68	140	209	76
Coast Range Sculpin	502	212	599	205
Sucker	156	89	194	193
3-Spined Stickleback	7,225	215	1,119	1,049
Adult Pac. Lamprey	13	3	4	16
Juvenile Lamprey*	154	84	50	112
Pac. Giant Salamander	4	8	15	12
Painted Salamander	0	0	0	0
Rough Skinned Newt	2	3	0	8
Red-Legged Frog	0	2	0	2
Yellow-Legged Frog	0	0	0	0
Tailed Frog	0	1	0	1

* Ammocoete stage.

Juvenile Salmonid Captures

Trap catches of juvenile salmonids in YR 2007 were variable over time, with apparent multi-modal catch distributions for 0+ steelhead trout, 2+ steelhead trout, 0+ coho salmon, and 1+ coho salmon; and a modal distribution for 0+ Chinook salmon and 1+ steelhead trout catches.

0+ Chinook salmon daily catches in YR 2007 (Total = 43,233) ranged from 0 – 1,872, and averaged 318 fish per day. Catches in YR 2006 (Total = 16,773) ranged from 0 – 1,195 individuals, and averaged 129 fish per day. 0+ Chinook salmon daily catches in YR 2005 (Total = 10,827) ranged from 0 - 581 individuals, and averaged 91 fish per day. Daily catches in YR 2004 (Total = 61,778) ranged from 0 – 2,196 and averaged 547 per day. Daily 0+ Chinook salmon captures in YR 2007 expressed as a percentage of total 0+ Chinook salmon catch in YR 2007 ranged from 0.0 – 4.3%, and averaged 0.7%. The peak catch in YR 2007 occurred on 6/18/07, compared to 6/25/06 in YR 2006, 7/18/05 in YR 2005 and 6/17/04 in YR 2004.

0+ steelhead trout daily catches in YR 2007 (Total = 42,827) ranged from 0 – 1,929, and averaged 313 fish per day. Catches in YR 2006 (Total = 29,957) ranged from 0 – 2,535 individuals, and averaged 230 fish per day; catches in YR 2005 (Total = 1,345) ranged from 0 - 119 individuals, and averaged 11 per day; and daily catches in YR 2004 (Total = 18,642) ranged from 0 – 639 and averaged 154 per day. Daily 0+ steelhead captures in YR 2007 expressed as a percentage of total 0+ steelhead catch in YR 2007 ranged from

0.0 – 4.5% and averaged 0.7%. The peak catch in YR 2007 occurred on 6/22/07, compared to 6/28/06 in YR 2006, 5/08/05 in YR 2005, and 6/11/04 in YR 2004.

1+ steelhead trout daily catches in YR 2007 (Total = 6,679) ranged from 1 – 479, and averaged 49 per day. Catches in YR 2006 (Total = 7,660) ranged from 0 – 512 individuals, and averaged 58 fish per day. Daily catches in YR 2005 (Total = 2,033) ranged from 0 - 94, and averaged 17 per day. Daily catches in YR 2004 (Total = 6,371) ranged from 0 – 213 and averaged 56 per day. Daily 1+ steelhead trout captures in YR 2007 expressed as a percentage of total 1+ steelhead trout catch in YR 2007 ranged from 0.0 – 7.2% and averaged 0.7%. The peak catch in YR 2007 occurred on 6/18/07, compared to 6/21/06 in YR 2006, 5/03/05 in YR 2005 and 5/29/04 in YR 2004.

2+ steelhead trout daily catches in YR 2007 (Total = 1,198) ranged from 0 – 49 individuals, and averaged nine fish per day. Catches in YR 2006 (Total = 1,111) ranged from 0 – 45 individuals, and averaged eight fish per day. Daily catches in YR 2005 (Total = 417) ranged from 0 - 27, and averaged three individuals per day. Daily catches in YR 2004 (Total = 907) ranged from 0 – 39 and averaged eight per day. Daily 2+ steelhead trout captures in YR 2007 expressed as a percentage of total 2+ steelhead trout catches in YR 2007 ranged from 0.0 – 4.1%, and averaged 0.7%. The peak catch in YR 2007 occurred on 6/18/07, compared to 6/21/06 in YR 2006, 5/03/05 in YR 2005 and 5/16/04 in YR 2004.

0+ coho salmon daily catches in YR 2007 (Total = 293) ranged from 0 – 18, and averaged 2 fish per day. Catches in YR 2006 (Total = 108) ranged from 0 – 8 individuals, and averaged 0.8 fish per day. Daily catches in YR 2005 (Total = 53) ranged from 0 - 3 individuals, and averaged 0.4 fish per day. Daily catches in YR 2004 (Total = 202) ranged from 0 – 15 and averaged two fish per day. Daily 0+ coho salmon captures in YR 2007 expressed as a percentage of total 0+ coho salmon catch in YR 2006 ranged from 0.0 – 6.1% and averaged 0.7%. The peak catch in YR 2007 occurred on 7/30/07, compared to 6/21/06 in YR 2006, 6/24/05, 7/19/05 and 7/27/05 in YR 2005 and 7/18/04 in YR 2004.

1+ coho salmon daily catches in YR 2007 (Total = 34) ranged from 0 – 3, and averaged 0.3 fish per day. Catches in YR 2006 (Total = 72) ranged from 0 – 5 individuals, and averaged 0.5 fish per day. Daily catches in YR 2005 (Total = 39) ranged from 0 - 7 individuals, and averaged 0.3 fish per day. 1+ coho salmon daily catches in YR 2004 (Total = 69) ranged from 0 – 7 and averaged 0.6 fish per day. Daily 1+ coho salmon captures in YR 2007 expressed as a percentage of total 1+ coho salmon catch in YR 2007 ranged from 0.0 – 8.8% and averaged 0.7%. The peak catch in YR 2007 occurred on 5/11/07, compared to 5/20/06 in YR 2006, 5/06/05 in YR 2005 and 4/16/04 in YR 2004.

Cutthroat trout daily catches in YR 2007 (Total = 44) ranged from 0 – 3, and averaged 0.3 fish per day. Catches in YR 2006 (Total = 36) ranged from 0 – 3 individuals, and averaged 0.3 fish per day. Cutthroat trout catches in YR 2005 (Total = 9) ranged from 0 – 1 fish per day, and averaged 0.07 fish per day. Daily catches in YR 2004 (Total = 37) ranged from 0 – 3 and averaged 0.3 fish per day. The peak catch in YR 2007 occurred on

7/13/07, compared to 6/15/06 in YR 2006, and 5/01/04 and 7/11/04 in YR 2004. In YR 2005, the peak catch was only one individual, which occurred on nine separate days.

Days Missed Trapping

One day was not trapped (after trap deployment) in YR 2007 because a log jammed the trap's cone. The missed day of trapping did not appear to influence the total catch or population estimate of any juvenile salmonid to any large degree (Table 5). 1+ coho and cutthroat trout were not captured immediately before or after the missed day, thus no fish were considered to be missed on June 11, 2007.

Table 5. 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 2nd through August 17th (as a percentage of total without missed days in parentheses), lower Redwood Creek, Humboldt County, CA., 2007.

Age/spp.*	Catch	Population Level
0+KS	1,376 (3.29%)	3,639 (2.65%)
1+KS	-	-
0+ SH	639 (1.51%)	-
1+ SH	113 (1.72%)	408 (1.09%)
2+ SH	13 (1.10%)	159 (1.28%)
0+CO	2 (0.69%)	9 (0.86%)
1+CO	0 (2.86%)	0 (0.00%)
CT	0 (0.00%)	0 (0.00%)

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

0+ Chinook Salmon

0+ Chinook salmon were captured in each week during the trapping period in YR 2007 (Figure 3). The peak in weekly catches in YR 2007 (n = 10,056) occurred during the same time as in YR 2006 (6/18 – 6/24). The peak in YR 2007 occurred after two previous weeks of high catches (n = 18,825).

The pattern in emigration in YR 2007 was similar to YR 2006, and dissimilar to emigration in YRS 2004 and 2005 (Figure 3). Emigration in YRS 2005 – 2007 lack the large number of fry migrants captured in April compared to YR 2004 (Figure 3). Catches reached low values at the end of July in YRS 2004, 2006 and 2007; in YR 2005, catches reached low values by the first week of August (Figure 3).

Catches by month (not shown) also show the between-year variation in the catch distribution; the highest percentage of the total catch occurred in June (78%) in YR 2007, June (74%) for YR 2006, July (61%) for YR 2005 and June (47%) for YR 2004. The two most important months for capturing 0+ Chinook salmon were June and July (91%) in YR 2007, compared to June and July (97%) in YR 2006, June and July (83%) in YR 2005, and May and June (79%) in YR 2004.

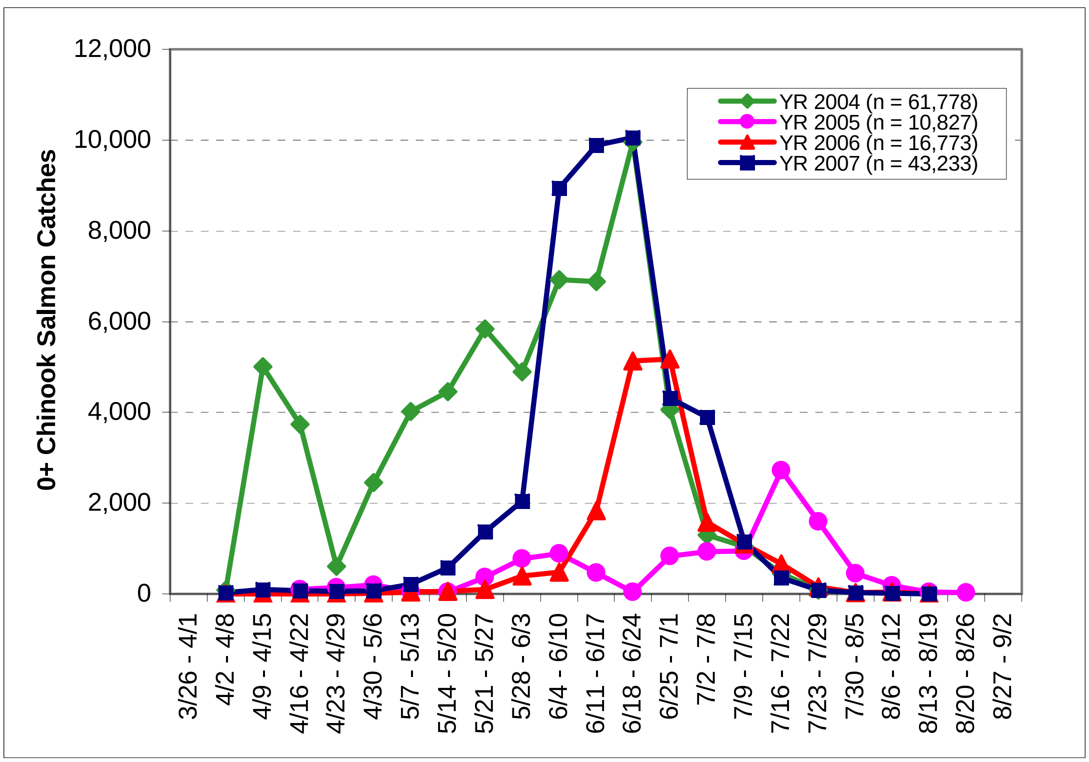


Figure 3. Comparison of 0+ Chinook salmon captures by week in YR 2007 with weekly catches in YRS 2004 - 2006, lower Redwood Creek, Humboldt County, CA.

1+ Chinook Salmon

No 1+ Chinook salmon were captured in YR 2007 and YR 2006, although 11 were captured in YR 2005 and two were captured in YR 2004.

0+ Steelhead Trout

0+ steelhead trout were captured each week during the trapping period in YR 2007 (Figure 4). Trap catches peaked during 6/18 – 6/24 (n = 9,517) in YR 2007, compared to 6/25 – 7/01 (n = 10,863) in YR 2006, 5/7 – 5/13 (n = 294) in YR 2005 and 6/11 – 6/17 (n = 3,547) in YR 2004. Low catches occurred during the first nine weeks each study year because fry had not yet emerged from spawning redds, or migrated downstream.

On a monthly basis, the greatest number of catches in occurred in June (n = 22,692 or 53% of total) in YR 2007, June (n = 17,293 or 58% of total) in YR 2006, May (n = 515 or 38% of total) in YR 2005, and June (n = 9,947 or 53% of total) in YR 2004. The two most important months for capturing 0+ steelhead trout were June and July (92%) in YR 2007, compared to June and July (92%) in YR 2006, May and July (65%) in YR 2005, and June and July (80%) in YR 2004.

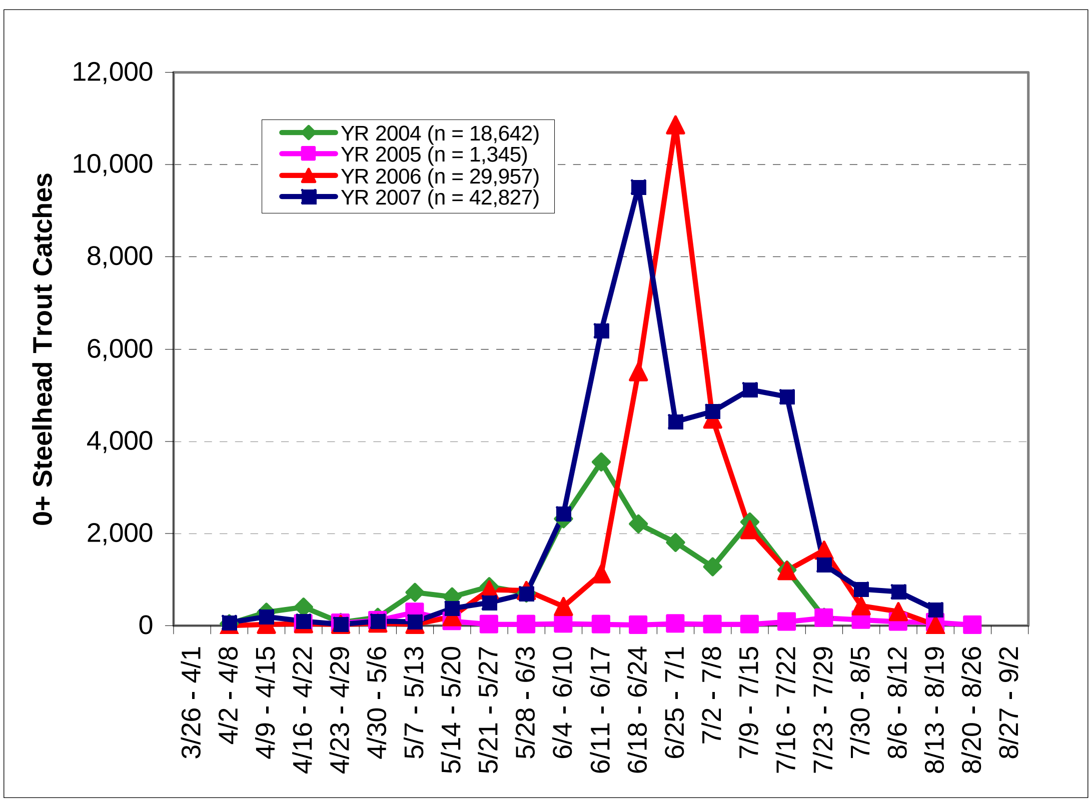


Figure 4. Comparison of 0+ steelhead trout captures by week in YR 2007 with weekly catches in YRS 2004 - 2006, lower Redwood Creek, Humboldt County, CA.

1+ Steelhead Trout

1+ steelhead trout were captured each week during the trapping period in YR 2007 (Figure 5). The peak in weekly catches in YR 2007 (n = 1,525) occurred during the same week as in YR 2006 (6/18 – 6/24), compared to 4/23 – 4/29 (n = 380) in YR 2005, and 5/14 – 5/20 (n = 1,058) in YR 2004 (Figure 5). The pattern of catches over time showed emigration in YRS 2007 and 2006 was skewed towards the middle to end of the trapping period compared to YRS 2004 and 2005.

On a monthly basis, the greatest number of catches in occurred in June (n = 4,013 or 60% of total) in YR 2007, June (n = 4,601 or 60% of total) in YR 2006, April (n = 690 or 34% of total) in YR 2005, and May (n = 3,004 or 47% of total) in YR 2004. The two most important months for capturing 1+ steelhead trout were June and July (78%) in YR 2007, compared to June and July (87%) in YR 2006, April and May (63%) in YR 2005, and May and June (75%) in YR 2004.

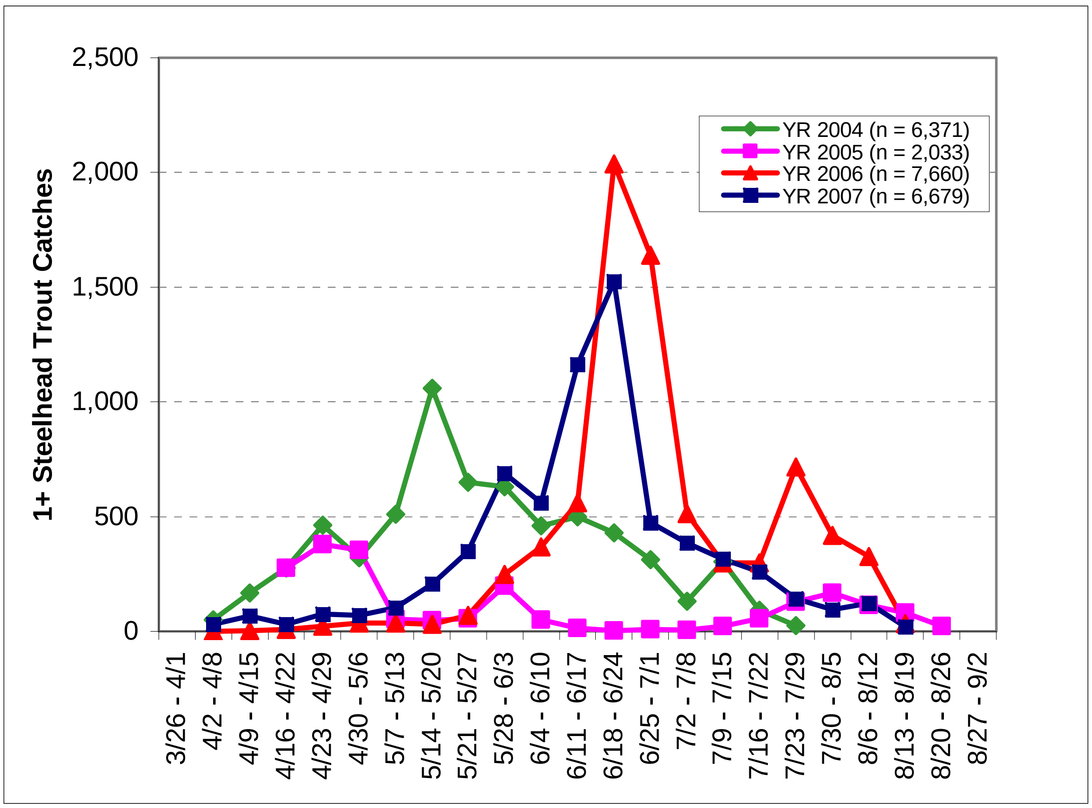


Figure 5. Comparison of 1+ steelhead trout captures by week in YR 2007 with weekly catches in YRS 2004 - 2006, lower Redwood Creek, Humboldt County, CA.

2+ Steelhead Trout

2+ steelhead trout were captured in each week during the trapping period in YR 2007 (Figure 6). Trap catches peaked during 6/18 – 6/24 (n = 219) in YR 2007, with a second smaller peak occurring 5/28 – 6/03 (n = 117). The peak in weekly catches in YR 2007 occurred during the same week as YR 2006 (peak catch = 217). The peak catch in YR 2005 occurred 4/30 – 5/06 (n = 93), and 5/14 – 5/20 (n = 188) in YR 2004 (Figure 6).

The pattern of catches over time showed emigration in YRS 2007 and 2006 was skewed towards the middle to end of the trapping period, compared to YRS 2004 and 2005 when catches were skewed towards the beginning to middle of the trapping period (Figure 6).

On a monthly basis, the greatest number of catches in occurred in June (n = 617 or 51% of total) in YR 2007, June (n = 557 or 50% of total) in YR 2006, May (n = 169 or 41% of total) in YR 2005, and May (n = 515 or 57% of total) in YR 2004. The two most important months for capturing 2+ steelhead trout were May and June (75%) in YR 2007, compared to June and July (72%) in YR 2006, April and May (70%) in YR 2005, and May and June (78%) in YR 2004.

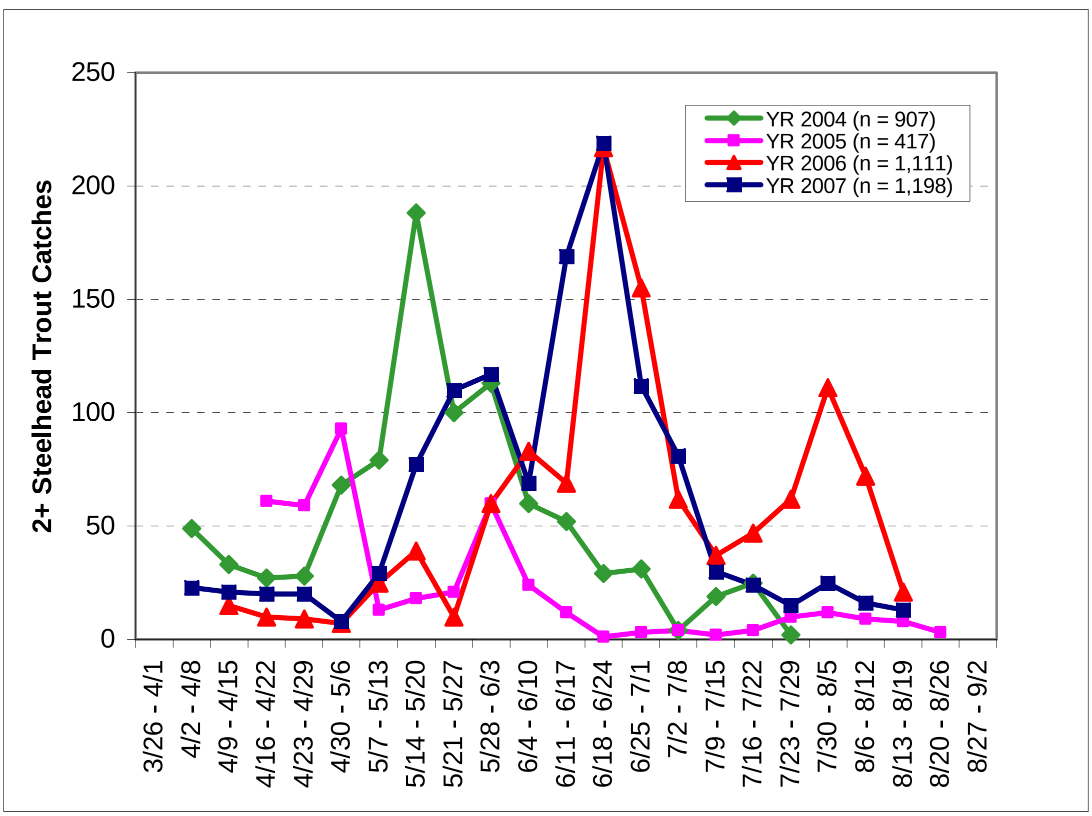


Figure 6. Comparison of 2+ steelhead trout captures by week in YR 2007 with weekly catches in YRS 2004 - 2006, lower Redwood Creek, Humboldt County, CA.

0+ Coho Salmon

0+ coho salmon were captured each week during the trapping period in YR 2007 (Figure 7). Trap catches peaked during 6/11 – 6/17 (n = 53) in YR 2007, with a second smaller peak occurring 7/30 – 8/05 (n = 30) (Figure 7). Trap catches peaked during 6/18 – 6/24 (n = 16) in YR 2006, 7/16 – 7/22 (n = 9) and 7/23 – 7/29 (n = 9) in YR 2005 and 7/16 – 7/22 (n = 36) in YR 2004 (Figure 7). Low catches occurred during the first five weeks each study year because fry had not yet emerged from spawning redds, or did not migrate downstream (Figure 7).

On a monthly basis, the greatest number of catches in YR 2007 occurred in June (n = 137 or 47% of total), compared to June (n = 36 or 33% of total) in YR 2006, July (n = 20 or 38% of total) in YR 2005, and July (n = 71 or 35% of total) in YR 2004. The two most important months for capturing 0+ coho salmon were June and July (83%) in YR 2007, June and July (66%) in YR 2006, June and July (58%) in YR 2005, and May and July (67%) in YR 2004.

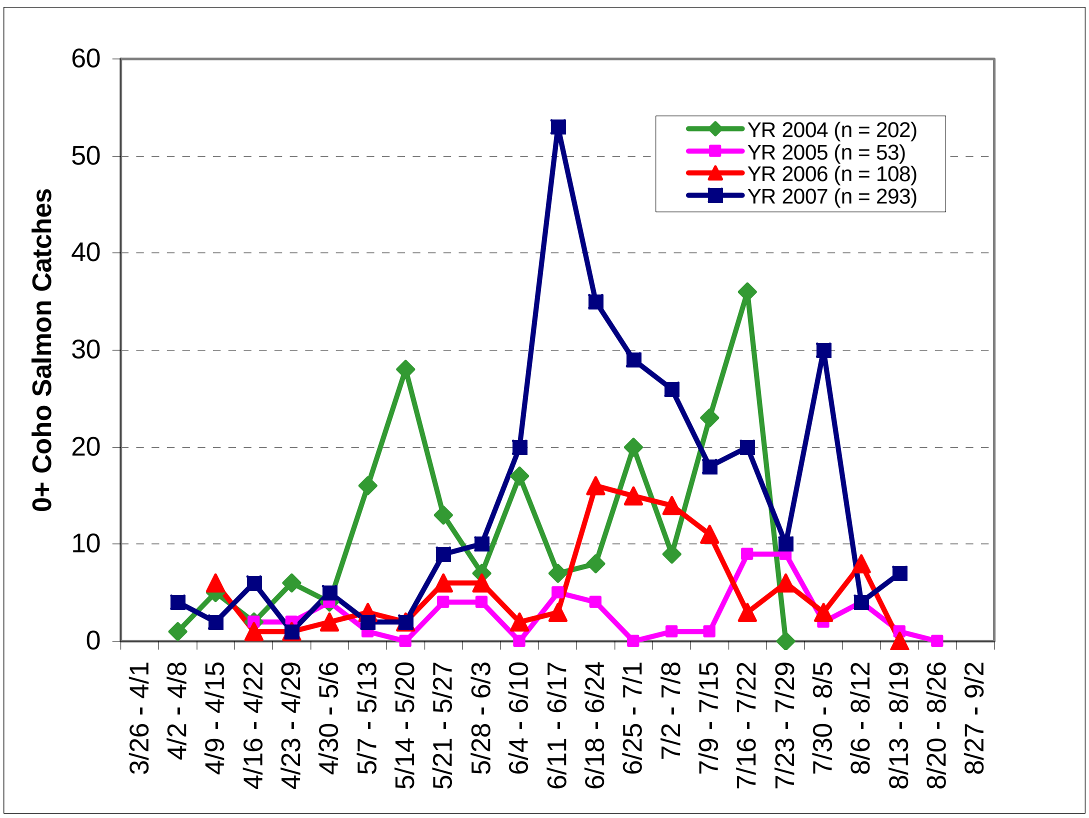


Figure 7. Comparison of 0+ coho salmon captures by week in YR 2007 with weekly catches in YRS 2004 - 2006, lower Redwood Creek, Humboldt County, CA.

1+ Coho Salmon

1+ coho salmon were captured in 9 out of 20 weeks of trapping in YR 2007, and the last capture occurred on 6/14/07 (Figure 8). No 1+ coho salmon were captured in any given study year during the latter part of June, or during July. Trap catches peaked during 5/21 – 5/27 (n = 9) in YR 2007, 5/28 – 6/03 (n = 18) in YR 2006, and 4/30 – 5/06 (n = 15 for YR 2005; n = 14 for YR 2004) in YRS 2005 and 2004 (Figure 8).

On a monthly basis, the greatest number of 1+ coho salmon catches for all study years occurred in May (n = 25 or 74% of total for YR 2007;n = 40 or 56% of total for YR 2006; n = 21 or 54% for YR 2005; n = 43 or 62% for YR 2004). The months of April and May accounted for 88% of the total catch in YR 2007, 79% of the total catch in YR 2006, 100% for YR 2005, and 97% for YR 2004. Catches in June accounted for 0.0 – 21% of the total catch per study year.

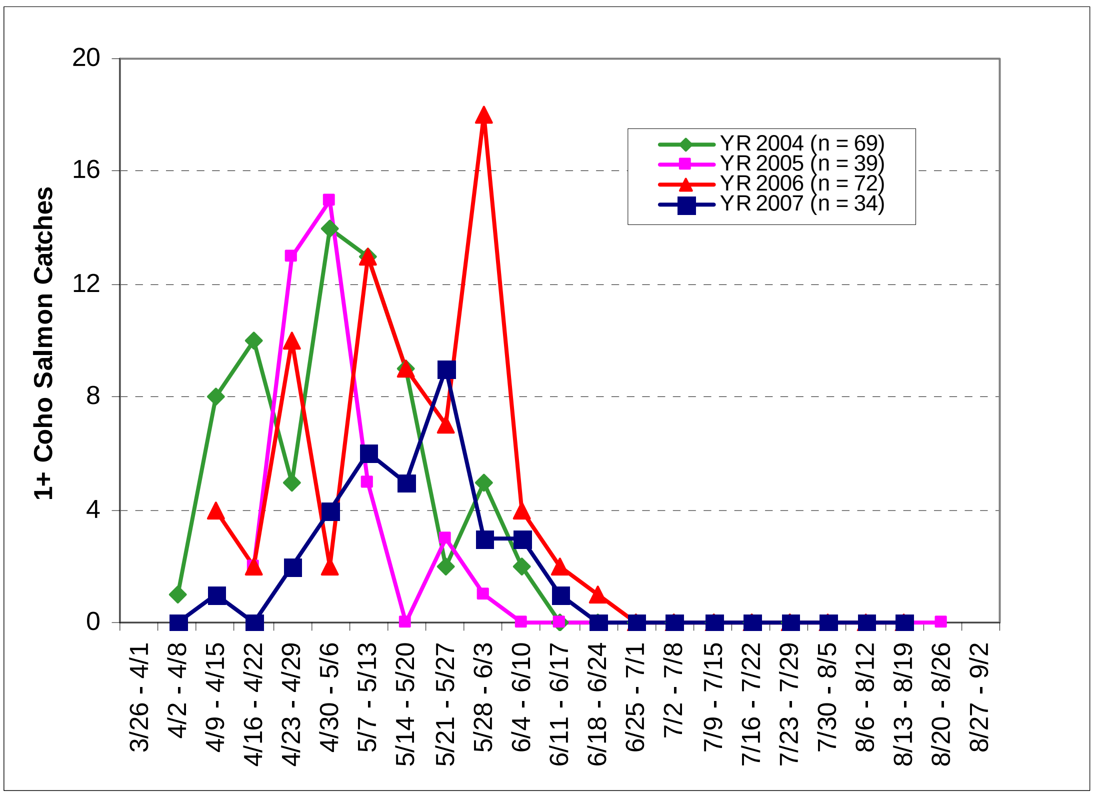


Figure 8. Comparison of 1+ coho salmon captures by week in YR 2007 with weekly catches in YRS 2004 - 2006, lower Redwood Creek, Humboldt County, CA.

Cutthroat Trout

Low numbers of cutthroat trout were captured each study year (Figure 9). Cutthroat trout were captured in 13 out of 20 weeks in YR 2007, 10 out of 19 weeks in YR 2006, 6 out of 19 weeks in YR 2005, and 13 out of 17 weeks in YR 2004. The weekly peak catch occurred 6/18 – 6/24 (n = 6) and 7/09 – 7/15 (n = 6) in YR 2007, compared to 7/23 – 7/29 (n = 6) in YR 2006, 4/16 – 4/22 (n = 2), 5/28 – 6/03 (n = 2), and 7/23 – 7/29 (n = 2) in YR 2005, and 5/14 – 5/20 (n = 10) in YR 2004 (Figure 9).

On a monthly basis, the greatest number of catches in YR 2007 occurred in July (21 or 48% of total), compared to July (n = 18 or 50% of total) in YR 2006, and May (n = 18 or 49%) in YR 2004. In YR 2005, the months of April – July each accounted for 22.2% of the total catch. The months of June and July accounted for 86% of the total catch in YR 2007, compared to 81% for June and July in YR 2006, and 70% for May and July in YR 2004.

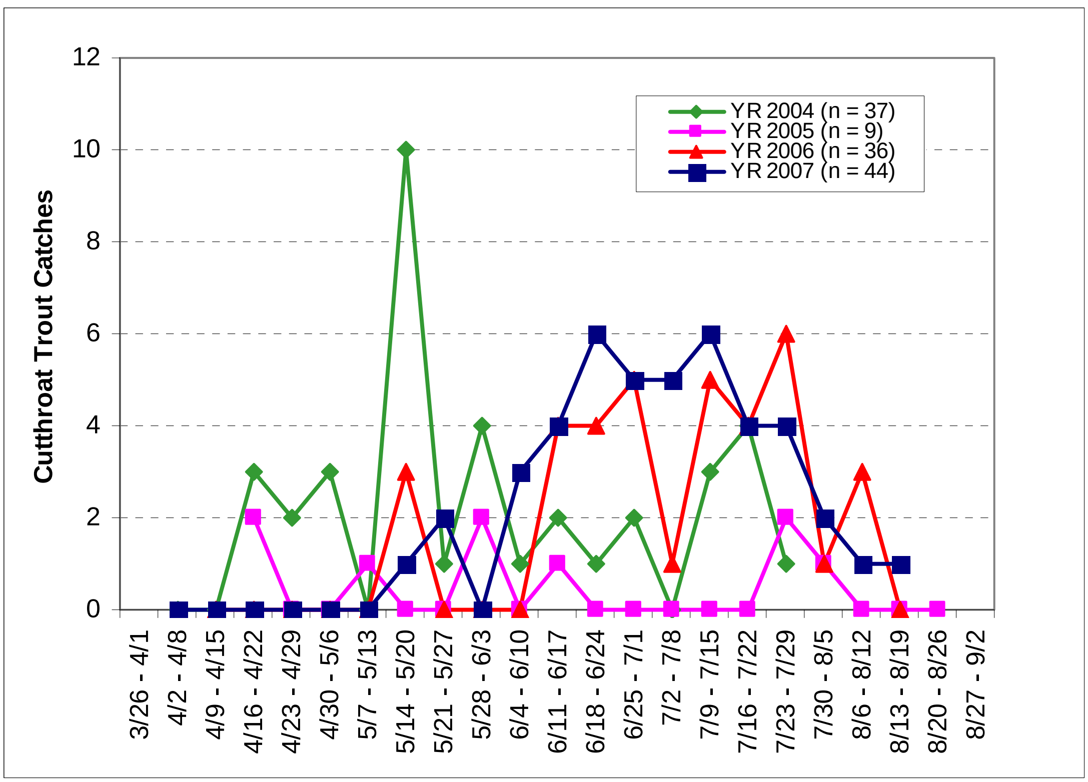


Figure 9. Comparison of cutthroat trout captures by week in YR 2007 with weekly catches in YRS 2004 - 2006, lower Redwood Creek, Humboldt County, CA.

Trapping Efficiencies

0+ Chinook Salmon

We fin clipped and released 3,682 young-of-year Chinook salmon upstream of the trap site during 77 efficiency trials over the course of trapping in YR 2007. The average number used in our weekly trials (includes 3 - 7 efficiency trials) was 184, and ranged from 10 – 500 per week. Weekly trapping efficiencies in YR 2007 ranged from 3.6 – 73.0%, averaged 29.9%, and were considerably higher than efficiencies in YRS 2004 and 2005 (Table 6).

Table 6. 0+ Chinook salmon trapping efficiency in YRS 2004 - 2007, lower Redwood Creek, Humboldt County, CA.

	0+ Chinook salmon trap efficiency (percentage)		
	Weekly trapping efficiency		
Study Year	Range	Average	Seasonal
2004	7.3 - 20.7	11.9	11.9
2005	5.0 - 31.4	11.7	9.6
2006*	0.0 - 84.0	33.0	31.4
2007*	3.6 - 73.0	29.9	34.7

* Trap moved 75 m downstream of previous location in YRS 2004 and 2005.

1+ Steelhead Trout

We fin clipped and released 2,162 one-year-old steelhead trout upstream of the trap site during 79 efficiency trials over the course of trapping in YR 2007. The average number used in our weekly trials (includes 2 - 6 efficiency trials) was 108, and ranged from 16 – 250 individuals per week. Weekly trapping efficiencies in YR 2007 ranged from 4.1 – 27.3%, and averaged 13.8% (Table 7). The average weekly trapping efficiency in YR 2007 was higher than averages for YRS 2004 - 2006 (Table 7).

Table 7. 1+ steelhead trout trapping efficiency in YRS 2004 - 2007, lower Redwood Creek, Humboldt County, CA.

	1+ steelhead trout trap efficiency (percentage)		
	Weekly trapping efficiency		
Study Year	Range	Average	Seasonal
2004	4.8 – 37.5	9.4	7.9
2005	0.0 – 7.7	4.4	4.6
2006*	2.8 – 26.1	13.5	17.3
2007*	4.1 – 27.3	13.8	10.9

* Trap moved 75 m downstream of previous location in YRS 2004 and 2005.

2+ Steelhead Trout

We fin clipped and released 744 two-year-old steelhead trout upstream of the trap site during 69 efficiency trials over the course of trapping in YR 2007. The average number used in our weekly trials (includes 1 - 6 efficiency trials) was 37, and ranged from 8 – 125 individuals per week. Weekly trapping efficiencies in YR 2007 ranged from 0.0 – 17.6%, and averaged 9.9% (Table 8). The average weekly trapping efficiency in YR 2007 was greater than averages for YRS 2004 - 2006 (Table 8).

Table 8. 2+ steelhead trout trapping efficiency in YRS 2004 - 2007, lower Redwood Creek, Humboldt County, CA.

	2+ steelhead trout trap efficiency (percentage)		
	Weekly trapping efficiency		
Study Year	Range	Average	Seasonal
2004	0.0 – 25.0	5.8	3.6
2005	0.0 – 33.3	4.3	2.3
2006*	0.0 – 12.7	6.1	7.9
2007*	0.0 – 17.6	9.9	8.7

* Trap moved 75 m downstream of previous location in YRS 2004 and 2005.

0+ Coho Salmon

We fin clipped and released 225 0+ coho salmon upstream of the trap site during 67 efficiency trials over the course of trapping in YR 2007. The average number used in our weekly trials (includes 1 - 6 efficiency trials) was 12 and ranged from 1 – 38 individuals per week. Weekly trapping efficiencies in YR 2007 ranged from 0.0 – 50.0%, and averaged 23.1% (Table 9).

Table 9. 0+ coho salmon trapping efficiency in YRS 2006 - 2007, lower Redwood Creek, Humboldt County, CA.

	0+ coho salmon trap efficiency (percentage)		
	Weekly trapping efficiency		
Study Year	Range	Average	Seasonal
2006*	0.0 – 75.0	23.5	20.5
2007*	0.0 – 50.0	23.1	24.7

* Trap moved 75 m downstream of previous location in YRS 2004 and 2005.

1+ Coho Salmon

We fin clipped and released 27 one plus-year-old coho salmon upstream of the trap site during 21 efficiency trials over the course of trapping in YR 2007. The average number used in our weekly trials (includes 1 - 5 efficiency trials) was 3, and ranged from 1 – 6 individuals per week. Weekly trapping efficiencies in YR 2007 ranged from 0.0 – 25.0%, and averaged 9.8% (Table 10). The average weekly trapping efficiency in YR 2007 was less than the average for YR 2006, and greater than averages for YRS 2004 and 2005 (Table 10).

Table 10. 1+ coho salmon trapping efficiency in YRS 2004 - 2007, lower Redwood Creek, Humboldt County, CA.

	1+ coho salmon trap efficiency (percentage)		
	Weekly trapping efficiency		
Study Year	Range	Average	Seasonal
2004	0.0 – 25.0	3.7	3.6
2005	0.0 – 20.0	5.2	9.1
2006*	0.0 – 50.0	11.0	8.9
2007*	0.0 – 25.0	9.8	13.9

* Trap moved 75 m downstream of previous location in YRS 2004 and 2005.

Cutthroat Trout

We fin clipped and released 36 cutthroat trout upstream of the trap site during 29 efficiency trials over the course of trapping in YR 2007. The average number used in our weekly trials (includes 1 - 6 efficiency trials) was four, and ranged from 1 – 7 individuals per week. Weekly trapping efficiencies in YR 2006 ranged from 0.0 – 100.0%, and averaged 26.9% (Table 11).

Table 11. Cutthroat trout trapping efficiency in YRS 2006 - 2007, lower Redwood Creek, Humboldt County, CA.

	Cutthroat trout trap efficiency (percentage)		
	Weekly trapping efficiency		
Study Year	Range	Average	Seasonal
2006*	0.0 – 100.0	26.9	20.0
2007*	0.0 – 60.0	34.4	38.9

* Trap moved 75 m downstream of previous location in YRS 2004 and 2005.

Population Estimates

0+ Chinook Salmon

The population estimate (or production) of 0+ Chinook salmon emigrating past the trap in lower Redwood Creek in YR 2007 equaled 141,059 individuals with a 95% CI of 130,068 – 152,049 (Figure 10). Population estimate error (or uncertainty) equaled $\pm$ 7.8%. Population emigration in YR 2007 was greater than YRS 2005 and 2006, much less than YR 2004 (Figure 10), and 45% less than the previous three year average ($N_{avg\ 3yr}$ = 257,068).

Correlation of time (study year) on yearly population estimates indicated a non-significant negative relationship (p = 0.24, r = 0.77, power = 0.17) (Figure 10). Peaks in streamflows (11,000 cfs) capable of redd scour occurred each study year.

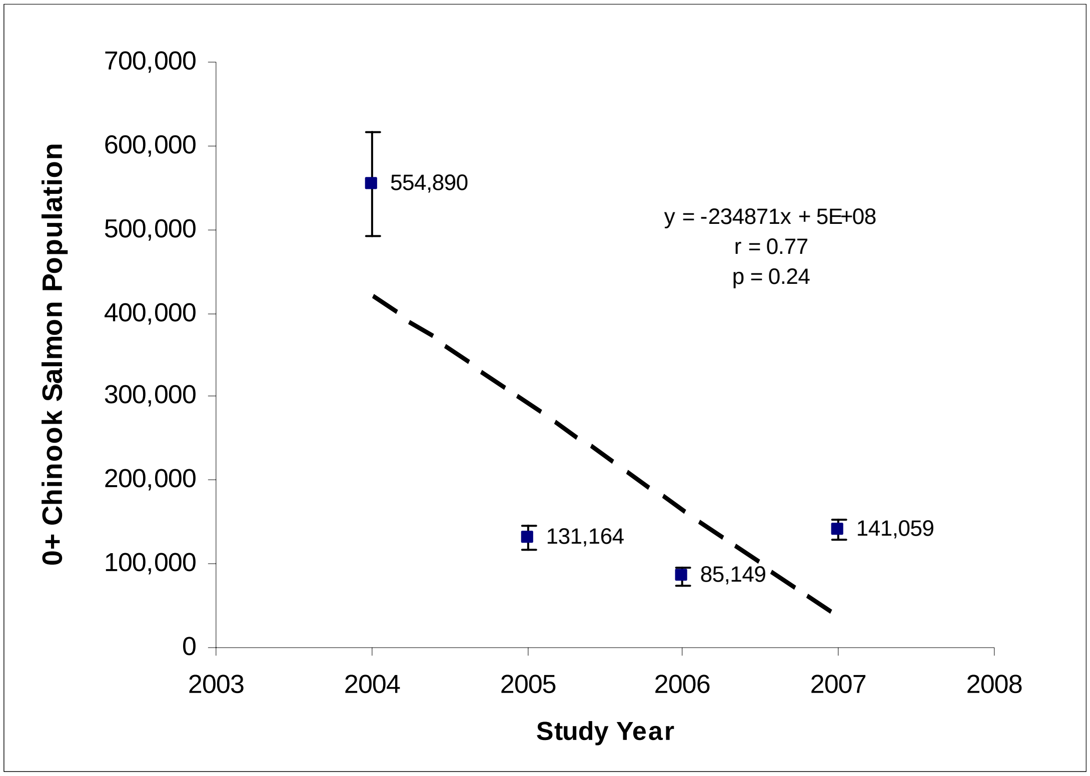


Figure 10. 0+ Chinook Salmon population estimates (error bars are 95% confidence interval) in YRS 2004 – 2007. Numeric values next to box represent number of individuals. Line of best fit is a regression line, with corresponding equation, correlation value (r), and p value. Lower Redwood Creek, Humboldt County, CA.

The number of 0+ Chinook salmon (at population level) per mile, kilometer, and watershed acreage upstream of the trap site in YR 2007 was about 45% less than values for the previous three year average (YRS 2004 – 06) (Table 12).

Table 12. Estimated population of 0+ Chinook salmon per anadromous stream mile (93) and stream kilometer (150), and watershed acreage (151,922) upstream of the trap site, YRS 2004 - 2007.

Study Year	0+KS/mi	0+KS/km	0+KS/acre
2004	5,967	3,699	3.7
2005	1,410	874	0.9
2006	916	568	0.6
Average:	2,764	1,714	1.7
2007	1,517	940	0.9

Monthly population emigration peaked in June (N = 108,504 or 77% of total) in YR 2007, June (N = 72,925 or 86% of total) in YR 2006, July in YR 2005 (N = 77,386 or 59% of total), and June (N = 292,155 or 53% of total) in YR 2004.

The two most important months for 0+ Chinook salmon population emigration were May and June (91%) in YR 2007, June and July (96%) in YR 2006, June and July (83%) in YR 2005, and May and June (78%) in YR 2004.

The pattern in population emigration on a weekly basis in YR 2007 was similar to the previous three year average, except for the lack of relatively large number of fry emigrating during April (Figure 11). Population emigration in YR 2007 was generally confined to a three week period (6/04 – 6/24), which accounted for 69% of the total emigration (Figure 11).

The greatest peak in weekly migration in YR 2007 occurred 6/18 – 6/25 (N = 38,315), one week later than the peak in YR 2006 (Table 13). For the four study years, three peaks occurred in June, and one in July (Table 13).

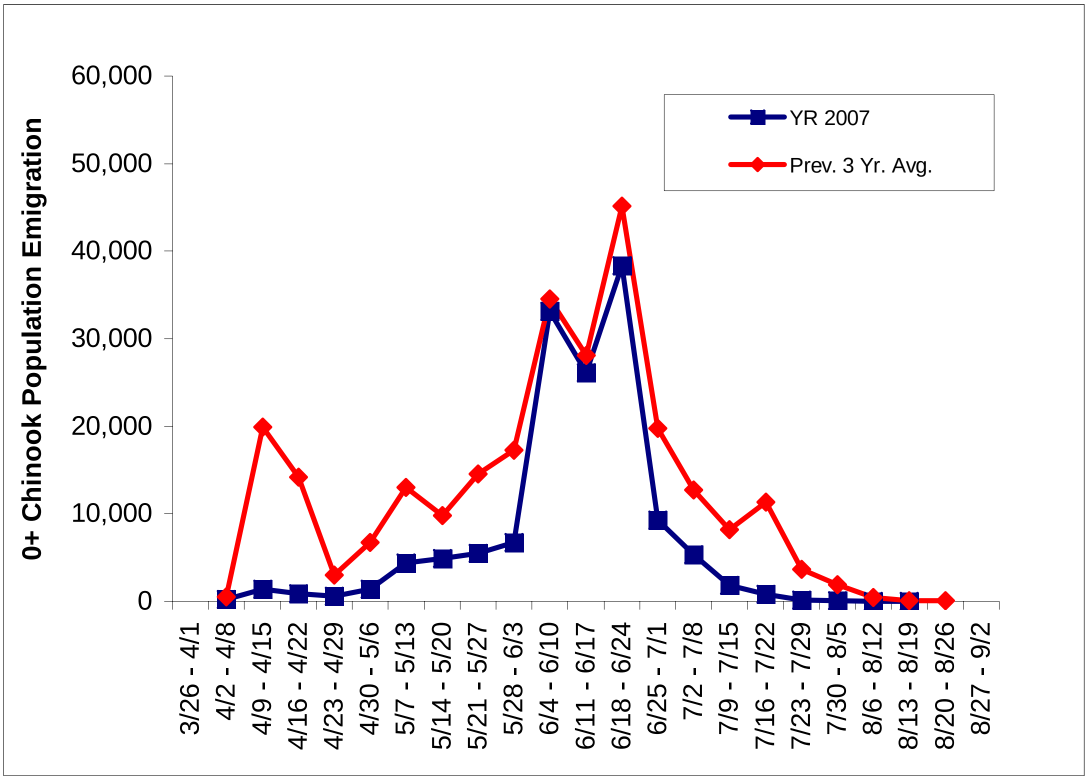


Figure 11. Comparison of 0+ Chinook salmon weekly population emigration in YR 2007 with the previous three year average (YRS 2004 – 06), lower Redwood Creek, Humboldt County, CA.

Table 13. 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)

0+ Chinook salmon migrants consisted of fry and fingerlings, and the number and percentage of 0+ Chinook salmon migrants grouped into fry or fingerling categories varied among study years (Table 14). In YR 2007, fry comprised 2.7% and fingerlings comprised 97.3% of the total Chinook salmon population (Table 14). There was a significant, non-random distribution in the percentage of fry and fingerlings in YR 2007 (Chi-square, $p < 0.00001$), such that more fingerlings than expected were present in the population. There were also more fingerlings and less fry than expected in YR 2007 compared to the previous three year average (Chi-square, $p < 0.00001$). The number of fry in a given study year was positively related to total population abundance each study year (Regression, $p = 0.003$, $R^2 = 0.99$, power = 1.0).

Table 14. Comparison of the production of 0+ Chinook salmon partitioned into fry and fingerling categories for each study year (percentage of average and total population in parentheses), 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
Avg.	28,236 (11.0)	228,832 (89.0)
2007	3,772 (2.7)	137,287 (97.3)

0+ Chinook salmon fry and fingerling migrants showed differences in abundance and migration timing each study year, and for the previous three year average (Figure 12). Fry (Avg. FL = 40.0 mm) migration in YR 2007 generally occurred near the onset of trapping, peaked near the middle of April (same week as for the previous three year average), gradually diminished to low values by the end of May, and from June onward no fry were present (Figure 12). Fingerling (Avg. FL = 69.6 mm) migration in YR 2007 began in mid April (very low numbers), peaked during late June (one week after the average peak for three years), and gradually decreased to low values by mid to late July (Figure 12). The pattern of migration between YR 2007 and the previous three year average was very similar.

The two noticeable modes to the distribution for the previous three year average and YR 2007 (although not as visible due to Y scale axis) do not necessarily indicate two different runs of adult Chinook salmon entered Redwood Creek because of great differences in FL or Wt (Figure 12). For example, average FL for migrants (Fry) during 4/09/07 – 4/15/07 (peak in migration) was 39 mm, compared to the average fingerling FL of 72 mm during 6/11/07 – 6/17/07, and 77 mm during 7/02/07 – 7/08/07 (Figure 12). Had there been two runs of adults at different times, we would expect the average FL's during 6/11/07 – 6/17/07 and 7/02/07 – 7/09/07 to be nearly the same as average FL during 4/09/07 – 4/15/07.

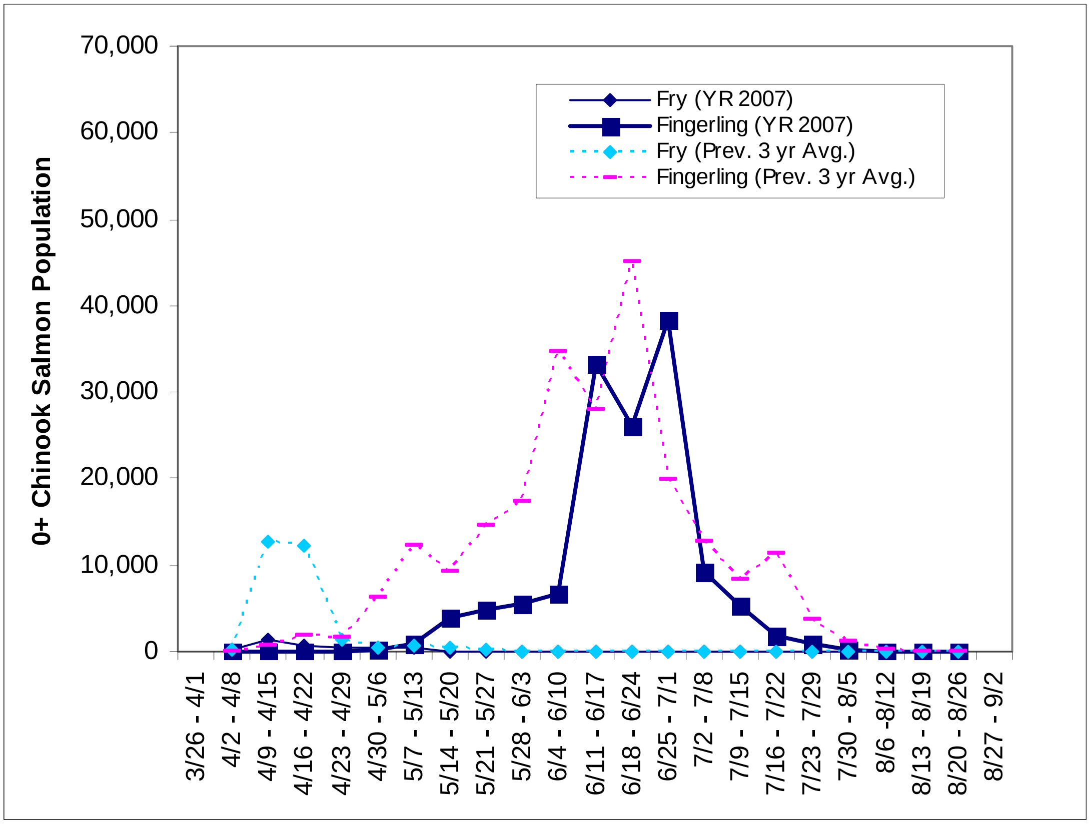


Figure 12. 0+ Chinook salmon fry (FL < 45 mm) and fingerling (FL > 44 mm) population emigration in YR 2007 compared to the previous three year average, lower Redwood Creek, Humboldt County, CA.

<u>1+ Steelhead trout</u>

The population estimate (or production) of 1+ steelhead trout emigrating past the trap site in lower Redwood Creek in YR 2007 equaled 37,683 individuals with a 95% CI of 33,591 – 41,774 (Figure 13). Population estimate error (or uncertainty) equaled $\pm$ 10.9%. Population emigration in YR 2007 was greater emigration in YR 2005, less than emigration in YRS 2004 and 2006 (Figure 13), and 27% less than the previous three year average ($N_{avg\ 3yr}$ = 51,686).

Correlation of time (study year) on yearly population estimates indicated a non-significant negative relationship (p = 0.31, r = 0.69, power = 0.13) (Figure 13).

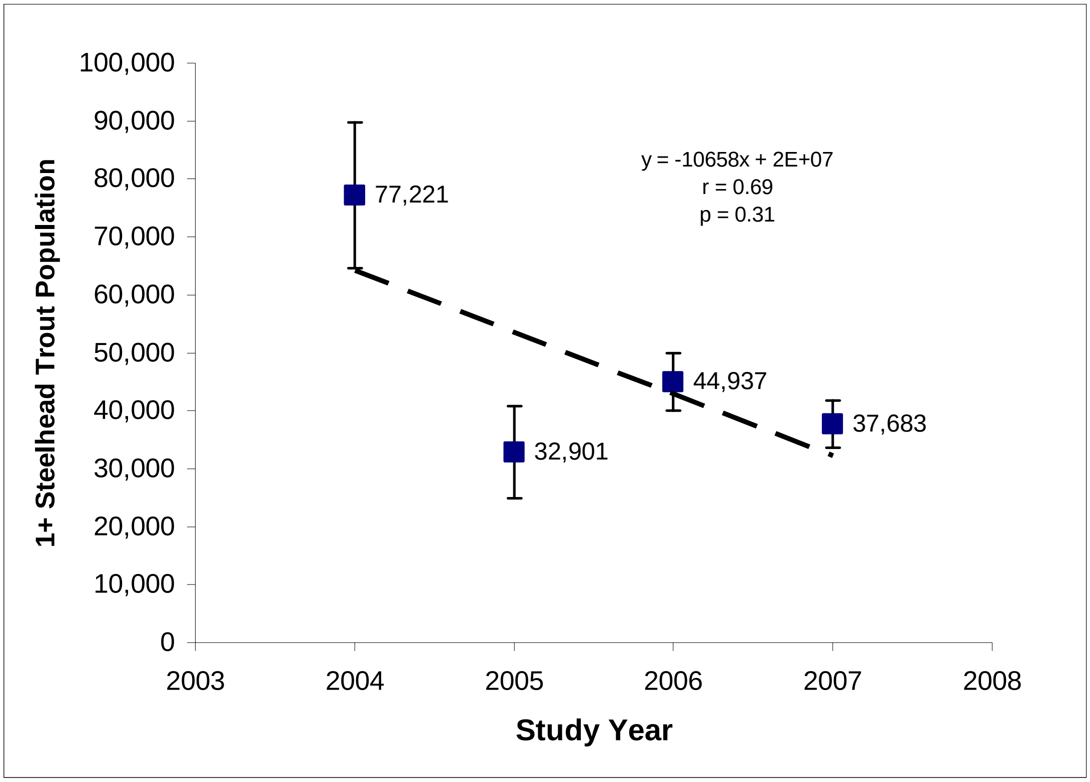


Figure 13. 1+ steelhead trout population estimates (error bars are 95% confidence interval) in YRS 2004 – 2007. Numeric values next to box represent number of individuals. Line of best fit is a regression line, with corresponding equation, correlation value (r), and p value. Lower Redwood Creek, Humboldt County, CA.

The number of 1+ steelhead trout (at population level) per mile, kilometer, and watershed acreage upstream of the trap site in YR 2007 was about 27% less than values for the previous three year average (YRS 2004 – 2006) (Table 15).

Table 15. Estimated population of 1+ steelhead trout per anadromous stream mile (93), stream kilometer (150), and watershed acreage (151,922) upstream of the trap site, YRS 2004 – 2007.

Study Year	1+SH/mi	1+SH/km	1+SH/acre
2004	830	515	0.51
2005	354	219	0.22
2006	483	300	0.30
Average:	556	345	0.34
YR 2007	405	251	0.25

Monthly population emigration peaked in June (N = 17,777 or 47% of total) in YR 2007, June (N = 27,317 or 61% of total) in YR 2006, April in YR 2005 (N = 11,192 or 34% of total), and May (N = 32,906 or 43% of total) in YR 2004.

The two most important months for 1+ steelhead trout population emigration were May and June (71%) in YR 2007, June and July (61%) in YR 2006, April and May (68%) in YR 2005, and May and June (76%) in YR 2004.

The pattern in population emigration on a weekly basis in YR 2007 showed similarities and differences between the previous three year average (Figure 14). Emigration in YR 2007 peaked during the same time as for the previous three year average, yet lacked additional peaks during April, May, and early August (Figure 14). Emigration in YR 2007 was more confined compared to the previous three year average (Figure 14).

The greatest peak in weekly migration in YR 2007 occurred 6/18 – 6/25 (N = 5,483), as did the peak in YR 2006 (Table 16). For the four study years, two peaks occurred in June, one during late April/early May, and one in May (Table 16).

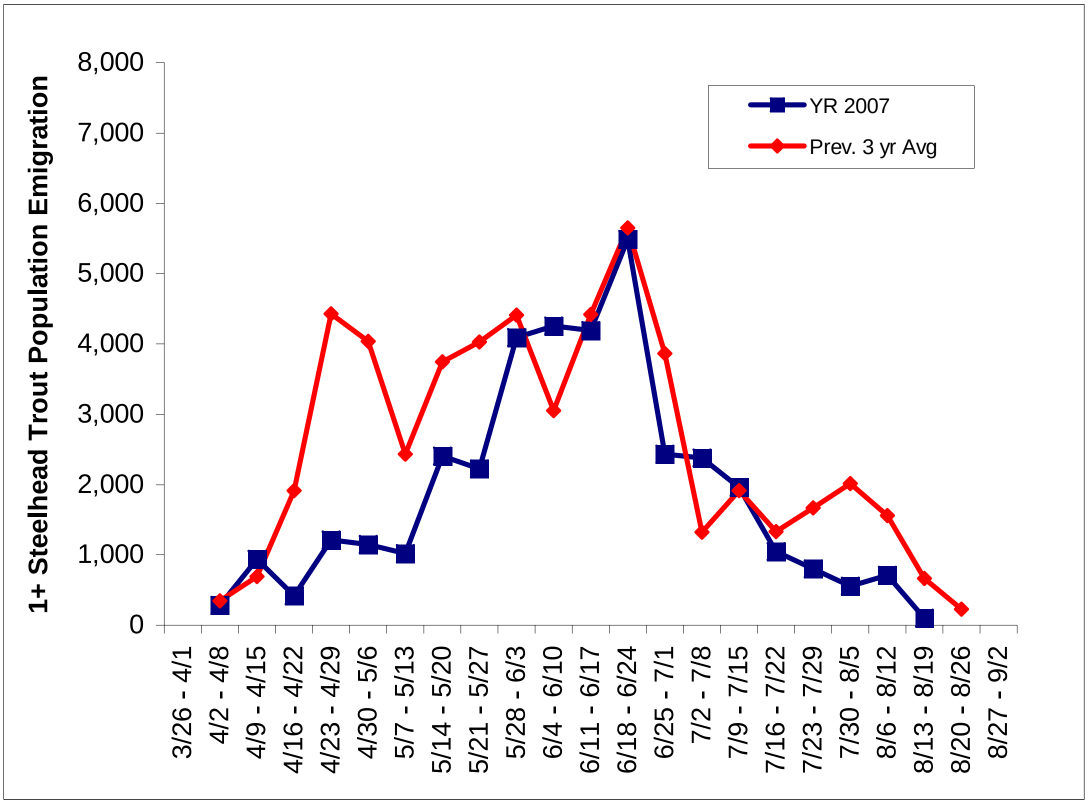


Figure 14. Comparison of 1+ steelhead trout weekly population emigration in YR 2007 with the previous three year average, lower Redwood Creek, Humboldt County, CA.

Table 16. 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)

2+ Steelhead trout

The population estimate (or production) of 2+ steelhead trout emigrating past the trap site in lower Redwood Creek in YR 2007 equaled 12,607 individuals with a 95% CI of 9,416 – 15,798 (Figure 15). Population estimate error (or uncertainty) equaled ± 25.3%.

Population emigration in YR 2007 was slightly higher than emigration in YR 2006, 1.4 times the emigration in YR 2005, 35% less than emigration in YR 2004 (Figure 15), and about 6% less than the previous three year average ($N_{avg\ 3yr}$ = 13,399).

Correlation of time (study year) on yearly population estimates indicated a non-significant negative relationship (p = 0.49, r = 0.51, power = 0.08) (Figure 15).

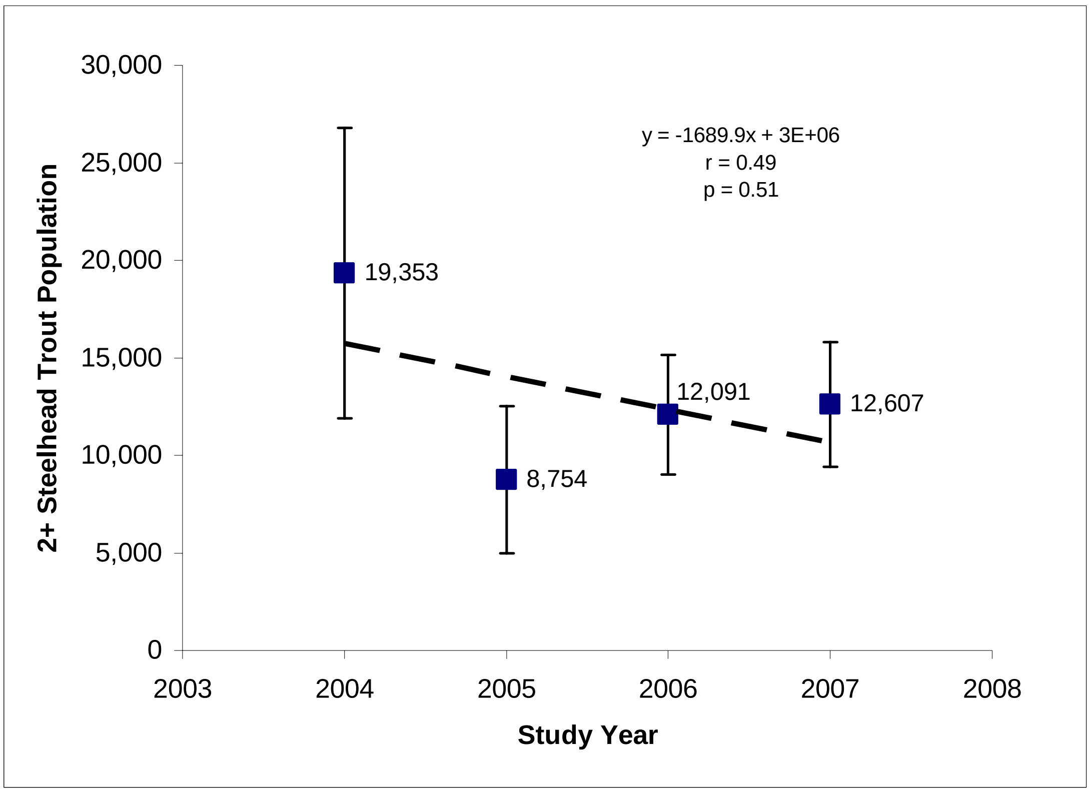


Figure 15. 2+ steelhead trout population estimates (error bars are 95% confidence interval) in YRS 2004 – 2007. Numeric values next to box represent number of individuals. Line of best fit is a regression line, with corresponding equation, correlation value (r), and p value. Lower Redwood Creek, Humboldt County, CA.

The number of 2+ steelhead trout (at population level) per stream mile, stream kilometer, and watershed acreage upstream of the trap site in YR 2007 was close to values to YR 2006, and about 6% less than values for the previous three year average (Table 17).

Table 17. Estimated population of 2+ steelhead trout per anadromous stream mile (93) and stream kilometer (150), and watershed acreage (151,922) upstream of the trap site, YRS 2004 – 2006.

Study Year	2+SH/mi	2+SH/km	2+SH/acre
2004	208	129	0.13
2005	94	58	0.06
2006	130	80	0.08
Average:	144	89	0.09
2007	136	84	0.08

Monthly population emigration peaked in June (N = 7,733 or 61% of total) in YR 2007, June (N = 6,766 or 56% of total) in YR 2006, May in YR 2005 (N = 3,738 or 43% of total), and May (N = 11,956 or 62% of total) in YR 2004.

The two most important months for 2+ steelhead trout population emigration were May and June (83%) in YR 2007, June and July (75%) in YR 2006, April and May (73%) in YR 2005, and May and June (81%) in YR 2004.

The pattern in population emigration on a weekly basis in YR 2007 was much more confined than emigration for the previous three year average; the majority of emigration in YR 2007 occurred during May – July (Figure 16). The peak in emigration in YR 2007 occurred near the middle of June, and was seven weeks later than the peak for the previous three year average (Figure 16).

The greatest peak in weekly migration in YR 2007 occurred 6/18 – 6/25 (N = 3,066), as did the peak in YR 2006 (Table 18). For the four study years, two peaks occurred during late April/early May, and two in June (Table 18).

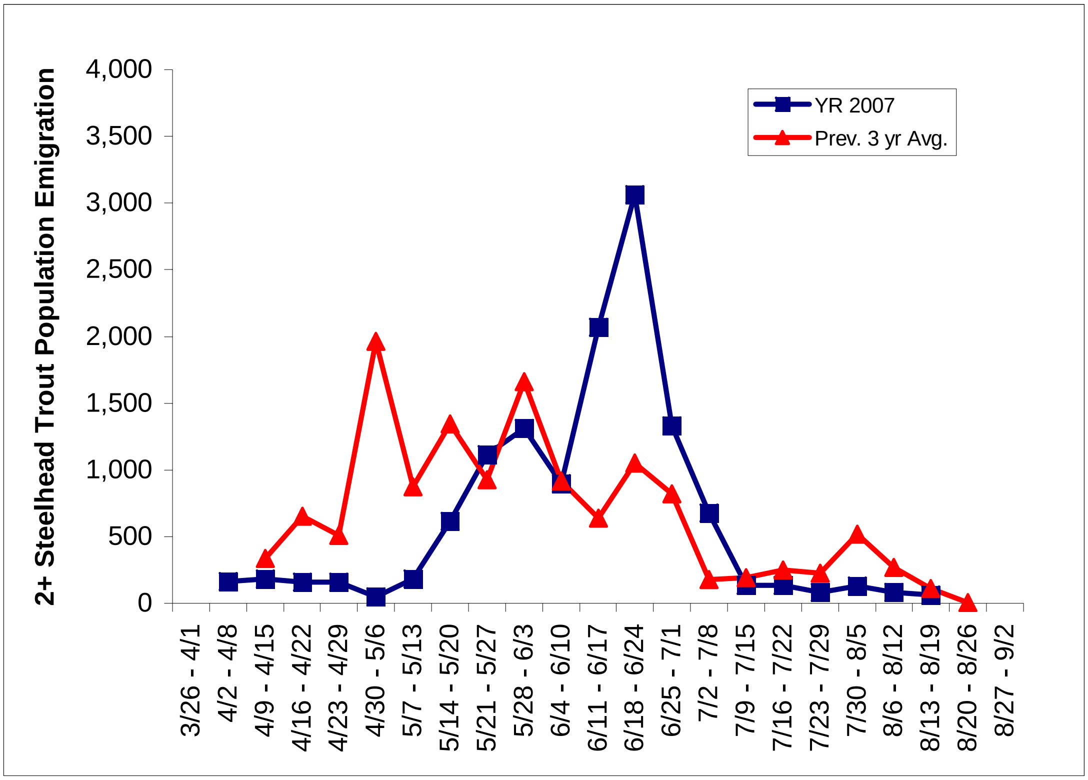


Figure 16. Comparison of 2+ steelhead trout weekly population emigration in YR 2007 with the previous three year average, lower Redwood Creek, Humboldt County, CA.

Table 18. 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)

0+ Coho Salmon

The population estimate of 0+ coho salmon emigrating past the trap site in lower Redwood Creek in YR 2007 equaled 1,057 individuals with a 95% CI of 793 – 1,320 (Figure 17). Population estimate error (or uncertainty) equaled ± 25%. Population emigration in YR 2007 was 2.1 times the estimate in YR 2006. Population estimates were not determined in YRS 2004 and 2005.

In YR 2007, there were 11 coho salmon per anadromous stream mile, 7 per anadromous stream kilometers, and 0.007 per watershed acreage upstream of the trap site; in YR 2006, there were five coho salmon per anadromous stream mile, three per anadromous stream kilometers, and 0.003 per watershed acreage upstream of the trap site.

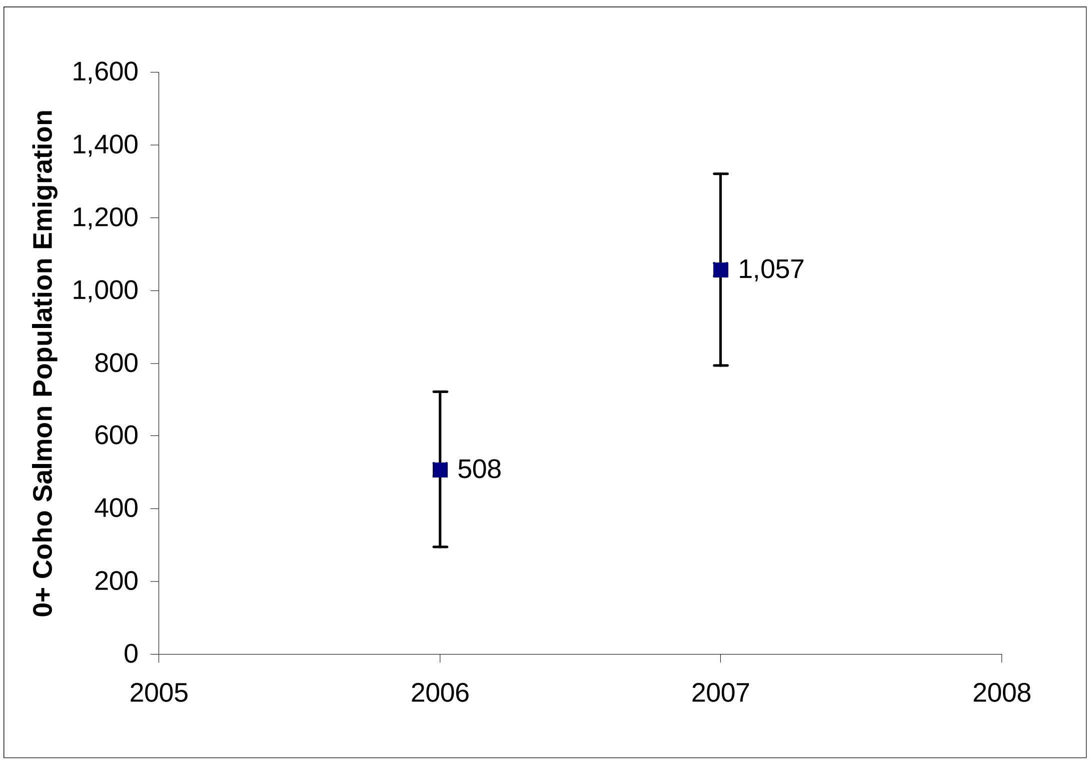


Figure 17. 0+ coho salmon population estimates (error bars are 95% confidence intervals) in YRS 2006 and 2007. Numeric values next to box represent number of individuals. Lower Redwood Creek, Humboldt County, CA.

Monthly population emigration peaked in June (N = 569 or 54%) in YR 2007, and June (N = 230 or 45% of total) in YR 2006. The two most important months for emigration were June and July in YRS 2006 and 2007, which accounted for 84% of total emigration in YR 2007, and 78% in YR 2006.

Weekly emigration peaked during 6/11 – 6/17 in YR 2007, two weeks before the peak in YR 2006 (Figure 18).

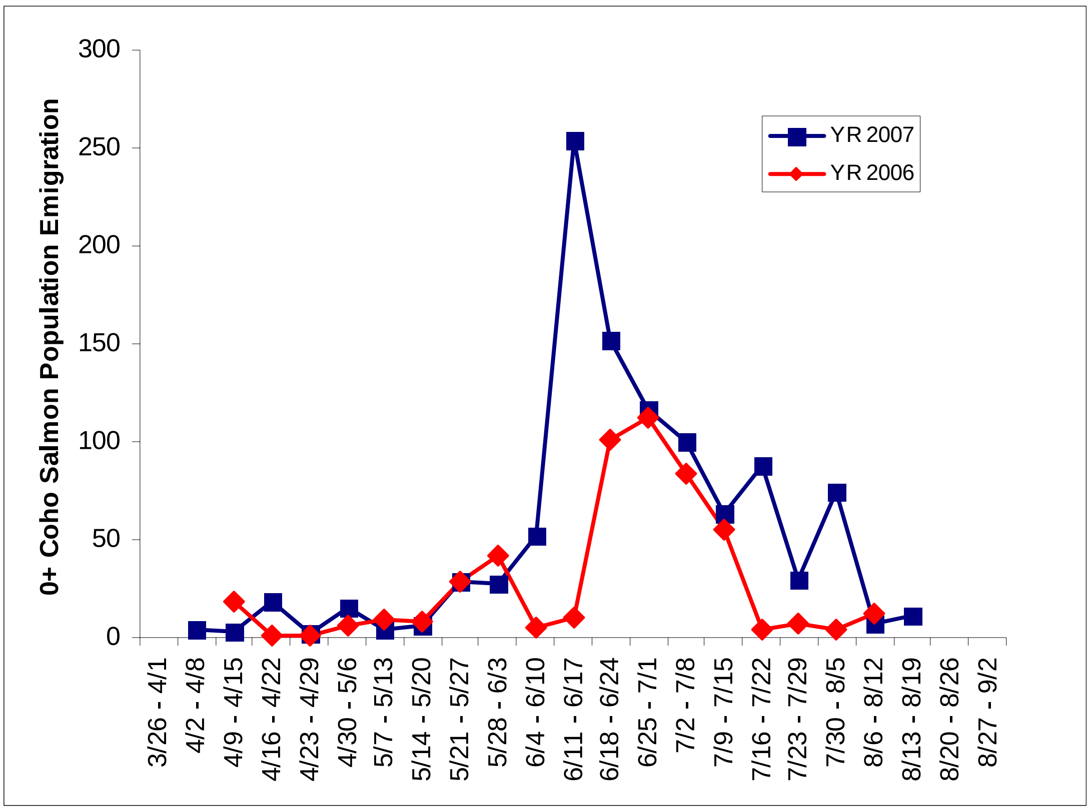


Figure 18. 0+ coho salmon weekly population emigration in YRS 2006 and 2007, lower Redwood Creek, Humboldt County, CA.

1+ Coho Salmon

The population estimate (or production) of 1+ coho salmon emigrating past the trap site in lower Redwood Creek in YR 2007 equaled 102 individuals with a 95% CI of 53 – 150 (Figure 19). Population estimate error (or uncertainty) equaled ± 48%, primarily due to low sample sizes for mark and recapture experiments.

Population emigration in YR 2007 was 76% less than emigration in YR 2006, 44% less than emigration in YR 2005, 81% less than emigration in YR 2004, and 73% less than emigration for the previous three year average ($N_{avg\ 3yr}$ = 382).

Correlation of time (study year) on yearly population estimates indicated a non-significant negative relationship (p = 0.33, r = 0.67, power = 0.12) (Figure 19).

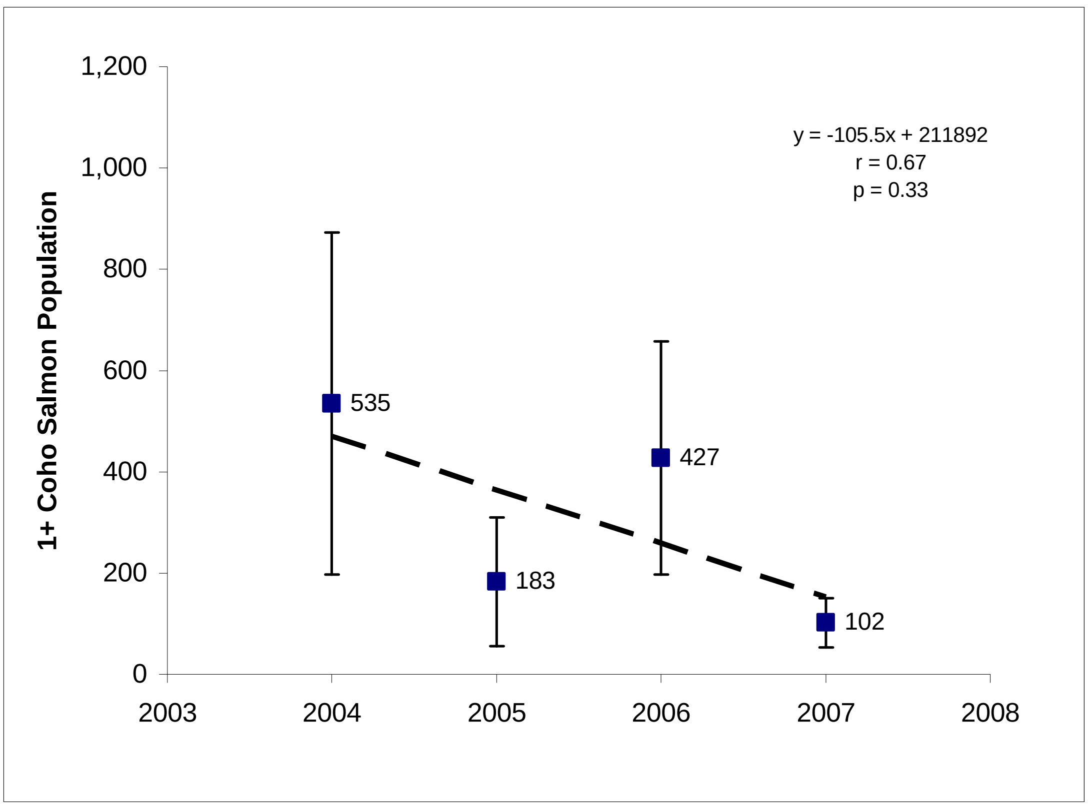


Figure 19. 1+ coho salmon population estimates (error bars are 95% confidence interval) in YRS 2004 – 2007. Numeric values next to box represent number of individuals. Line of best fit is a regression line, with corresponding equation, correlation value (r), and p value. Lower Redwood Creek, Humboldt County, CA.

The number of 1+ coho salmon (at population level) per stream mile, stream kilometer, and watershed acreage upstream of the trap site in YR 2007 was 68 – 76% less than values for the previous three year average (Table 19).

Table 19. Estimated population of 1+ coho salmon per anadromous stream mile (93), stream kilometer (150), and watershed acreage (151,922) upstream of the trap site, YRS 2004 – 2007.

Study Year	1+CO/mi	1+CO/km	1+CO/acre
2004	6	4	0.004
2005	2	1	0.001
2006	5	3	0.003
Average:	4	3	0.003
2007	1	0.7	0.001

Monthly population emigration peaked in May (N = 81 or 79% of total) in YR 2007, May (N = 241 or 56% of total) in YR 2006, May in YR 2005 (N = 126 or 69% of total), and May (N = 374 or 70% of total) in YR 2004. The months of May and June accounted for 93% of the total population abundance in YR 2007; April and May accounted for 81% of the total population emigration in YR 2006, 99% of the total in YR 2005, and 98% of the total in YR 2004.

Population emigration on a weekly basis showed the difference in the migration pattern in YR 2007 compared to the previous three year average (Figure 20). Emigration in YR 2007 was more confined compared to the previous three year average; and peak emigration in YR 2007 occurred three weeks after the peak for the previous three year average (Figure 20).

Weekly emigration peaked in May in YR 2007, June in YR 2006, May in YR 2005, and late April/early May in YR 2004 (Table 20). Population emigration ended during the week of 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. Study years with higher population abundance experienced a higher weekly peak in emigration (Table 20).

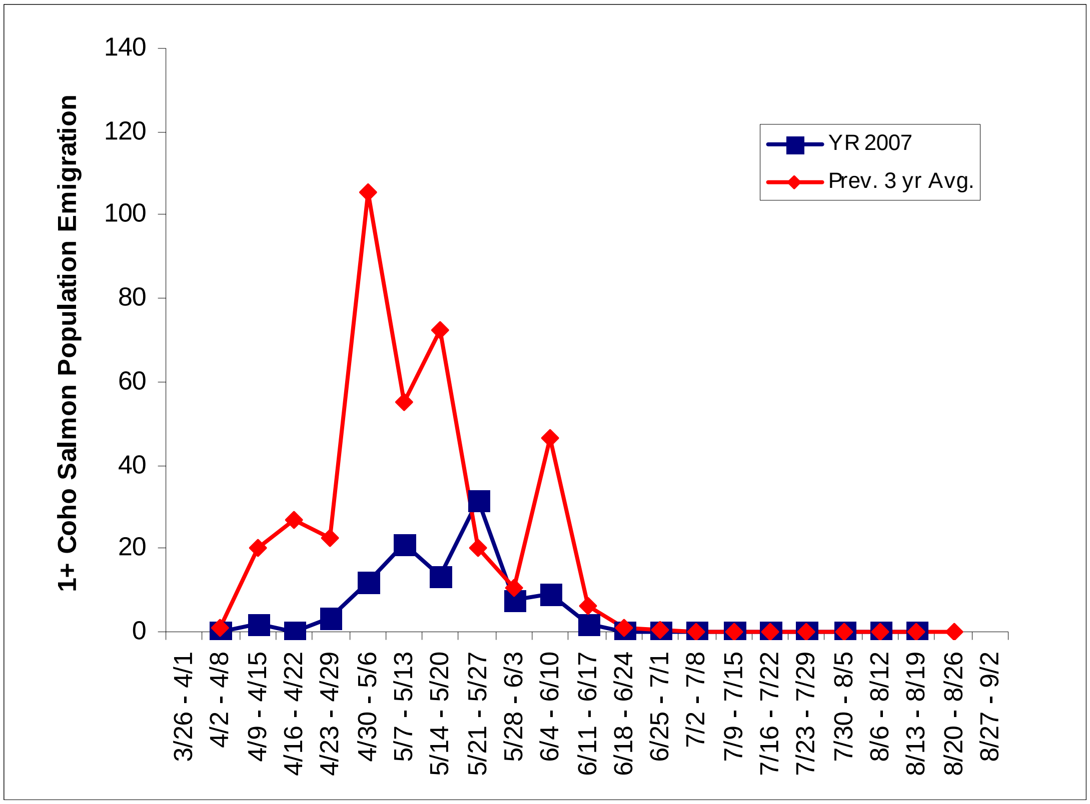


Figure 20. Comparison of 1+ coho salmon weekly population emigration in YR 2007 with the previous three year average, lower Redwood Creek, Humboldt County, CA.

Table 20. 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)

Cutthroat Trout

The population estimate (or production) of cutthroat trout (age 1 and older) emigrating past the trap site in lower Redwood Creek in YR 2007 equaled 85 individuals with a 95% CI of 58 – 113 (Figure 21). Population estimate error (or uncertainty) equaled ± 32%. Population estimates were not determined in YRS 2004 and 2005.

In YRS 2006 - 2007, there was one cutthroat trout per anadromous stream mile, 0.6 per anadromous stream kilometer, and 0.001 per watershed acreage upstream of the trap site.

Monthly population emigration peaked in July (N = 43 or 51% of total) in YR 2007, and July (N = 51 or 53% of total) in YR 2006; June and July accounted for 92% of the total in YR 2007, and 88% of the total in YR 2006.

Weekly emigration peaked during 7/09 – 7/15 in YR 2007, and 7/23 – 7/29 in YR 2006 (Figure 22).

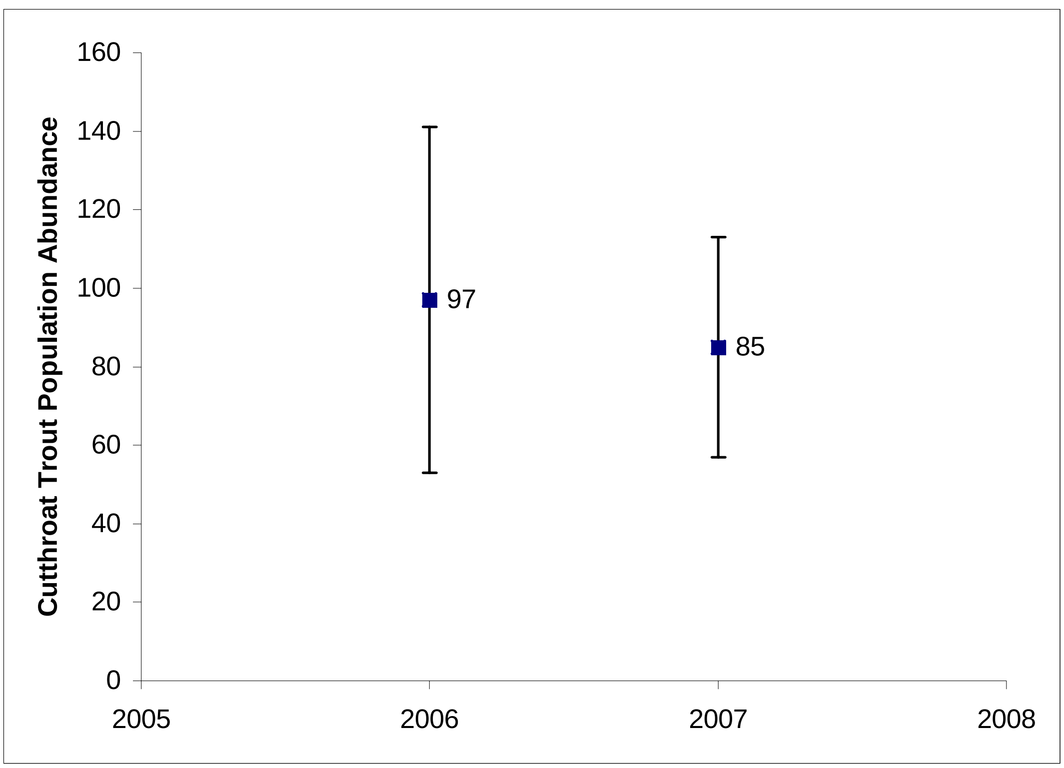


Figure 21. Cutthroat trout population estimates in YRS 2006 and 2007 (error bars are 95% confidence intervals). Numeric values next to box represent number of individuals. Line of best fit is a regression line, with corresponding equation, correlation value (r), and p value. Lower Redwood Creek, Humboldt County, CA.

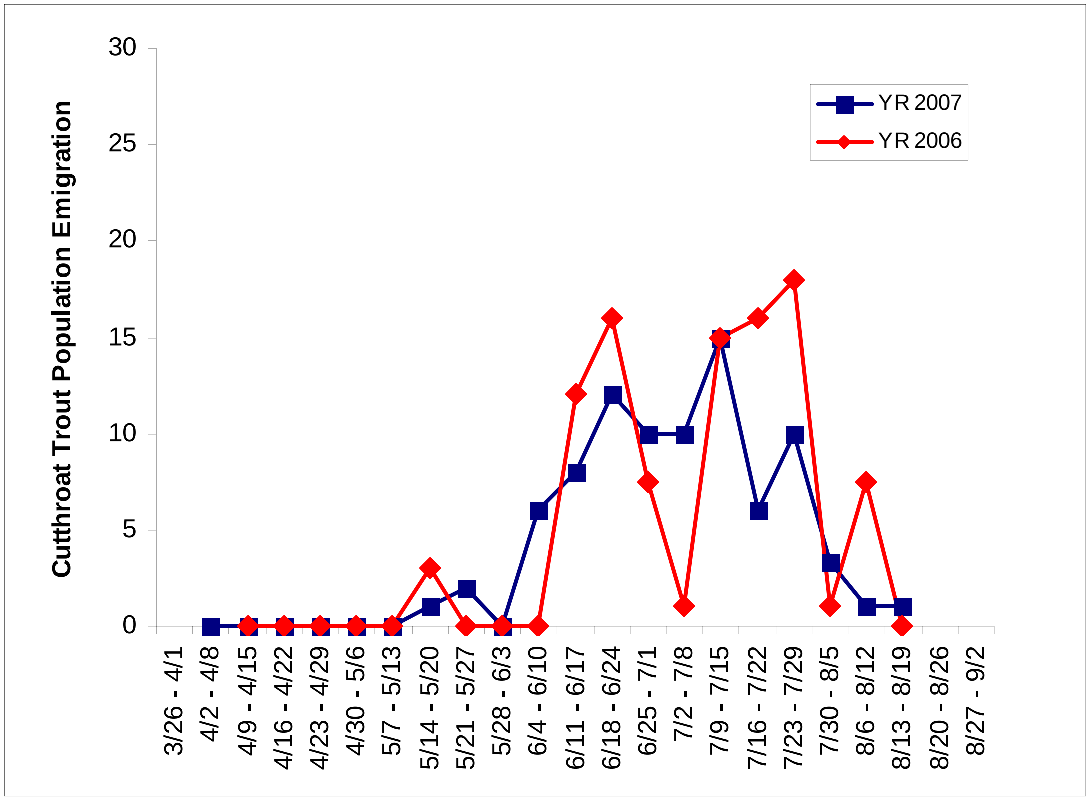


Figure 22. Cutthroat trout weekly population emigration in YRS 2006 and 2007, lower Redwood Creek, Humboldt County, CA.

Age Composition of Juvenile Steelhead Trout

The following percentages represent maximum values for 1+ and 2+ steelhead trout because their population estimates were compared to catches of 0+ steelhead trout (ie the actual catches of 0+ steelhead trout are less than expected 0+ steelhead trout population migration). Far more 1+ steelhead trout migrated downstream than either 0+ or 2+ steelhead trout each study year, except for YR 2007 when slightly more 0+ steelhead trout migrated downstream than 1+ steelhead trout (Table 21). Using catch and population data, the ratio of 0+ steelhead trout to 1+ steelhead trout to 2+ steelhead trout equaled 3.4:3.0:1 in YR 2007, 2.5:3.7:1.0 in YR 2006, 0.2:3.8:1 in YR 2005, and 1:4:1 in YR 2004. The ratio of 1+ steelhead trout to 2+ steelhead trout was 3:0 in YR 2007, and close to 4:1 in YRS 2004 - 2006.

Table 21. Comparison of 0+ steelhead trout, 1+ steelhead trout, and 2+ steelhead trout percent composition of total juvenile steelhead trout downstream migration in YRS 2004 - 2007, lower Redwood Creek, Humboldt County, CA.

	Percent composition of total juvenile steelhead trout emigration		
Study Year	0+ steelhead*	1+ steelhead	2+ steelhead
2004	16.2	67.0	16.8
2005	3.1	76.5	20.4
2006	34.4	51.7	13.9
Combined:	20.4	63.2	16.4
Averaged:	17.9	65.1	17.0
2007	46.0	40.5	13.5

* Uses actual catches instead of population estimate.

Fork Lengths and Weights

0+ Chinook Salmon

We measured (FL mm) 2,666 and weighed (g) 2,031 0+ Chinook salmon in YR 2007 (Table 22). Average FL (66.6 mm) and Wt (3.20 g) in YR 2007 was the second lowest of record (Table 22). Standard error of the mean each study year was less than 0.4 mm for FL, and less than 0.10 g for Wt. The mode in fork length (mm) was 75 mm in YR 2007, 80 mm in YR 2006, 90 mm in YR 2005, and 70 mm in YR 2004; the mode in weight (g) was 0.5 g in YR 2007, 5.4 g in YR 2006, 1.1 g in YR 2005, and 0.5 g in YR 2004.

The average size of fry (FL < 45 mm) was 40.0 mm in YR 2007, 38.5 mm in YR 2006, 40.6 mm in YR 2005, and 39.9 mm in YR 2004; average size of fingerlings (FL > 44 mm) was 69.6 mm in YR 2007, 76.5 mm in YR 2006, 76.4 mm in YR 2005, and 63.5 mm in YR 2004.

Table 22. 0+ Chinook salmon average and median fork length (mm) and weight (g) in YRS 2004 - 2007, 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
Avg.			69.2			3.99	

Average weekly FL (mm) significantly increased over time (weeks) each study year (Correlation, p = 0.000001, r ranged from 0.89 - 0.97, power = 1.0 for each test) (Figure 23). The increases in average FL over time show growth was taking place, and from 4/09 – 8/06 0+ Chinook salmon grew 0.36 mm/d in YR 2007. Growth equaled 0.30 mm/d in YR 2006, 0.37 mm/d in YR 2005, and 0.30 mm/d in YR 2004.

Average weekly FLs (mm) in each study year were positively related to the percentage of fingerlings each week (Regression, YR 2007, $R^2 = 0.76$, p = 0.000001, power = 1.0; YR 2006, $R^2 = 0.62$, p = 0.0002, power = 1.0; YR 2004, $R^2 = 0.77$, p = 0.000003, power = 1.0; YR 2005, $R^2 = 0.55$, p = 0.0003, power = 0.99).

Average weekly fork lengths (mm) among study years showed significant variation, however, statistical assumptions were not met. Median weekly FL (mm) among study years showed statistically, significant variation (Kruskal-Wallis One-Way Anova On Ranks, p = 0.020). Further analysis revealed that median FL in YR 2007 (69.9 mm) was not significantly different than median FL's in YRS 2004 (63.0 mm), 2005 (79.2 mm), or 2006 (78.5) (Kruskal-Wallis Multiple-Comparison Z-Value Test with Bonferroni control, z value < 2.6383). Median FL in YR 2005 and 2006 were not statistically different (z value < 2.6383, however, each were significantly greater than median FL in YR 2004 (Kruskal-Wallis Multiple-Comparison Z-Value Test with Bonferroni control, z value > 2.6383 for each test).

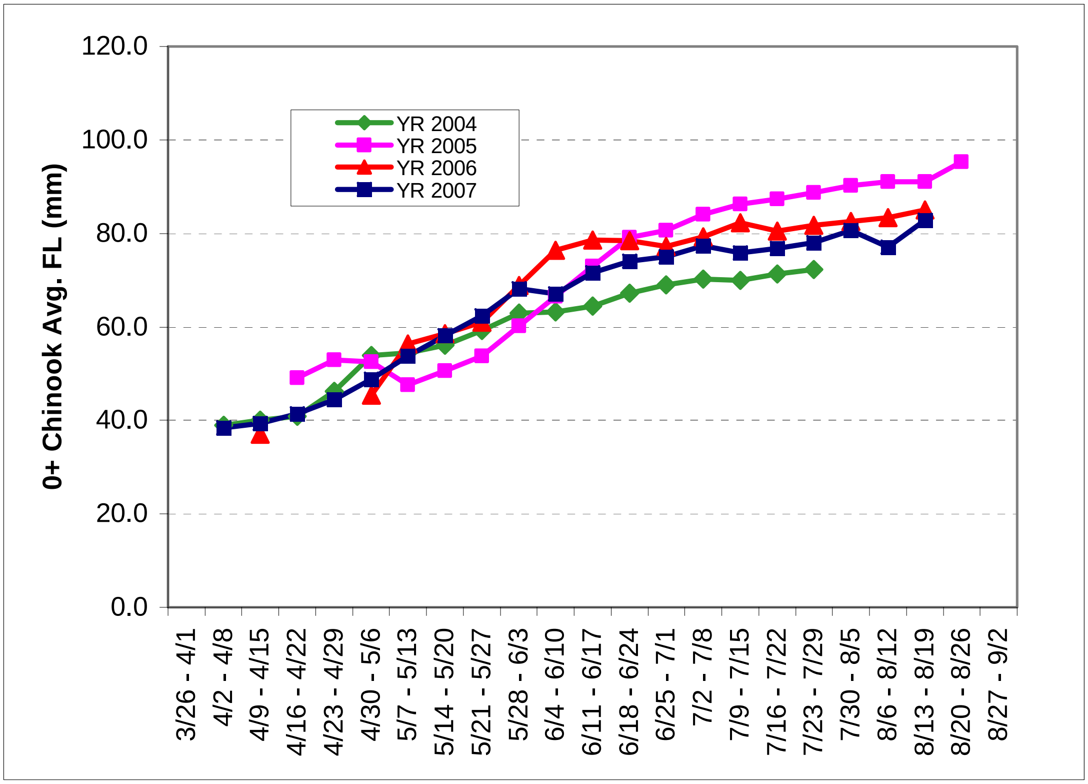


Figure 23. 0+ Chinook salmon average weekly fork lengths (mm) in YRS 2004 – 2007, lower Redwood Creek, Humboldt County, CA.

Average weekly Wt (g) significantly increased over time (weeks) each study year (Correlation, $p = 0.000001$, r ranged from = 0.95 - 0.98, power = 1.0) (Figure 24). The pattern of average weekly Wt's was similar to the pattern for average weekly FL's, except for a larger spread among lines from the middle to end of the trapping periods.

The increases in average Wt over time show growth was taking place, and from 4/09 – 8/05 0+ Chinook salmon grew 0.04 g/d. Growth equaled 0.05 g/d in YR 2006, 0.07 g/d in YR 2005, and 0.03 g/d in YR 2004.

Average weekly Wts (g) in each study year were positively related to the percentage of fingerlings each week (Regression, YR 2007, $R^2 = 0.65$, p = 0.0.00002, power = 1.0; YR 2006, $R^2 = 0.47$, $p = 0.002$, power = 0.93; YR 2005, $R^2 = 0.55$, $p = 0.0003$, power = 0.99; YR 2004, $R^2 = 0.63$, $p = 0.0001$, power = 1.0).

Similar to average weekly FL data, average weekly Wt (g) among study years showed significant variation, however, statistical assumptions were not met. Median weekly Wt (g) among study years showed statistically, significant variation (Kruskal-Wallis One-Way Anova On Ranks, $p = 0.01$). Further analysis revealed that median Wt in YR 2007 (3.73 g) was not significantly different than median FL's in YRS 2004 (2.84 g), 2005

(5.53 g), or 2006 (5.35 g) (Kruskal-Wallis Multiple-Comparison Z-Value Test with Bonferroni control, z value < 2.6383). Median Wt in YR 2005 and 2006 were not statistically different (z value < 2.6383), however, each were significantly greater than median Wt in YR 2004 (Kruskal-Wallis Multiple-Comparison Z-Value Test with Bonferroni control, z value > 2.6383 for each test).

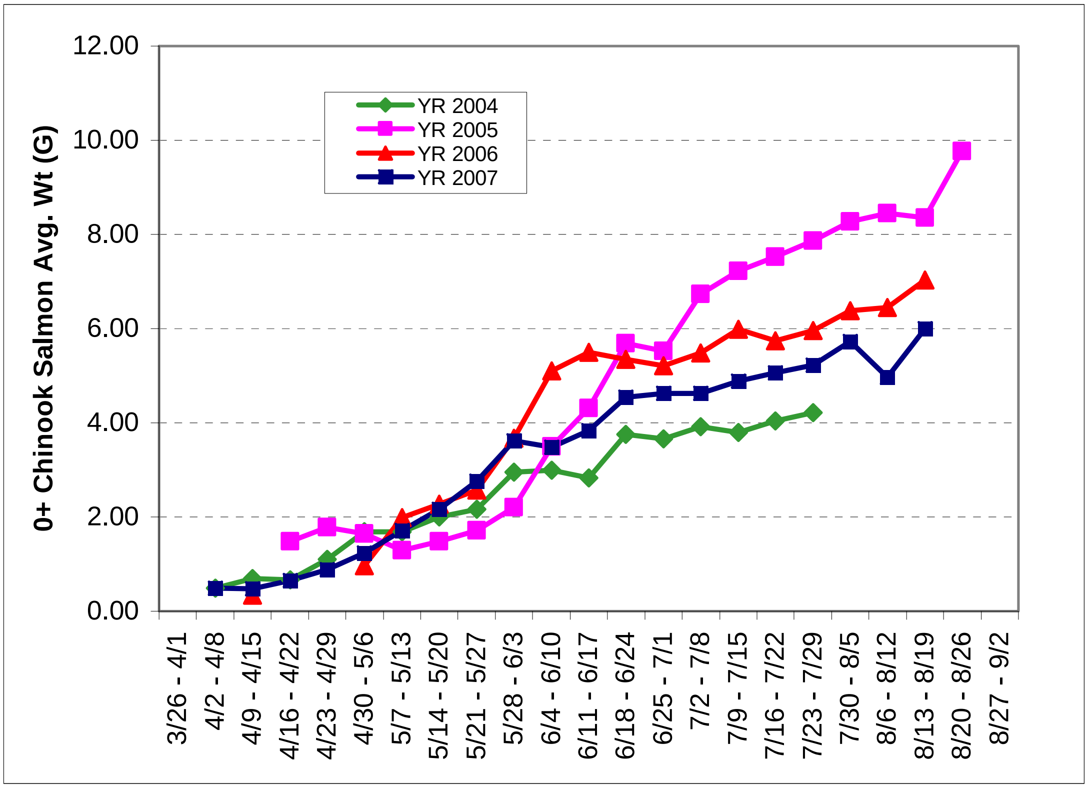


Figure 24. 0+ Chinook salmon average weekly weights (g) in YRS 2004 - 2007, lower Redwood Creek, Humboldt County, CA.

1+ Chinook Salmon

No yearling Chinook salmon juveniles were captured in YR 2007 or YR 2006, however, average fork length in YR 2005 equaled 109 mm (n = 11), and in YR 2004 equaled 101 mm (n = 2).

0+ Steelhead Trout

We measured (FL mm) 3,355 0+ steelhead trout in YR 2007 (Table 23). Average FL (53.8 mm) in YR 2007 was greater than the averages for YRS 2004 and 2005, and less than the average for YR 2006 (Table 23). Standard error of the mean for fork lengths each study year was less than 0.7 mm. The mode in fork length (mm) was 30 mm in YR 2007, 58 mm in YR 2006, 30 mm in YR 2005, and 29 mm in YR 2004.

Average weekly FL (mm) significantly increased over time (weeks) each study year (Correlation, p = 0.000001, r ranged from 0.98 - 0.99, power = 1.0 for each test) (Figure 25). The increases in average FL over time show growth was taking place, and from 4/09 – 8/17 0+ steelhead trout grew 0.32 mm/d. Growth equaled 0.36 mm/d in YR 2006, 0.34 mm/d in YR 2005, and 0.34 mm/d in YR 2004.

Median weekly fork lengths (mm) among study years were not significantly different (Kruskal-Wallis One-Way ANOVA on Ranks, p > 0.05).

Table 23. 0+ steelhead trout average and median fork length in YRS 2004 - 2007, 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	-	-	-
Avg.			52.6		-	-	-

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

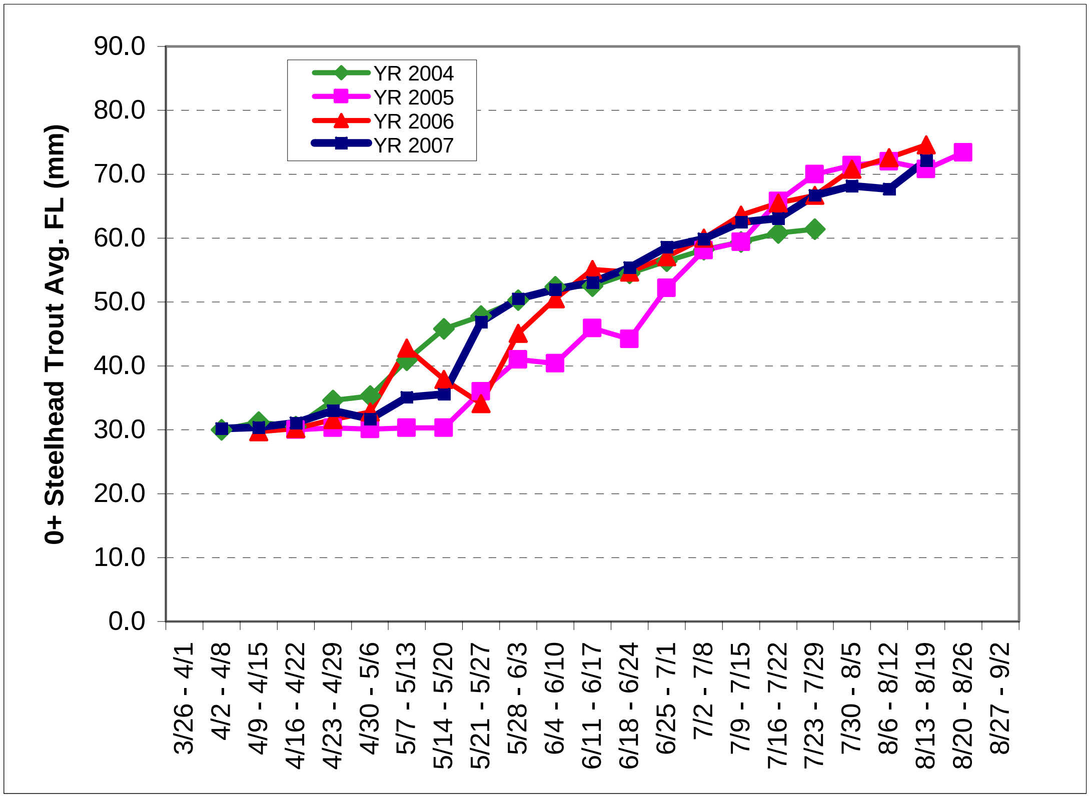


Figure 25. 0+ steelhead trout average weekly fork lengths (mm) in YRS 2004 - 2007, lower Redwood Creek, Humboldt County, CA.

1+ Steelhead Trout

We measured (FL mm) 2,761 and weighed (g) 2,146 1+ steelhead trout in YR 2007 (Table 24). Average FL and Wt among study years showed little variation, the greatest difference between years was 6.4 mm and 1.3 g, respectively (Table 24). Average FL (88.6 mm) and Wt (7.88 g) in YR 2007 was less than the average FL and Wt in YR 2005, and greater than average FL and Wt in YRS 2004 and 2006 (Table 24). Standard error of the mean for fork lengths was less than 0.4 mm each study year; and for Wt was less than 0.12 g each study year.

The mode in fork length (mm) was 85 mm in YR 2007, 80 mm in YR 2006, 82 mm in YR 2005, and 70 mm in YR 2004; the mode in weight (g) was 5.8 g in YR 2007, 4.8 g in YR 2006, 6.6 g in YR 2005, and 3.8 g in YR 2004.

Table 24. 1+ steelhead trout average and median fork length (mm) and weight (g) in YRS 2004 - 2007, 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
Avg.			87.7			7.74	

Average weekly FL (mm) in YR 2007 significantly increased over time (Correlation, $p < 0.01$, $r = 0.57$, power = 0.79) (Figure 26), unlike YRS 2004 – 06 when average FL did not significantly change over time (Correlation, $p > 0.05$ for each test). There was significant variation in average weekly FL among study years (ANOVA, $p = 0.0008$, power = 0.96), such that average weekly FL in YR 2005 was significantly greater than average weekly FL in YR 2004 (Tukey-Kramer Multiple Comparison Test, $p < 0.0125$); no other significant differences among study years were detected (Tukey-Kramer Multiple Comparison Test, $p > 0.0125$).

Similar to FL data, average weekly Wt (g) in YR 2007 significantly increased over time (Correlation, $p < 0.05$, $r = 0.56$, power = 0.77) (Figure 27), unlike YRS 2004 – 06 when average Wt did not significantly change over time (Correlation, $p > 0.05$ for each test). There was significant variation in average weekly Wt among study years (ANOVA, $p = 0.0008$, power = 0.85). Further testing showed average weekly Wt in YR 2005 was significantly greater than average weekly Wt in YR 2004 (Tukey-Kramer Multiple Comparison Test, $p < 0.0125$); no other significant differences among study years were detected (Tukey-Kramer Multiple Comparison Test, $p > 0.0125$).

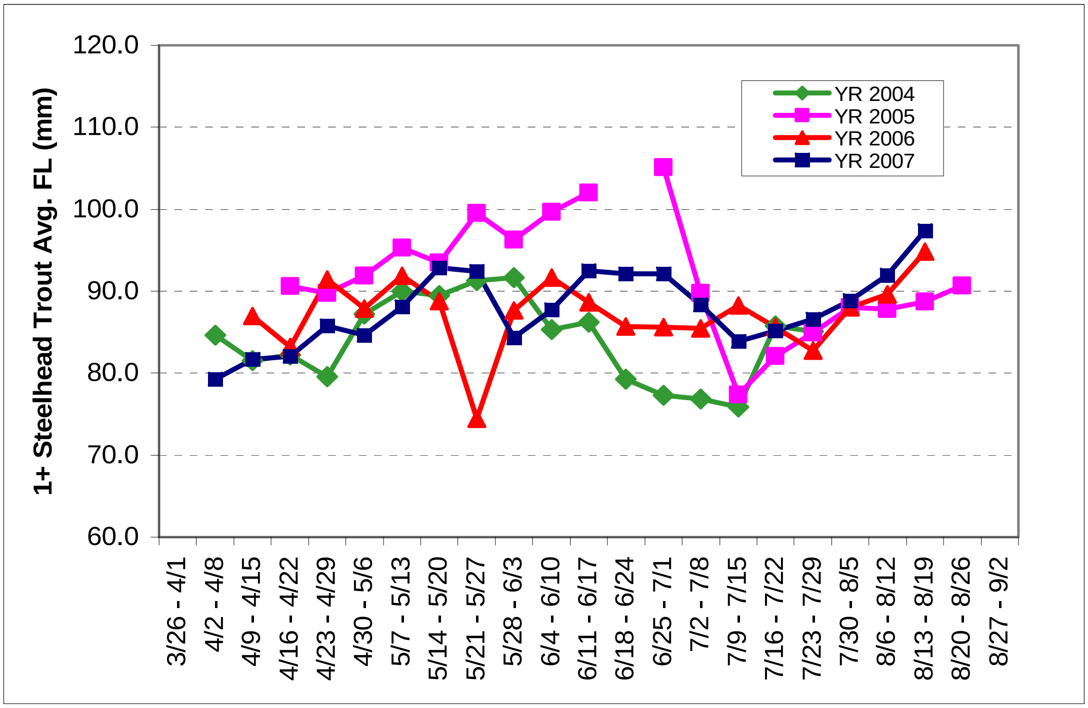


Figure 26. 1+ steelhead trout average weekly fork lengths (mm) in YRS 2004 - 2007, lower Redwood Creek, Humboldt County, CA.

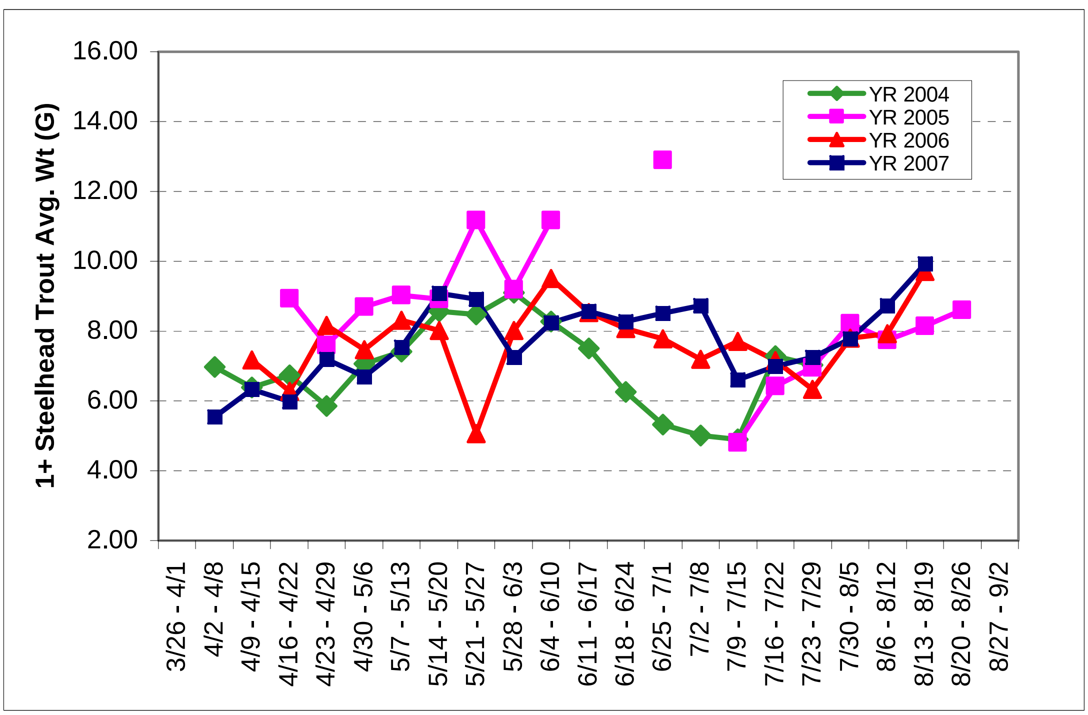


Figure 27. 1+ steelhead trout average weekly weights (g) in YRS 2004 - 2007, lower Redwood Creek, Humboldt County, CA.

2+ Steelhead Trout

We measured (FL mm) 1,148 and weighed (g) 1,098 2+ steelhead trout in YR 2007 (Table 25). Average FL (141.7 mm) in YR 2007 was greater than the average in YR 2006, and less than averages in YRS 2004 and 2005 (Table 25).

Average Wt in YR 2007 was greater than averages in YRS 2004 and 2006, and less than the average in YR 2005 (Table 25). Standard error of the mean for fork lengths was less than 1.1 mm each study year; and for weights was less than 0.66 g each study year.

The mode in fork length (mm) was 121 mm in YR 2007, 122 mm in YR 2006, 120 mm in YR 2005, and 125 mm in YR 2004; the mode in weight (g) was 18.7 g, 19.9 g, and 20.7 g in YR 2007, 19.8 g in YR 2006, 18.5 g in YR 2005, and 18.8 g in YR 2004.

Table 25. 2+ steelhead trout average and median fork length (mm) and weight (g) in YRS 2004 - 2007, 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
Avg.			141.5			30.40	

The pattern of 2+ steelhead trout average weekly FL's (mm) over time in YRS 2004 - 2007 was similar (Figure 28). Average weekly FL's in YRS 2007, 2006 and 2004 significantly decreased over time (weeks) (Correlation; YR 2007, = 0.007, r = 0.58, power = 0.82; YR 2006, p = 0.02, r = 0.52, power = 0.65; YR 2004, p = 0.002, r = 0.79, power = 1.0); no significant change in average FL over time was detected in YR 2005 (Correlation, p > 0.05). Median fork lengths among study years were not significantly different (Kruskal-Wallis One-Way ANOVA on Ranks, p > 0.05).

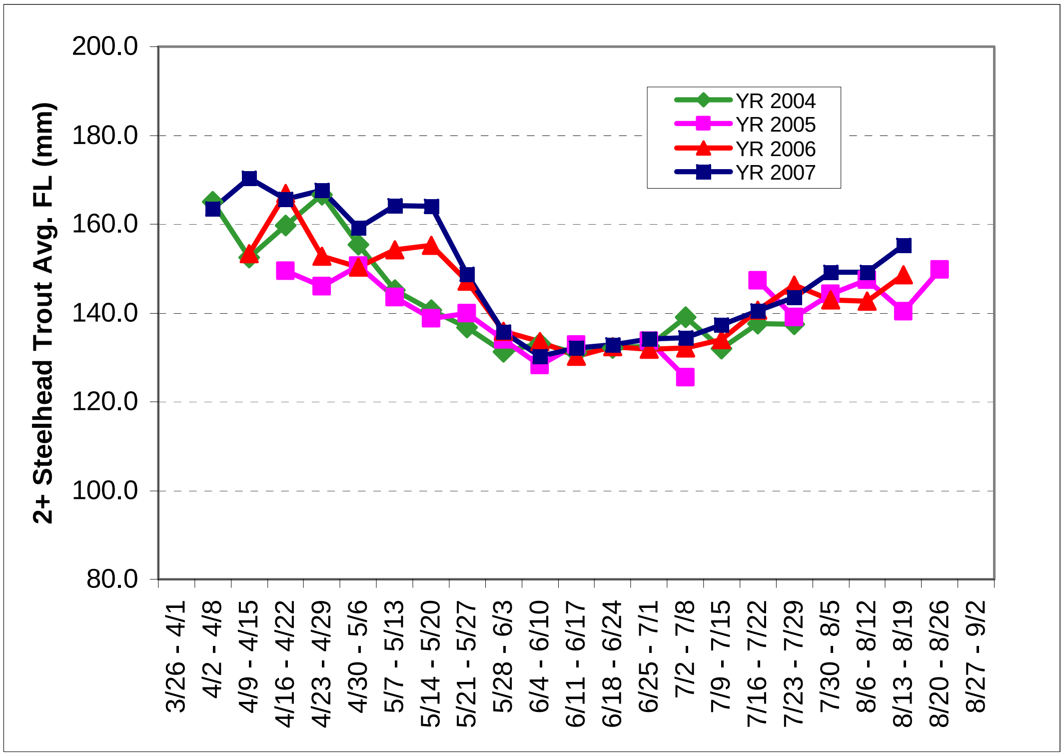


Figure 28. 2+ steelhead trout average weekly fork lengths (mm) in YRS 2004 - 2007, lower Redwood Creek, Humboldt County, CA.

The pattern of 2+ steelhead trout average weekly Wt's (g) over time in YRS 2004 – 2006 was also similar (Figure 29); however, significant changes over time (weeks) were only detected in YR 2007 (Correlation, $p = 0.02$, $r = 51$, negative slope, power = 0.67), and 2004 (Correlation, $p = 0.0001$, $r = 0.80$, negative slope, power = 1.0). Median weekly Wt's among study years were not significantly different (Kruskal-Wallis One-Way ANOVA on Ranks, $p > 0.05$).

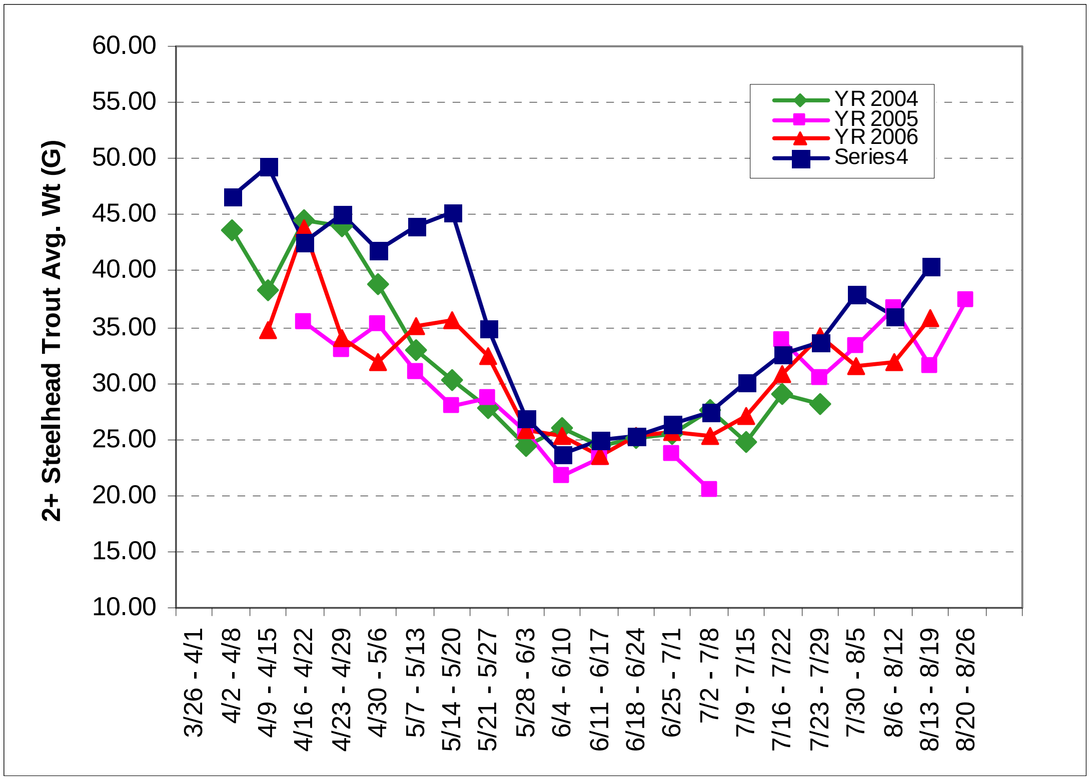


Figure 29. 2+ steelhead trout average weekly weights (g) in YRS 2004 - 2007, lower Redwood Creek, Humboldt County, CA.

0+ Coho Salmon

We measured (FL mm) 290 and weighed (g) 276 0+ coho salmon in YR 2007 (Table 26). Average FL and Wt in YR 2007 was greater than averages in previous study years (Table 26). Standard error of the mean was less than 2.0 mm each study year for FL, and less than 0.30 g for Wt.

The mode(s) in fork length (mm) was 67 and 76 mm in YR 2007, 60, 71, 72, 73, 74, and 78 mm (all sizes had n = 6) in YR 2006, 38 mm in YR 2005, and 60 and 65 mm in YR 2004; the mode in weight (g) was 2.4 g in YR 2007, 3.0 and 4.6 g in YR 2006, 2.7 g in YR 2005, and 3.2 g in YR 2004.

Table 26. 0+ coho salmon average and median fork length (mm) and weight (g) in YRS 2004 - 2007, 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
Avg.			65.0			3.51	

* First year population estimate was determined.

Average weekly FL's in YRS 2004 – 2007 increased over time (Figure 30). Significant positive changes over time were detected for YRS 2007, 2006 and 2005 (Correlation; YR 2007, p = 0.000001, r = 0.91, power = 1.0; YR 2006, p = 0.0005, r = 0.83, power = 0.99; YR 2005, p = 0.00006, r = 0.97, power = 1.0); and after removing week 1 (recognizable outlier), a significant positive change was also detected in YR 2004 (Correlation, p = 0.000003, r = 0.93, power = 1.0). Median weekly fork length among study years did not show significant variation (Kruskal-Wallis One-Way ANOVA on Ranks (p > 0.05).

0+ coho salmon average weekly Wts (g) significantly increased (+) over time each study year (Figure 31) (Correlation; p ranged from 0.0004 – 0.000008, r = 0.83 – 0.98, power = 0.99 – 10). Average weekly Wts (g) among study years were not significantly different (ANOVA, p > 0.05, power = 0.08).

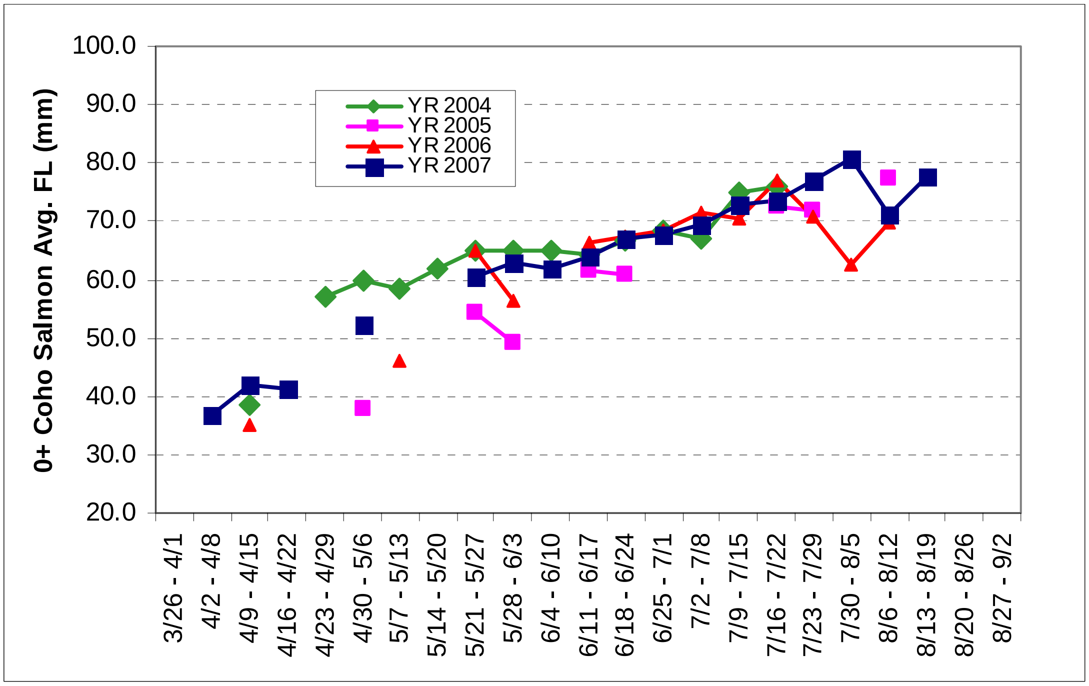


Figure 30. 0+ coho salmon average weekly fork lengths (mm) in YRS 2004 - 2007, lower Redwood Creek, Humboldt County, CA.

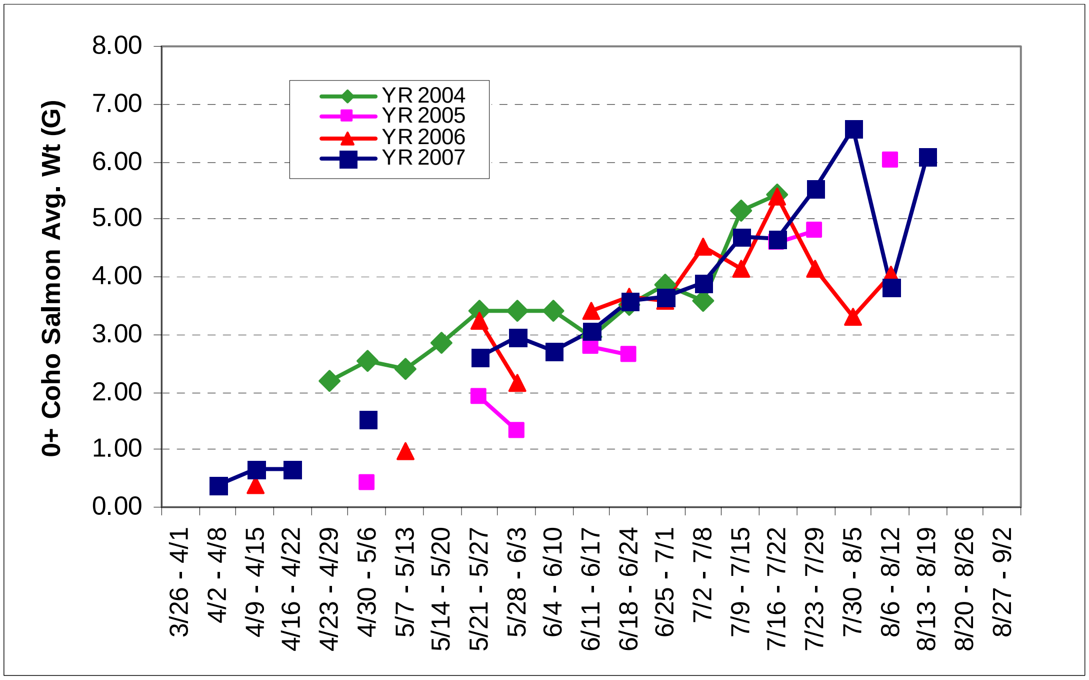


Figure 31. 0+ coho salmon average weekly weights (g) in YRS 2004 - 2007, lower Redwood Creek, Humboldt County, CA.

1+ Coho Salmon

We measured (FL mm) and weighed (g) 34 1+ coho salmon in YR 2007 (Table 27). Average FL and Wt among study years showed little variation, the greatest difference between years was 4.5 mm and 1.3 g, respectively (Table 27). Average FL and Wt in YR 2007 was the lowest of record (Table 27). Standard error of the mean for FL was less than 2.0 mm for each study year; and for Wt was less than 0.65 g each study year.

The modes in FL (mm) were 98, 107, 110, 111, and 112 (n = 2 for each size) in YR 2007, 111 mm in YR 2006, 112 mm in YR 2005, and 105 mm in YR 2004. The modes in Wt (g) were 10.1, 11.2, and 14.9 g in YR 2007, 12.5 g in YR 2005, and 16.1 g in YR 2004; in YR 2006, 11 values had the same frequency (n = 2).

Table 27. 1+ coho salmon average and median fork length (mm) and weight (g) in YRS 2004 - 2007, 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	12.3
Avg.			106.3			12.98	

Average weekly fork length in YR 2004 significantly increased over time (Correlation, $r = 0.86$, $p = 0.006$, slope is positive, power = 0.93) (Figure 32); however, no significant changes were detected in YRS 2005 - 2007 (Correlation, $p > 0.05$ for each test). Average weekly FL's among study years were not significantly different (ANOVA, $p > 0.05$, power = 0.21).

Average weekly Wt significantly changed over time in YR 2007 (Correlation, $r = 0.83$, $p = 0.04$, slope is positive, power = 0.62) and YR 2004 (Correlation, $r = 0.80$, $p = 0.017$, slope is positive, power = 0.77); and average Wt in YR 2005 and 2006 did not significantly change over time (Correlation, $p > 0.05$, power = 0.06 and 0.8, respectively) (Figure 33). Average weekly Wt's (g) among study years were not significantly different (ANOVA, $p > 0.05$, power = 0.18).

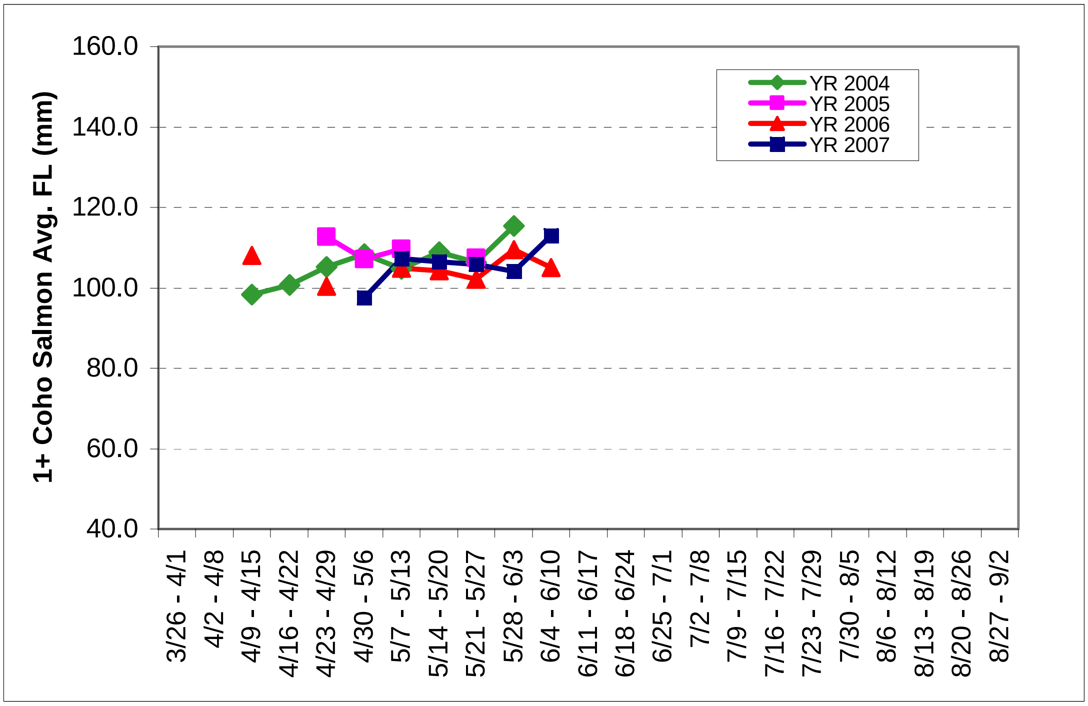


Figure 32. 1+ coho salmon average weekly fork lengths (mm) in YRS 2004 - 2007, lower Redwood Creek, Humboldt County, CA.

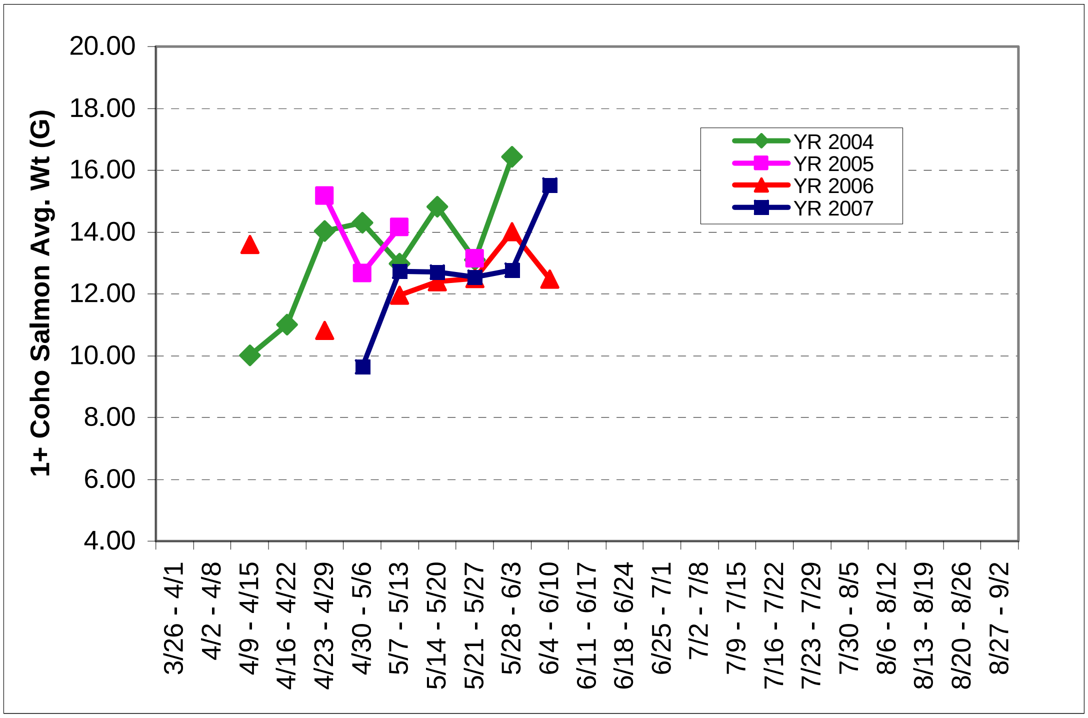


Figure 33. 1+ coho salmon average weekly weights (g) in YRS 2004 - 2007, lower Redwood Creek, Humboldt County, CA.

Cutthroat Trout

We measured 44 (FL mm) and weighed (g) 44 cutthroat trout in YR 2007 (Table 28). Average FL in YR 2007 was greater than averages for YRS 2004 and 2006, and less than the average for YR 2005 (Table 28); average Wt in YR 2007 was greater than averages for YRS 2004 – 06 (Table 28). Standard error of the mean for fork length was less than 34 mm each study year; and for Wt was less than 18 g each study year.

There were six modes in FL (mm) in YR 2007 (frequency = 2), YR 2006 (frequency = 2) and in YR 2004 (frequency = 2); there was not a mode in FL (mm) in YR 2005. The mode in Wt (g) was 36.7 g in YR 2007, 66.1 g in YR 2006, and 41.9 g in YR 2004. There was not a mode in Wt (g) in YR 2005.

Using FL measurements per day (due to low sample size per week), the median FL among study years showed significant variation (Kruskal-Wallis One-Way ANOVA on Ranks, $p < 0.001$). Further testing showed median FL in YR 2007 and YR 2006 were significantly greater than median FL in YR 2004 (Kruskal-Wallis Multiple-Comparison Z-Value Test with Bonferroni control, z value > 2.6383 for each test); no other significant differences were detected (Kruskal-Wallis Multiple-Comparison Z-Value Test with Bonferroni control, z value < 2.6383).

Wt data showed similar relationships such that median Wt in YR 2007 and YR 2006 were significantly greater than YR 2004 (Kruskal-Wallis Multiple-Comparison Z-Value Test with Bonferroni control, z value > 2.6383 for each test). No other significant differences in median Wt among years were detected (Kruskal-Wallis Multiple-Comparison Z-Value Test with Bonferroni control, z value < 2.6383).

Table 28. Cutthroat trout average and median fork length (mm) and weight (g) in YRS 2004 - 2007, 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
Avg.			198.7			79.58	

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 29). A totally random distribution would equal 33.3% for each designation (parr, pre-smolt, smolt).

In YR 2007 there were statistically more 1+ steelhead trout parr designations compared to the parr designation for the previous three year average (Chi-square, $p < 0.000001$). There were no significant differences between pre-smolt and smolt designations in YR 2007 with the previous three year average (Chi-square, $p = 0.08$).

The proportions of 2+ steelhead trout pre-smolt and smolt designations were significantly different than previous three year average, such that there were more pre-smolt and less smolt designations in YR 2007 (Chi-square, $p < 0.00001$).

The combined percentage of pre-smolts and smolts for 1+ steelhead trout was nearly 100%, and for 2+ steelhead trout, equaled 100% (Table 29).

Table 29. Developmental stages of captured 1+ and 2+ steelhead trout in YRS 2004 - 2007, 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
Avg.	0.2	23.4	76.4	0.0	3.2	96.8
2007	0.5	22.4	77.1	0.0	6.1	93.9

Additional Experiments

Re-Migration

In YR 2007, we did not recapture any of the pit tagged fish released from upper Redwood Creek in YR 2006 (Table 30), and in YR 2006 we did not recapture any of the 1+ and 2+ steelhead trout marked and released with elastomer (n = 146 for 1+SH, 37 for 2+SH) in YR 2005. We also did not recapture any pit tagged fish released in YR 2005 (0+ Chinook, n = 555; 1+ steelhead, n = 147; 2+ steelhead, n = 46) in YR 2006 (Table 30).

Table 30. Data for testing re-migration of 0+ Chinook salmon, 1+ steelhead trout, and 2+ steelhead trout released from upper Redwood Creek to be recaptured in upper or lower Redwood Cr the following year, Humboldt County, CA., 2007.

		Re-Migration Experiments	
YR	Species at Age*	Number Marked and Released	Percent Recapture the Following Year
2005	0+ KS	555	0.00
2006	0+ KS	121	0.00
2004	1+ SH	577	0.00
2005	1+ SH	293	0.00
2006	1+ SH	246	0.00
2004	2+ SH	223	0.00
2005	2+ SH	83	0.00
2006	2+ SH	38	0.00

* Age/species designations are the same as in Figure 2.

Travel Time, Travel Rate, and Growth

0+ Chinook Salmon

We recaptured 245 pit tagged 0+ Chinook salmon at the lower trap in YR 2007 (Table 31). Percent recapture per release group ranged from 0.0 – 67% (Table 31).

Table 31. Release groups, sample size, and percent recapture of pit tagged 0+ Chinook salmon released from upper Redwood Creek, and recaptured in lower Redwood Creek, Humboldt County, CA., 2007.

Pit Tagged 0+ Chinook Salmon			
Release Group	Sample Size	No. of Recaptures	Percent Recapture
5/22/2007	3	2	66.7
5/27/2007	2	0	0.0
5/29/2007	21	7	33.3
5/31/2007	39	18	46.2
6/02/2007	25	8	32.0
6/04/2007	39	12	30.8
6/05/2007	45	15	33.3
6/07/2007	61	16	26.2
6/10/2007	35	12	34.3
6/12/2007	74	23	31.1
6/14/2007	45	19	42.2
6/19/2007	47	18	38.3
6/21/2007	78	24	30.8
6/24/2007	58	28	48.3
6/26/2007	52	22	42.3
7/03/2007	36	13	36.1
7/08/2007	24	6	25.0
7/10/2007	4	1	25.0
7/20/2007	2	1	50.0
7/23/2007	1	0	0.0
Sum:	691	245	

Initial fork lengths of recaptured juveniles ranged from 67 – 80 mm, and averaged 71.9 mm (Appendix 5). Time to travel the 29 miles between traps ranged from 2.5 – 29.5 d, averaged 10.7 d (median = 8.5 d, mode = 3.5 d) (Table 32). Average travel time in YR 2007 was greater than average travel time in YRS 2005 and 2006 (Table 32). Travel time (transformed) in YR 2007 was significantly related to FL (transformed) at time 2 (Regression, $p < 0.000001$, $R^2 = 0.34$, positive slope, power = 1.0), and WT (transformed) at time 2 (Regression, $p < 0.000001$, $R^2 = 0.34$, positive slope, power = 1.0). The regressions of stream discharge, stream temperature, and lunar phase on travel time each failed regression assumption tests (even with transformations), and results were not valid (NCSS 97).

Travel rate (mi/d) ranged from 1.0 – 11.6 mi/d, and averaged 4.0 mi/d (median = 3.4 mi/d, mode = 8.3 mi/d) (Table 32). The regressions of stream discharge, stream temperature, lunar phase, and size (T1 and T2) on travel rate each failed regression assumption tests (even with transformations), and results were not valid (NCSS 97).

Similar to experiments in YRS 2005 – 06, multiple fish released from the same release group (n = 14 groups) in YR 2007 were frequently recaptured at the lower trap on the same day. For example, the group released on 6/24/2007 (n = 58), had seven individuals recaptured on 7/04/2007. Seventy-eight percent of the release groups (which had recaptures in lower Redwood Creek) had fish recaptured on the same day as other fish in that release group. Of the 245 total recaptures, 64% (n = 158) occurred on days when other pit tag fish were also recaptured. In contrast, some fish that were released at the same time (as a group) were recaptured on varying dates. For example, travel time for recaptured individuals (n = 6) from the 7/08/07 release group ranged from 3.5 – 29.5 days, and averaged 13.5 d.

The final average size (FL) of recaptured pit tagged 0+ Chinook ranged from 68 – 90 mm, and averaged 75.9 mm; final Wt ranged from 3.21 – 7.71 g, and averaged 4.63 g (Appendix 5). Unlike previous study years, the regression of initial size on final size failed assumption tests, and results were not valid (NCSS 97).

Seventy-three percent (n = 179) of the 245 recaptured pit tagged 0+ Chinook salmon showed positive growth in FL and 27% (n = 66) showed no increase in FL. For the 234 recaptures where Wt was recorded, 78.6% (n = 184) showed an increase in Wt, 19.7% (n = 46) showed no growth, and 1.7% (n = 4) lost Wt.

On average, the 0+ Chinook salmon gained 3.9 mm in length, and experienced a positive percent change in FL of 5.5% in YR 2007 (Table 32). 0+ Chinook salmon showed, on average, positive growth in FL for absolute growth rate (Avg. = 0.29 mm/d), relative growth rate (Avg. = 0.004 mm/mm/d), and specific growth rate scaled [Avg. = 0.397 % (mm/d)] (Table 32). Growth values in YR 2007 were greater than values in YRS 2005 and 2006 (Table 32).

Table 32. Comparison of travel time (d), travel rate (mi/d), and various growth statistics in YRS 2005 - 2007 for pit tagged 0+ Chinook salmon released in upper Redwood Cr and recaptured in lower Redwood Cr, Humboldt County, CA.

	Pit Tagged 0+ Chinook Salmon Recaptures		
	Average Values (median in parentheses)		
Variable	YR 2005 (n = 27)	YR 2006 (n = 28)	YR 2007 (n = 245)
Emigrational			
Travel Time (d)	7.5 (5.5)	8.0 (6.5)	10.7 (8.5)
Travel Rate (mi/d)	8.2 (5.3)	5.5 (4.5)	4.0 (3.4)
Growth Index(FL)			
Δ in FL*	2.8 (2.0)	2.8 (2.0)	3.9 (3.0)
% Change in FL	3.65 (2.47)	3.87 (2.82)	5.48 (4.23)
AGR*	0.22 (0.19)	0.24 (0.30)	0.29 (0.33)
RGR*	0.003 (0.002)	0.003 (0.004)	0.004 (0.004)
SGRsc*	0.279 (0.232)	0.323 (0.395)	0.397 (0.430)

* Δ in FL = change in FL (mm), AGR = absolute growth rate (FL mm/d), RGR = relative growth rate (FL mm/mm/d), SGRsc = specific growth rate scaled, [FL %(mm/d)].

The relationship of travel time on various FL and Wt growth indices was significant and positive. Travel time (transformed) explained more of the variation (78%) in percent change in FL (transformed) than any other variable tested (Figure 34). Travel rate (mi/d) was inversely related to change in Wt (transformed) (Regression, $p < 0.00001$, $R^2 = 0.66$, power = 1.0).

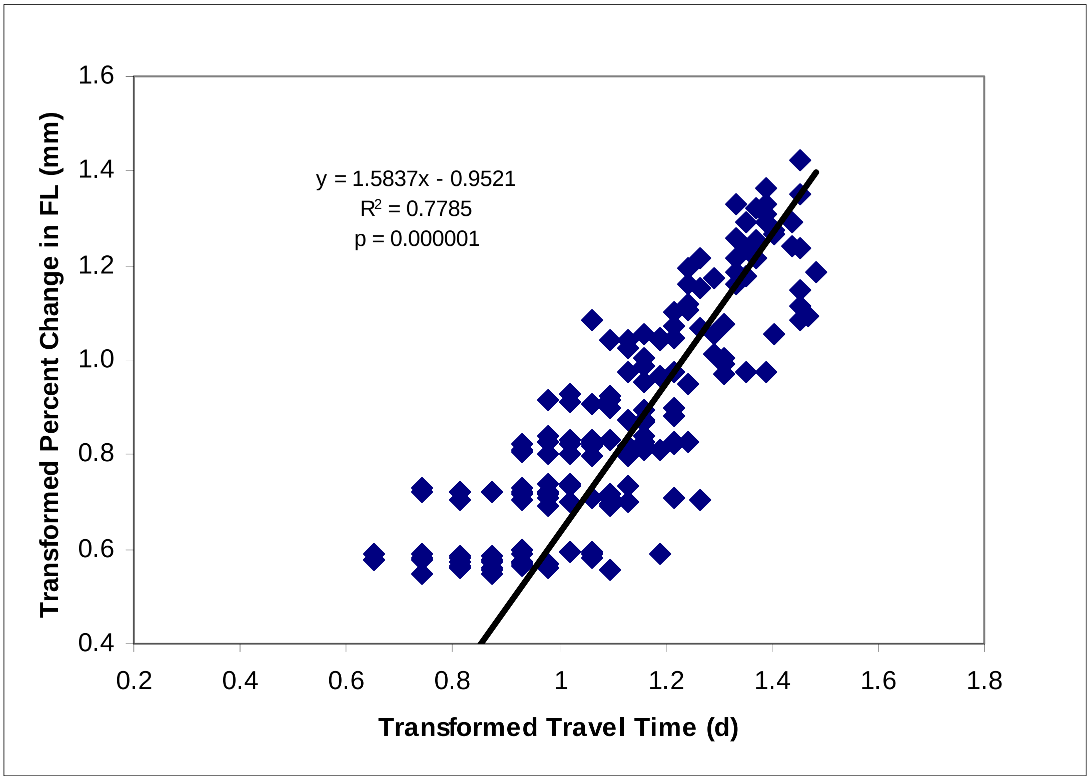


Figure 34. Linear regression of transformed travel time (d) on transformed percent change in FL (mm) for pit tagged 0+ Chinook salmon (n = 245) recaptured at the lower trap in Redwood Creek, Humboldt County, CA. 2007.

Separate growth statistics were determined for recaptured pit tagged 0+ Chinook salmon individuals showing only positive growth (Table 33). On average, pit tagged Chinook salmon absolute growth rate equaled 0.402 mm per day for FL, and 0.066 g per day for Wt (Table 33).

Table 33. Growth statistics for recaptured pit tagged 0+ Chinook salmon that showed only positive growth in FL (n = 179) and Wt (n = 184) while traveling 29 mi downstream to lower Redwood Creek, Humboldt County, CA., 2007.

	Positive Growth							
	% Change in		AGR*		SGRsc*		RGR*	
	FL	Wt	FL	Wt	FL	Wt	FL	Wt
Min.	2.5	2.0	0.138	0.010	0.197	0.189	0.002	0.002
Max.	25.4	106.8	0.762	0.148	1.000	3.652	0.011	0.044
Avg.	**7.5**	**23.6**	**0.402**	**0.066**	**0.544**	**1.547**	**0.006**	**0.018**
SEM**	0.4	1.4	0.009	0.002	0.012	0.046	0.0001	0.0006

* Abbreviations are the same as in Table 32. ** Standard error of the mean.

We took detailed notes on whether the partial, upper caudal fin clips (secondary mark for pit tagged fish) and scars from pit tag surgery (scalpel) were visible to the observer (naked eye). Fish that fell within the not visible category spent a longer time traveling downstream, and exhibited higher growth than individuals in the two other categories (Table 34).

Table 34. Visibility of partial fin clips and surgery scars, percent change in FL, and absolute growth rate (per visibility category) for recaptured pit tagged 0+ Chinook salmon in lower Redwood Cr, Humboldt County, CA., 2007.

	Average values for recaptured pit tagged 0+ Chinook Salmon				
Visibility	n*	Travel Time (d)	Travel Rate (mi/d)	% Change in FL (mm)	AGR** FL (mm/d)
Partial Fin Clip					
Visible	204	8.6	4.4	3.9	0.264
Barely Visible	9	17.1	1.9	9.3	0.353
Not Visible	32	21.8	1.4	14.3	0.461
Surgery Scar					
Visible	203	8.5	4.5	3.9	0.265
Barely Visible	20	18.0	1.8	10.8	0.412
Not Visible	22	23.9	1.2	15.2	0.444

* Designates sample size. ** AGR FL = absolute growth rate in FL, mm/d.

0+ Steelhead Trout

During the first travel time experiment with 0+ steelhead trout, we recaptured 12 out of 100 individuals (original number marked and released from upper trap) at the lower trap. Travel time ranged from 4.5 – 43.5 d, and averaged 17.4 d; travel rate (mi/d) ranged from 0.67 - 6.44 mi/d, and averaged 2.41 mi/d. We recaptured three individuals out of 100 marked and released during the second experiment; travel time ranged from 8 -19 d, and averaged 11.7 d. Recapture data for the second experiment was limited by removing the lower trap when more marked fish were presumably migrating downstream.

1+ Steelhead Trout

We recaptured 18 pit tagged 1+ steelhead trout at the lower trap in YR 2007 (Appendix 6). Percent recapture per release group ranged from 0.0 – 16.7%, and averaged 2.6% (Appendix 6).

Initial fork lengths of recaptured juveniles (n =18) ranged from 68 – 115 mm, and averaged 83.9 mm (Appendix 7). The final size of recaptured pit tagged 1+ steelhead trout in YR 2007 ranged from 83 – 121 mm, and averaged 99.1 mm; final Wt ranged from 6.01 – 21.01 g, and averaged 10.77 g (Appendix 7). The final size (FL, Wt) was positively related to initial size at release (Regression, FL: $p < 0.001$, $R^2 = 0.53$, positive slope, power = 0.98; WT: $p < 0.001$, $R^2 = 0.60$, positive slope, power = 1.00).

Time to travel the 29 miles between traps in YR 2007 ranged from 3.5 – 55.5 d, and averaged 29.5 (median = 29.0 d) (Appendix 7). Travel time in YR 2006 averaged 20.8 d, and travel time in YR 2005 (n = 5) averaged 12.4 d (Table 35). Differences in average travel time among study years were significant (ANOVA, $p < 0.10$, power = 0.63). Further testing proved that travel time in YR 2007 was significantly greater than travel time in YR 2005 (Bonferroni All-Pairwise Multiple Comparison Test, $p < 0.033$).

Travel time was significantly related to average daily lunar phase (during the migratory period) (Regression, $p < 0.05$, $R^2 = 0.34$, positive slope, power = 0.77), average daily discharge in upper Redwood Cr (Regression, $p < 0.01$, $R^2 = 0.40$, positive slope, power = 0.87), average daily discharge in lower Redwood Cr (Regression, $p < 0.01$, $R^2 = 0.41$, positive slope, power = 0.88), and average daily discharge of upper and lower Redwood Cr (Regression, $p < 0.01$, $R^2 = 0.41$, positive slope, power = 0.88). Travel time was also significantly related to average daily stream temperatures in upper Redwood Cr (Regression, $p < 0.01$, $R^2 = 0.45$, negative slope, power = 0.92), average daily stream temperature in lower Redwood Cr (Regression, $p < 0.01$, $R^2 = 0.44$, negative slope, power = 0.91), and the average daily stream temperature in upper and lower Redwood Creek (Regression, $p < 0.01$, $R^2 = 0.45$, negative slope, power = 0.92). The best model for explaining the variation in travel time included lunar phase and average stream discharge (average of both gages) (Regression, $p < 0.01$, Adj. $R^2 = 0.51$, positive slope for each variable, power = 0.73).

Travel rate (mi/d) in YR 2007 ranged from 0.5 – 8.3 mi/d, and averaged 1.6 mi/d (median = 1.0 mi/d) (Appendix 7, Table 35). Travel rate in YR 2006 (n = 6) averaged 4.0 mi/d (median = 2.1 mi/d), and in YR 2005 (n = 5) averaged 5.8 mi/d (median = 2.9 mi/d). There were significant differences in median travel rate among study years (Kruskal Wallis One-Way ANOVA on Ranks, $p < 0.10$). Further testing showed that travel rate in YR 2007 was significantly less than travel rate in YR 2005 (Kruskal-Wallis Multiple-Comparison Z value Test, $p < 0.033$). The regressions of stream discharge, stream temperature, lunar phase, and size (T1 and T2) on travel rate each failed regression assumption tests, and results were not valid (NCSS 97). The regression of lunar phase on the transformed travel rate was significantly negative (Regression, $p < 0.001$, $R^2 = 0.60$, negative slope, power = 1.0).

Ninety-four percent (n = 17) of the 18 recaptured pit tagged 1+ steelhead trout showed positive growth in FL and 6% (n = 1) showed no change in FL; 89% (n = 16) showed an increase in Wt , and 11% (n = 2) showed no change in Wt.

On average, the 1+ steelhead trout gained 15.2 mm in length, and experienced a positive percent change in FL of 18.7% in YR 2007 (Table 35). 1+ steelhead trout showed, on average, positive growth in FL for absolute growth rate (Avg. = 0.47 mm/d), relative growth rate (Avg. = 0.006 mm/mm/d), and specific growth rate scaled [Avg. = 0.521 %(mm/d)] (Table 35). Growth in YR 2007 was greater than growth in YR 2006 (Table 35).

Table 35. Comparison of travel time (d), travel rate (mi/d), and various growth statistics in YRS 2005 - 2007 for pit tagged 1+ steelhead trout released in upper Redwood Cr and recaptured in lower Redwood Cr, Humboldt County, CA.

	Pit Tagged 1+ Steelhead Trout Recaptures		
	Average Values (median in parentheses)		
Variable	YR 2005 (n = 5)**	YR 2006 (n = 6)	YR 2007 (n = 18)
Emigrational			
Travel Time (d)	12.4 (10.0)	20.8 (15.5)	29.5 (29.0)
Travel Rate (mi/d)	5.8 (2.9)	4.0 (2.1)	1.59 (1.0)
Growth Index(FL)			
Δ in FL*	-	10.0 (6.5)	15.2 (15.0)
% Change in FL	-	12.6 (9.19)	18.74 (19.74)
AGR*	-	0.31 (0.32)	0.47 (0.49)
RGR*	-	0.004 (0.004)	0.006 (0.006)
SGRsc*	-	0.350 (0.398)	0.521 (0.571)

* Abbreviations are the same as in Table 32.
** Includes 3 elastomer marked fish and 2 pit tagged fish.

The relationship of travel time on various growth indices was significantly positive for each test (Regression, $p < 0.05$); and travel rate on growth was significantly negative for each test (Regression, $p < 0.05$) (Appendix 8). Travel time (d) explained more of the variation in delta FL and Wt, and percent change in FL and Wt than other variables tested (Appendix 8). The variation in travel time (d) explained 85% of the variation in delta FL (Figure 35).

Growth indices (change in size, percent change in size, AGR, SGRsc and RGR) were positively related to travel time, average stream discharge, and lunar phase; and negatively related to travel rate and water temperature (Appendix 8). AGR (Wt) was best modeled using lunar phase and stream discharge (Adj. $R^2 = 0.67$), and AGR (FL) was best modeled using lunar phase ($R^2 = 0.69$). The variation in SGRsc (FL, Wt) and RGR (FL, Wt) was best explained by the variation in lunar phase (Appendix 8, R^2 ranged from 0.62 to 0.74).

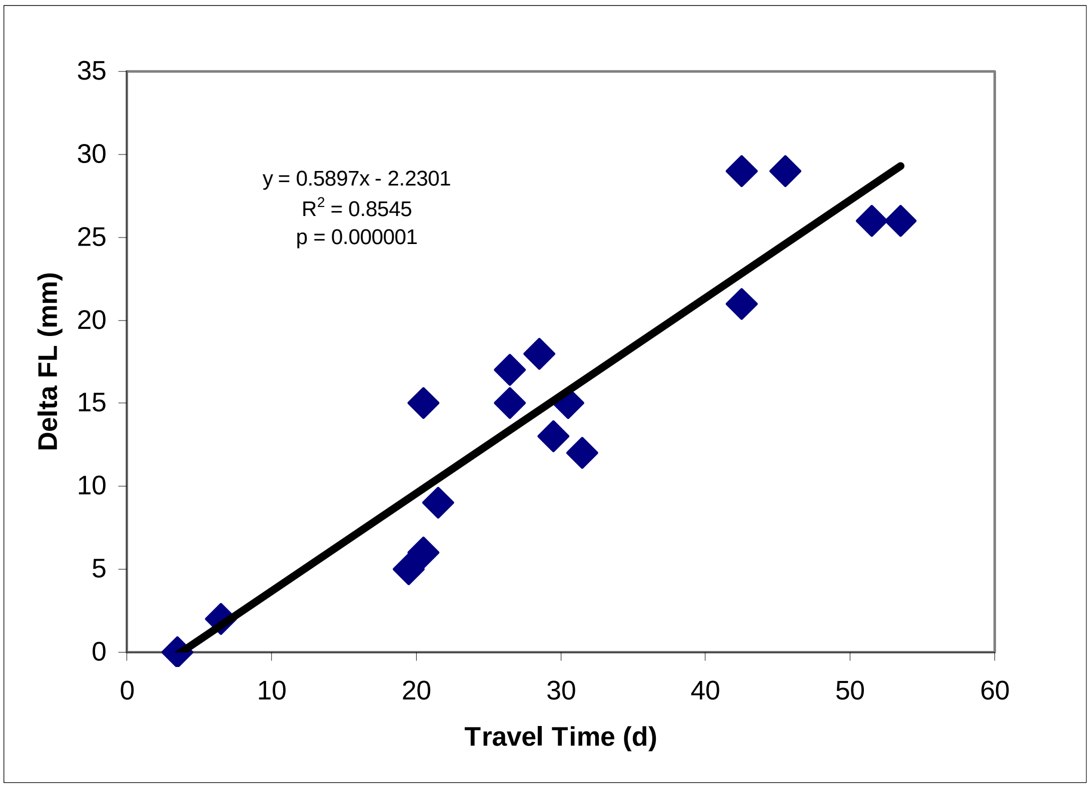


Figure 35. Linear regression of travel time (d) on change in FL (mm) for pit tagged 1+ steelhead trout (n = 18) recaptured at the lower trap in Redwood Creek, Humboldt County, CA., 2007.

2+ Steelhead Trout

We recaptured one pit tagged 2+ steelhead trout in YR 2007 that took 18.5 d to reach the lower trap.

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 2007 ranged from 0.00 – 0.10%, and using all data (pooling) was 0.06% of the total captured and handled (Table 36).

Table 36. Trapping mortality for juvenile salmonids captured in YR 2007, lower Redwood Creek, Humboldt County, CA.

	Trap Mortality in YR 2007		
Age/spp.	No. captured	No. of mortalities	Percent mortality
0+ Chinook	43,233	14	0.03
0+ Steelhead	42,827	42	0.10
1+ Steelhead	6,679	1	0.02
2+ Steelhead	1,198	0	0.00
Cutthroat trout	44	0	0.00
0+ Coho	293	0	0.00
1+ Coho	34	0	0.00
Overall:	94,308	58	0.06

Table 37. Comparison of trapping mortality of juvenile salmonids in four consecutive study years, lower Redwood Creek, Humboldt County, CA.

	Trap Mortality		
Study Year	No. captured	No. of mortalities	Percent mortality
2004	88,088	167	0.19
2005	14,734	146	1.00
2006	55,717	93	0.17
2007	94,308	58	0.06
Avg.			0.36

Stream Temperatures

The average daily (24 hr period) stream temperature from 4/03/07 – 8/17/07 was 15.29 ^{o}C (or 59.5 ^{o}F) (95% CI = 14.75 – 15.83 ^{o}C), with daily averages ranging from 8.83 – 20.26 ^{o}C (47.9 – 68.5 ^{o}F). Median daily temperature equaled 15.98 ^{o}C (or 60.8 ^{o}F). Average stream temperatures during the trapping periods in YRS 2004 – 2006 were similar (Table 38). Similar to past data, the average stream temperature during the trapping period in YR 2007 was inversely related to the average daily stream discharge (transformed) during the trapping period (Regression, $p < 0.000001$, $R^2 = 0.91$, slope is negative, power = 1.0). The minimum stream temperature in YR 2007 was 8.1 ^{o}C (46.6 ^{o}F) and occurred on 4/19/07; the maximum stream temperature was 24.2 ^{o}C (75.6 ^{o}F) (Table 38) and occurred on 7/22/07.

Table 38. Stream temperatures (^{o}C) (standard error of mean in parentheses) at the trap site during the trapping periods in YRS 2004 – 2007, 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
Avg.	15.5 (0.1)			59.9 (0.1)		

Average monthly stream temperatures during the majority of the trapping season (April – July) in YR 2007 ranged from 10.7 – 18.5 ^{o}C (51.3 – 65.3 ^{o}F) (Table 39). Highest stream temperatures occurred in the later part of the trapping season (June and July) each study year. Average monthly stream temperature (^{o}C) among study years was not significantly different (ANOVA, $p = 0.96$, power = 0.06).

Table 39. Average monthly stream temperature (^{o}C) (^{o}F in parentheses) at the trapping site in study years 2004 - 2007, lower Redwood Creek, Humboldt County, CA.

	Average stream temperature in Celsius (^{o}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)
Avg.	11.1 (52.0)	13.7 (56.7)	16.1 (61.0)	18.5 (65.3)	

The MWAT during the trapping period in YR 2007 at the trap site was 19.2 ^{o}C (66.6 ^{o}F); and occurred on 7/21/07, the same time for MWAT in YR 2006 (Table 40). MWMT in YR 2007 was 22.4 ^{o}C (72.3 ^{o}F) and occurred on 7/31/07 (Table 40).

Table 40. Maximum weekly average temperature (MWAT) and maximum weekly maximum temperature (MWMT) for stream temperatures ^{o}C (^{o}F in parentheses) at the trap site in lower Redwood Creek, Humboldt County, CA., study years 2004 – 2007.

	MWAT		MWMT	
Study Year	Date of occurrence	^{o}C (^{o}F)	Date of occurrence	^{o}C (^{o}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)

The average stream temperature increased over the study period in YR 2007 (Correlation, $p < 0.0001$, $r = 0.94$, slope is positive, power = 1.0) (Figure 36), as well as in past study years (Figure 37). Similar to past study years, average daily stream temperature (transformed) in YR 2007 was significantly related to the stream gage height (transformed) at the trapping site (Regression, $p < 0.05$, $R^2 = 0.94$, slope is negative, power = 1.0).

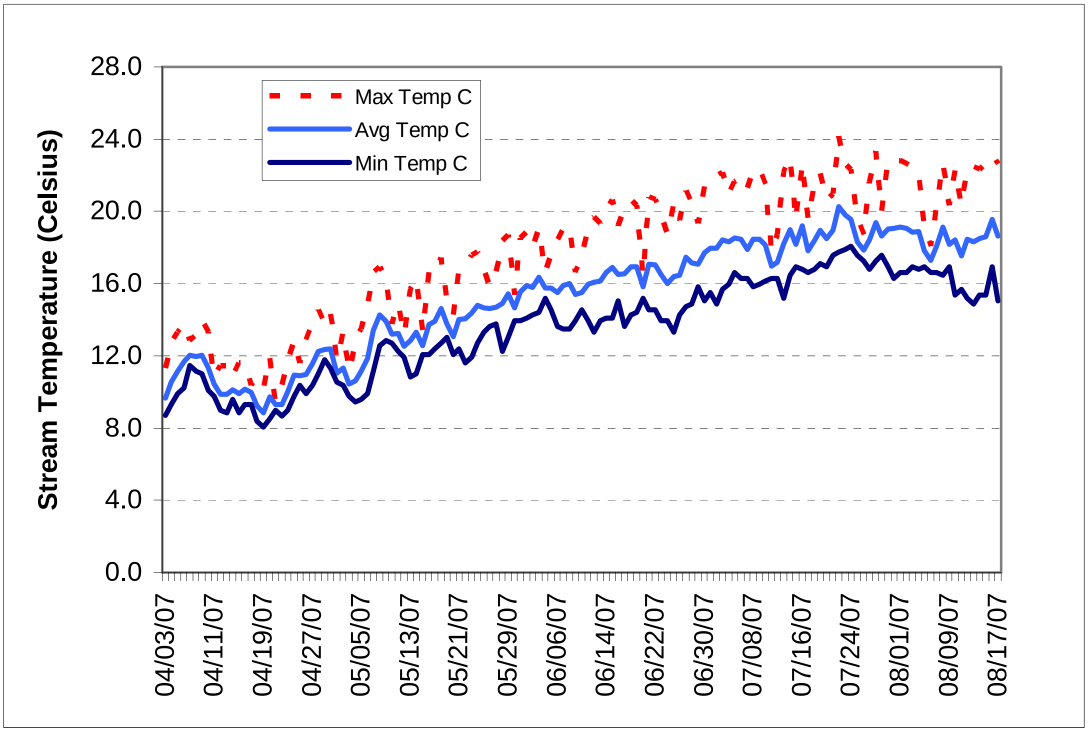


Figure 36. Average, minimum, and maximum stream temperatures (°C) in lower Redwood Creek, Humboldt County, CA., 2007.

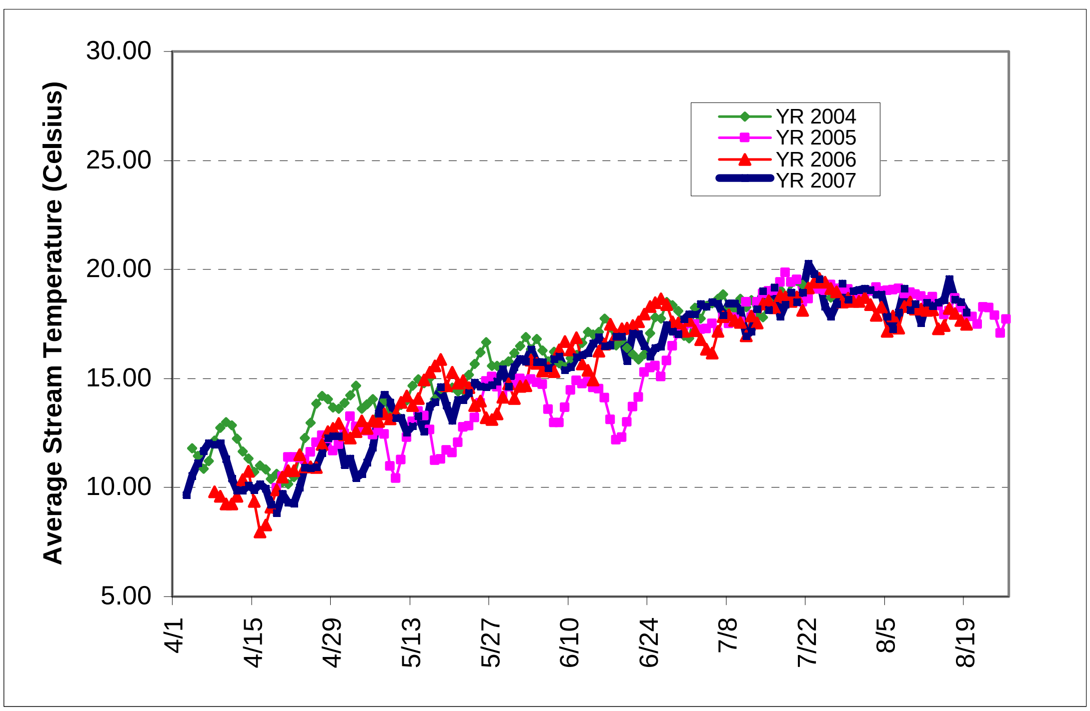


Figure 37. Average daily stream temperature (°C) in YRS 2004 - 2007, lower Redwood Creek, Humboldt County, CA.

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, if not impossible stream to monitor for adult salmon and steelhead populations on a long term basis using traditional techniques (weirs and spawning ground surveys) due to adult 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 fourth consecutive year of trapping in lower Redwood Creek occurred during an average water year with respect to rainfall amounts and average stream discharge measured at Orick, California. Rainfall in WY 2007 was 12% less than the historic average, 1.01 times the rainfall in WYS 2004 and 2005, and about 30% less than rainfall in WY 2006. In response to near average rainfall amounts, average discharge in WY 2007 was also average.

Rainfall during the majority of the trapping period in YR 2007 was 26% less than the historic average, and thus average stream discharge was about 21% less than average. The month of April accounted for most of the rainfall during the trapping periods, and was also the month with the highest average stream discharge. The lowest values in rainfall and stream discharge during the majority of the trapping period occurred in July each study year. However, 1.7 cm of precipitation occurred during July in WY 2007, when precipitation is normally less than 0.6 cm.

The environmental conditions for downstream migrant trapping in YR 2007 were not as harsh or as difficult to operate the trap compared to previous study years. One day of trapping was missed due to a log jamming the trap's cone on July 11, 2007. 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 2.7%, 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. We were able to greatly increase trapping efficiencies for most species at age in YR 2006 by moving the trap 75 m downstream of the previous year's location; in YR 2007, the trap was located at the same place as YR 2006. The new location had a higher gradient and a more confined stream channel compared to the location in YRS 2004 and 2005. Thus, this season's trapping resulted in very good estimates of wild Chinook salmon, steelhead trout, 0+ coho salmon emigration, and cutthroat trout abundance from areas upstream of the trapping site. The abundance estimate for yearling coho salmon was not as good, yet sample sizes for marking these fish were much smaller.

0+ Chinook Salmon

0+ Chinook salmon (ocean-type) were the most numerous migrant captured in three of four consecutive study years. 0+ Chinook salmon trap catches in YRS 2006 and 2007 were higher than catches in YRS 2004 and 2005, primarily due to increased trapping efficiencies by moving the smolt trap to a more favorable location. 0+ Chinook salmon were the most numerous migrant in Redwood Creek at the population level. The population abundance in YR 2007 was greater than YRS 2005 and 2006, much less (75%) than population abundance in YR 2004, and 45% less than the previous three year average. The overall trend in abundance over four consecutive study years was negative; however, statistical significance was not detected, most likely due to low sample size (n = 4 years).

The reduction in population abundance we observed in YR 2007 (and YRS 2005 and 2006) 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, or 3) some combination of factors 1 and 2. Changes in spawner distributions are not likely responsible for the large decrease because Chinook salmon do not generally spawn in mainstem areas below the trap site, and the number of spawners in Prairie Creek was less than average.

Currently, we cannot separate effects of lower adult population size during years with high, bedload mobilizing flows on the subsequent production of juveniles because: 1) adult counts are not conducted, and 2) peak flows capable of redd scour occurred each study year (YRS 2004 – 07). 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). High flows ($11{,}000^{+}$ cfs) measured at the Orick Gaging Station each study year could have mobilized (or jostled) redd gravels (Mary Ann Madej pers. comm. 2008) which would then cause high egg mortality in the redd. This hypothesis is also relevant to Chinook salmon upstream of the upper trap site (RM 33) in Redwood Creek because in three of the eight study years, high bedload mobilizing flows occurred during the spawning season and subsequent juvenile production was severely reduced (Sparkman 2008). Unfortunately, the timing of Chinook salmon spawning and redd incubation in

Redwood Creek occurs during the winter when high rainfall amounts and flood type flows occur. Perhaps the juveniles that survived bedload mobilizing flows in Redwood Creek were progeny of adults that: 1) buried their eggs deeper into the gravels than others, 2) chose redd sites that were less susceptible to scour, or 3) spawned after the peak flows.

Although 0+ Chinook salmon were migrating downstream each day during the trapping period in YR 2007, population emigration was generally confined to a 10 week period (5/7 – 7/15); three (6/4 – 6/24) of the 10 weeks accounted for 69% of the total abundance. The peak month for emigration was June in YRS 2004, 2006 and 2007, and July in YR 2005. Weekly population abundances in YR 2007 closely mirrored the previous three year average, except for lacking a relatively large number of fry emigrating in April. Weekly peaks in abundance during a given study year were relatively large, ranging from 28,000 – 110,980 individuals. Study years with larger population estimates also had a larger peak in weekly emigration. Weekly population emigration in a given study year closely resembled the catch distribution for that year. Population emigration reached low values (< 1,000 individuals) by late July for YR 2004, mid August for YR 2005, and mid July for YRS 2006 and 2007.

The 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 2007) are migrating shortly after emergence from spawning redds, and therefore are much smaller than the fingerlings (Avg. FL = 70 mm in YR 2007) 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 in migration timing between the two life history forms are evident by the two peaks in migration. For example, the first weekly peak (albeit very small) in population emigration in YR 2007 occurred during 4/09 – 4/15 (N = 1,380), and consisted solely of fry with an average FL of 39 mm; the second peak occurred during 6/11 – 6/17 (N = 33,183), and consisted of fingerlings with an average FL of 72 mm. The greatest peak occurred during 6/25 – 7/1 in YR 2007, and consisted of fingerlings with an average FL of 77 mm.

The two noticeable weekly peaks or modes to the distribution (both YR 2007 and previous three year average) do not necessarily indicate two different runs of adult Chinook salmon entered Redwood Creek because of great differences in FL or Wt. If the modes represented two different runs of adults, we would expect the FL's during each peak to be nearly the same. In other words, if the second mode represented a different group of adult fish, then their progeny should be smaller than what was observed due to differences in redd emergence timing [later emergence than the progeny for the first group of adults, assuming (reasonably) differences in intragravel water temperatures have a negligible affect on emergence timing], and the amount of time available to gain FL or Wt in the stream [less time for growth if emerge from redds much later than the first group, assuming (reasonably) differences in water temperatures could not account for the difference in size or growth]. A more likely explanation is that the fingerlings were born near the same time as the fry but further upstream; and grew in size as they remained in the stream and as they migrated downstream to be later captured. Some of the fingerlings could also have been fry born just upstream of the trap site that temporarily resided (upstream of the trap site) prior to downstream migration.

The emigration of 0+ Chinook salmon fry in YR 2007 began near the onset of trapping, reached a small peak in mid April, and gradually diminished to low values by mid May. Fingerling migration through lower Redwood Creek in YR 2007 began in mid to late April, peaked in mid and late June, and decreased to low values by late July. 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 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. The percentage of fry in the 0+ Chinook salmon population over four years ranged from 0.1 – 15%, and averaged 4.8%. 0+ Chinook salmon fingerlings comprised the majority of the population each year, with percentages ranging from 85 – 99.9% of total abundance. In contrast, the 0+ Chinook salmon population emigrating from upper Redwood Creek consisted of nearly equal numbers of fry and fingerlings when averaged over a seven year period (YRS 2000 – 06) and in YR 2007, 46% of the 0+ Chinook salmon emigrant population passing through upper Redwood Creek consisted of fry (Sparkman 2008). Clearly areas upstream of the trap site in upper Redwood Creek are important for adult Chinook salmon spawning.

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

Healey (1991) commented that fry are not surplus or lost production that will never augment future adult populations; therefore, fry should be part of a juvenile Chinook salmon emigrant population estimate. Chinook salmon fry in both upper and lower Redwood Creek often appear smolt-like (very silvery, parr marks nearly absent or obscured to some degree by silver colored scales) and can undergo smoltification while migrating downstream from upstream spawning or rearing areas (Allen and Hassler 1986, Quinn 2005). In addition, Myers el al. (1998) summarize that ocean-type Chinook salmon fry can migrate immediately to the ocean in sizes ranging from 30 – 45 mm FL. Healey (1980), Carl and Healey (1984), Allen and Hassler (1986), and Healey (1991) also report that Chinook salmon fry can immediately migrate downstream to the estuary and ocean. Although fry to adult survival is likely less than that of fingerlings, some of the fry do survive to adulthood (Unwin 1997) and thus make a contribution to the adult population (Healey 1991). Supportive evidence of fry to adult survival is hard to find in the literature probably because most long lasting marks or tags are too big for fry, with the exception of coded wire tags (1/2 tags) and otolith marking during egg incubation. The exact reasons (environmental, genetic, or some combination thereof) why Chinook salmon fry migrate downstream so early is worthy of additional study.

In 2008, I used linear regression to investigate any relationships between average streamflow (surrogate for habitat space), average stream temperature, and seasonal 0+ Chinook population estimate on the percentage of emigrating fry each year ($n = 8$) in upper Redwood Creek (Sparkman 2008). None of the regression models were significant, and in fact, the regressions were highly non-significant ($p > 0.70$); therefore, no relationships between measured habitat variables or juvenile Chinook salmon population size on the percentage of fry in any given year were detected (ie no density-dependent relationship was detected). The mechanism for fry dispersal in upper Redwood Creek, based upon our data, could be genetic. With respect to space or habitat availability and fry movement, downstream migrant trapping in Prairie Creek offers additional support. Prairie Creek is known as a relatively pristine stream, with old growth Redwood forests, cool stream temperatures, and high degrees of habitat complexity; yet, each year, regardless of the number of adults (and egg deposition) and subsequent juvenile production, Chinook salmon fry are captured in traps every year as they migrate downstream (Roelofs and Klatte 1996; Roelofs and Sparkman 1999, Walter Duffy, pers. com. 2008).

The average size (FL) of 0+ Chinook salmon emigrants in YR 2007 was the second lowest of record; 9.6 mm less than YR 2006, 7.7 mm less than YR 2005, and 6.8 mm greater than YR 2004. Over the four consecutive years, we observed a greater average FL for 0+ Chinook salmon emigrants during years of less abundance. Whether this is indicative of a density-dependent relationship remains to be tested given more study years. However, data from trapping in upper Redwood Creek shows a density-dependent relationship such that with increasing population abundance, the average size of the emigrants decreased. Whether the larger size of emigrants during years of low abundance will compensate for (potentially) reduced recruitment to adults remains unknown.

Regardless of the average size of emigrants per study year, the average size by week increased over the study period each study year. The increases in average weekly FL and Wt during the trapping periods were influenced by the increasing percentage of fingerlings in the catch over time each year. Unwin (1985) reported a similar finding in his trapping studies in New Zealand.

The increases in weekly FL's and Wt's indicate growth was taking place within the study periods each year. The rough or group estimate of growth rate (FL, 0.36 mm/d) in YR 2007 was 0.07 mm/d greater than growth in YRS 2006 and 2004, and 0.01 mm/d less than growth in YR 2005. Whether the observed variation in growth among study years is attributable to various physical parameters (water temperature, stream discharge) of Redwood Creek remains to be tested given more study years. The growth rates (FL) observed in Redwood Creek fall within the range of juvenile Chinook salmon growth rates (range = 0.21 – 0.64 mm/d) measured in other streams (Healey 1991, Bendock 1995). Healey (1991) reported that growth of juvenile Chinook salmon migrants in the Sacramento River, CA equaled 0.33 mm/d during a particular study, and Bendock (1995) determined growth to equal 0.64 mm/d in Deep Creek, Alaska. In accord with Healey (1991), these group growth estimates should be viewed cautiously because we do not know exactly how long fry and fingerlings have been residing in the stream after emerging from redds. Although these growth rate estimates are for groups of fish and do not necessarily represent individual growth rates, they do take into account a variety of fish sizes and environmental conditions, and should be meaningful.

The estimates of travel time (in days) for recaptured pit tagged 0+ Chinook salmon smolts (n = 245) should be viewed as a maximum because the lower trap captured these fish sometime prior to when the crew checks and empties the livebox at 0900. For example, if a pit tagged fish was captured at 0200 and the crew emptied the trap's livebox at 0900, then travel time would be off by 7 hours. Travel time may also be positively biased if the juveniles resided in the stream during daylight hours and primarily migrated downstream at night (likely scenario). In contrast to travel time, travel rate should be viewed as a minimum for similar reasons; the individual's rate would be higher than what was observed if they were captured prior to checking the trap's livebox, and higher if they primarily migrated at night. Nevertheless, our experiments gave insight into individual juvenile Chinook salmon migration and growth between the two trap sites, which in turn may reflect stream habitat conditions, the salmon stock in Redwood Creek, or variable cohort behavior.

The lower trap in Redwood Cr (RM 4) captured 35% of the pit tagged 0+ Chinook salmon released at the upper trap. The recapture of pit tagged 0+ Chinook salmon per release group in YR 2007 (as well as YRS 2005 and 2006) was variable. For one release group (6/24/07, n = 58 released), seven individuals were recaptured on the same day at the lower trap (7/04/07), which suggests these fish traveled together as a group. Of the 18 release groups where recaptures occurred, 78% showed some schooling behavior; however, no release group showed complete or 100% schooling behavior. In contrast to multiple recaptures that occurred on the same day, four separate release groups had multiple recaptures (from the same release group) that occurred on different days at the lower trap. For example, six individuals from the 7/08/07 release group (n = 24) were recaptured at the lower trap anywhere from 3.5 – 29.5 d after release from the upper trap; these fish did not travel as a group. Travel time for 0+ Chinook salmon smolts in YR

2007 to migrate the 29 miles downstream ranged from 2.5 – 29.5 d, and averaged 10.7 d; average travel time in YR 2007 was higher than YR 2005 (Avg. travel time = 7.5 d) and YR 2006 (Avg. travel time = 8.0 d). On average, 0+ Chinook salmon in YRS 2005 - 2007 moved downstream to the lower trap in fewer days than 2+ steelhead trout (n = 7, range = 2 to 35 d, Avg. = 13 d) and 1+ steelhead trout (n = 9, range = 2 to 32 d, Avg. = 15 d) in YR 2004, and fewer days than 1+ steelhead trout in YR 2005 (n = 5, Avg. travel time = 12 d), YR 2006 (n = 6, Avg. = 21 d), and YR 2007 (n = 18, Avg. = 29.5 d). Thus, for the past four years, 0+ Chinook salmon traveled the 29 miles downstream in less days than juvenile steelhead trout. Travel time for 0+ Chinook salmon smolts to reach the lower trap in YR 2007 was positively related to size at time 2 (FL, Wt); however, the model left considerable amounts of variation unexplained (66%). Travel time was not related to: 1) stream temperature, 2) stream discharge, or 3) lunar phase. Smith et al. (2003) found that travel time decreased with increasing discharge for wild sub-yearling Chinook salmon in the Salmon River; however, they also state that the longest travel time occurred during the highest stream discharge.

Travel rate in YR 2007 ranged from 1.0 – 11.6 mi/d (1.6 – 18.7 km/d), averaged 4.0 mi/d (6.4 km/d), and was less than travel rate in YR 2005 (8.2 mi/d) and YR 2006 (5.5 mi/d). The upper range in travel rate in YR 2007 (18.7 km/d) for Chinook salmon fingerlings in Redwood Creek was lower than that observed in the upper Rogue River (24.0 km/d) (Healey 1991); however, the average travel rate (6.4 km/d) from upper Redwood Creek in YR 2007 was much higher than the average (1.6 km/d) put forward by Allen and Hassler (1986). Raymond (1968) found that the average travel rate for yearling Chinook salmon smolts (stream-type) in a free flowing section of the Columbia River was 24 km/d during lower river discharges and 40 km/d during moderate river discharges. We were not able to statistically model travel rate in YR 2007 using any independent variable because data failed model assumptions. The next step in analysis will be to stratify the data among the months of June and July, which may allow for data to meet model assumptions.

Healey (1991) reported results from a study in the Rogue River, Oregon in which the travel rate of spring Chinook salmon fingerlings was positively related to fish size and stream discharge in one year, and negatively related to stream discharge in the following year. Quinn (2005) reported that the rate at which 0+ Chinook salmon traveled downstream in the Columbia River was positively related to size. Achord et al. (2007) were able to determine that the variability in stream-type juvenile Chinook salmon (Age-1) travel rate among study years in the Columbia River was related to stream temperatures during Autumn and Spring, and stream discharge during March. They found that even small increases in temperature (0.325 ^{o}C for Autumn and 0.29 ^{o}C for Spring), or flow (625 cfs) would decrease the median passage date by 1 d (Achord et al. 2007). Unfortunately, there appears to be a lack of data in the literature to compare individual travel time and travel rate with our data collected on juvenile Chinook salmon (ocean-type) in Redwood Creek. Many of the studies using pit tags with juvenile Chinook salmon are within the Columbia River system, which for the most part is not comparable to Redwood Creek; Redwood Creek is much smaller in size, does not have impoundments, and the stream flow is unregulated, among other differences.

Individual growth was expressed using a variety of indices and equations to facilitate comparisons with information found in the literature. The majority of studies appear to report growth using one index or another which makes comparisons difficult if that growth index is not used in a given study. Compounding the problem of comparing data is the difficulty in finding studies that determined individual growth rates for 0+ Chinook salmon ocean-type smolts (FL > 67 mm), and in un-regulated river systems (upstream of estuaries).

In YR 2007, 73% of the 245 recaptured pit tagged 0+ Chinook salmon showed positive growth in FL, 27% showed no change in FL, 78% showed positive growth in Wt, 20% showed no change in Wt, and 2% lost Wt. Thus, the majority of Chinook salmon smolts showed growth.

Absolute growth rate (FL) in YR 2007 ranged from 0.0 – 0.76 mm/d, and averaged 0.29 mm/d. The average value (0.29 mm/d) in YR 2007 was higher than average AGR in YR 2005 (0.22 mm/d) and YR 2006 (0.24 mm/d). Average absolute growth rate (FL) in YRS 2005 - 2007 were comparable to the group growth rate for Chinook salmon fingerlings in the Nitinat River (0.21 mm/d) and about 2/3 less than the group growth rate determined in the Cowichan River (0.62 mm/d), British Columbia (Healey 1991). Koehler et al. (2006) determined that ocean-type juvenile Chinook salmon grew 0.50 – 0.67 mm/d in the littoral areas of Lake Washington, WA during March – June. Kjelson et al. (1982) *in* Koehler et al. (2006) determined the growth rate of juvenile Chinook salmon (Fall Race) in the Sacramento River equaled 0.33 mm/d. Connor and Burge (2003) reported a growth rate of 1.3 mm/d for Chinook salmon smolts in the Snake River. Weber and Fausch (2005) placed wild ocean-type Chinook salmon juveniles into enclosures along the margin of the Sacramento River and determined the average specific growth rate (Wt) over three years ranged from about 0.03 – 0.045 g/d, which was much higher than the average specific growth rate (un-scaled) we determined for Redwood Creek Chinook salmon in YR 2007 (0.01 g/d). The average absolute growth rate (FL) for recaptured pit tagged fingerlings (0.29 mm/d) in Redwood Creek was about 15% less than the group growth rate (0.34 mm/d) calculated for fry and fingerlings in YR 2007 using the average weekly FL data. However, the latter estimate includes fry (which may have a higher absolute growth rate than fingerlings) and probably is not influenced by zero growth like the average for the individual growth rates were. For example, the absolute growth rate for pit tagged Chinook salmon juveniles in Redwood Creek showing only positive growth ranged from 0.14 - 0.76 mm/d and averaged 0.402 mm/d, which was higher than the group estimate previously calculated (0.34 mm/d) by 0.062 mm/d.

The growth (Percent Change in FL and Wt) of the 245 recaptured pit tagged 0+ Chinook salmon was successfully modeled using linear regression. Models with migration variables (travel time, travel rate) explained more of the variation in growth than other variables tested, similar to data collected in YRS 2005 and 2006. Percent change in FL was positively related to travel time, and travel time explained 78% of the variation in growth; change in Wt (delta Wt) was negatively related to travel rate, and travel rate explained 66% of the variation in delta Wt. Thus, fish that took longer to reach the lower trap gained more length or weight than fish that traveled the distance in a shorter amount of time; and fish that traveled at a faster rate to the lower trap did not gain as much weight as those fish which traveled slower. This in turn suggests fish that took a longer amount of time to migrate downstream had more time to forage for food, feed, and convert the food to growth. The energy required for foraging was offset by the amount or quality of food eaten. Fish that traveled at a higher rate spent more time traveling downstream (expending energy) than foraging for food. Beamer et al. (2004) found that the growth of juvenile ocean-type Chinook salmon (in Skagit Bay) was positively related to the amount of time juveniles spent in the delta; and Achord et al. (2007) found that the growth of juvenile Chinook salmon in the Snake River was positively related to travel time.

1+ Chinook Salmon

1+ juvenile Chinook salmon (stream-type) in Redwood Creek represent the third juvenile Chinook salmon life history, and appear to be in very low abundance as evidenced by trap catches totaling less than 14 individuals in four years of trapping. No 1+ Chinook salmon were captured in YRS 2006 – 2007. Stream-type juvenile Chinook salmon are easily differentiated from ocean-type by size at time of downstream migration. The average size (FL mm) in April 2005, for example, was 113 mm for 1+ Chinook salmon and 51 mm for 0+ Chinook salmon.

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 (Stream type) because few if any spring-run Chinook salmon are observed during spring and summer snorkel surveys in Redwood Creek (Dave Anderson, pers. comm. 2008). For example, in 22^+ 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. 2007). 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.

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 report that the stream-type life history probably evolved after the ocean-type colonized (post glacial period) the rivers in study. An important question which may be unanswerable, is whether the one year old life history for juvenile Chinook salmon in Redwood Cr was more prevalent prior to the changes in the watershed associated with land use activities and flood events.

The 1+ Chinook salmon life history pattern may be important for increased ocean survival of Chinook salmon juveniles, and general species diversity (Don Chapman pers. comm. 2003, Sparkman 2006).

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 (over-seeding), 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 fish emigrate at low densities or low population levels.

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 2008). Young-of-year steelhead trout downstream migration in Redwood Creek is considered to be stream redistribution (passive and active) because juvenile steelhead 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 2008). Perhaps the most important finding with respect to 0+ steelhead trout in YR 2007 (and YR 2006) was the lower trap's recapture of 15 out of 200 individuals (Fl 40 mm – 55 mm) released from the upper trap site with partial upper or lower caudal fin clips. To the best of my knowledge, these were the first experiments to show 0+ steelhead trout may cover considerable distances while moving downstream, in this case 29 mi, in search of rearing areas.

Trap catches in YR 2007 (and YR 2006) were considerably higher than catches in YRS 2004 and 2005, and may in part reflect an increase in the total number of adult spawners upstream of the trap site. Another likely, positive influence on trap captures was setting and operating the trap in the same favorable location as in YR 2006 (75 m downstream of the location in YRS 2004 and 2005), which greatly increased the measured trapping efficiencies of other juvenile salmonids. Thus, there is a high probability that the new trap position also helped catch more of the 0+ steelhead trout downstream migration compared to previous study years. We do not perform mark/recapture experiments with 0+ steelhead trout because many are too small (FL < 35 mm) to effectively mark without harm, and therefore the population estimate would not represent the total number moving downstream, just those that are large enough to be marked. Depending upon the study year and specific months within a given study year, smaller 0+ steelhead trout can constitute a sizable fraction of the 0+ steelhead trout downstream migration and trap catch. Differences in 0+ steelhead trout trap catches among years could also be attributable to a simple change in the percentage of the total 0+ steelhead trout population (each year) that migrated downstream. For example, Johnson's data (2004) showed that the percentage of young-of-year steelhead trout fry that out-migrated compared to total post emergent fry production (out-migrants and over-summer fry and parr) over a 12 year period in the upper mainstem of Lobster Creek, Oregon varied considerably from year to year, and ranged from 20 to 85%; a similar relationship was found in East Fork Lobster Creek utilizing 13 years of data. Thus, it is possible that we had good production of young-of-year steelhead trout upstream of the trap site, and the fry and parr did not migrate downstream in any great percentage of the total production. The new trap location would not change the amount of upstream river miles (eventually passing by the trap) to any large degree because the trap was only relocated 75 m downstream of the trap's location in YRS 2004 and 2005.

The pattern of 0+ steelhead trout migration in YR 2007 showed similarities and differences between emigration in previous study years. Trap catches were low in the beginning of each study year because fry had not yet emerged from redds, or initiated downstream migration. Trap catches did not increase in any given year until late May and early June, and excluding YR 2005, weekly peaks occurred in mid to late June. Weekly peaks in catches ranged from a low of 294 in YR 2005 to a high of 10,863 in YR 2006; in YR 2007 the peak in weekly catches equaled 9,517 individuals. The most important month for downstream migration, based upon trap catches, was June for three of four study years; June accounted for up to 58% of total catches by study year. The two most important months for capturing 0+ steelhead trout were June and July for YRS 2004, 2006, and 2007, and May and July for YR 2005.

The average FL in YR 2007 was greater than YRS 2004 and 2005, and less than the average in YR 2006. However, FL differences among study years were slight to moderate (2.0 – 6.2 mm), and may not be biologically meaningful. Average weekly FL increased over time each study year and indicated growth was taking place, which in turn suggests habitat conditions and the availability of prey items were sufficient for growth. Average FL for the first three to five weeks each study years were representative of post emergent fry (FL < 35 mm), and thereafter, average FL's were more representative of the parr form which are typically larger than fry (due to growth). The estimated growth rate in YR 2007 (0.32 mm/d) was 0.04 mm/d less than growth in YR 2006, and 0.02 mm/d less than growth in YRS 2004 and 2005. Whether such differences in growth rate among years are biologically meaningful is unknown. The relationship of various physical variables (water temperature, stream discharge) on 0+ steelhead growth will be tested given more study years.

The 0+ steelhead trout captured by the lower trap indicated these fish are going to rear for some time period in lower Redwood Creek, including the estuary. Dave Anderson (pers. comm. 2008), for example, routinely captures young-of-year steelhead trout (and coho salmon) in the estuary during summer and early fall sampling; thus, the condition of lower Redwood Creek and the estuary can impact 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 were the most numerous juvenile steelhead trout migrating downstream through lower Redwood Creek in three of four consecutive study years. The ratio of 1+ steelhead trout to 0+ steelhead trout to 2+ steelhead trout was 3.0:3.4:1.0 in YR 2007, and pooling all year's data equaled 4:2:1 (same ratio as for all years averaged). On a percentage basis, 1+ steelhead trout comprised 40 – 77% of the total juvenile steelhead downstream migration each study year, and averaged 57% over the four year period.

Population emigration in YR 2007 (37,683 $\pm$ 11%) was 16% less than YR 2006, 1.15 times greater than YR 2005, and 51% less than YR 2004. The preliminary short term trend over years was negative, yet non-significant. The 1+ steelhead population emigrating from upper Redwood Creek over the past eight years are showing a significant negative trend (Sparkman 2008). Whether the smolt populations of 1+ steelhead trout passing through lower Redwood Creek are also showing a true negative trend will take more study years to statistically determine.

In addition to differences in population abundance among study years, there were temporal differences in monthly and weekly emigration. In YR 2007, most of the 1+ steelhead trout smolts emigrated during June (47% of total), compared to June (61% of total) in YR 2006, April (34%) in YR 2005 and May (43%) in YR 2004. Depending upon study year, April-May, May-June, or June-July were the two most important months for emigration. The peak in weekly emigration in YR 2007 occurred during the same week as in YR 2006, and well after peaks in YRS 2004 and 2005; for the four study years, two of the peaks occurred in June, one in late April/early May, and the other in May. Although I did not present such data, weekly population emigration in a given study year closely resembled the weekly catch distribution for that year.

The average size of 1+ steelhead trout migrants in YR 2007 (88.6 mm, 7.88 g) fell between averages for YRS 2004 – 2006, and was about 2.2 mm smaller than the largest average observed in YR 2005. Average FL (and Wt) in YR 2007 increased over time, and indicated growth was taking place. The increase over time contrasts previous year's data when average FL and Wt did not change over time. Average weekly FL and Wt in YR 2007 was not statistically different than previous study years, however, averages in FL and Wt in YR 2005 were significantly greater than average FL and Wt in YR 2004.

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 (0.1 - 0.5%), and indicated that few 1+ steelhead trout migrated downstream in a stream-residence form (parr). In contrast, the majority of 1+ steelhead trout (68 – 86%) in a given study year were emigrating in a smolt stage. The percentage of 1+ steelhead trout showing smolt characteristics (77%) in YR 2007 was slightly greater (by 0.7 percentage points) than for the previous three year average; and statistical significance was not detected. 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 in upper Redwood Creek were positively related to stream discharge ($n = 7$, $p < 0.05$), and negatively related to water temperatures ($n = 7$, $p < 0.05$) (Sparkman 2007). 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. 2007) 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. 2007). 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), and 2006 (n = 246). Each 2+ steelhead trout captured by the traps were inspected for marks and scanned for pit tags, which were 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 adequate based upon a study by Newby et al. (2007).

The lower trap in Redwood Creek captured 3.7% of the pit tagged 1+ steelhead trout released at the upper trap in Redwood Valley. The time required to travel 29 miles downstream in YR 2007 ranged from 3.5 – 55.5 d, and averaged 29.5 d. Average travel time in YR 2007 was greater than average travel times in YRS 2006 (Avg. = 21 d), 2005 (Avg. = 12 d), and 2004 (Avg. = 15 d), with significant differences between YR 2007 and YR 2005. Travel time in YR 2007 was significantly related to lunar phase (+), stream discharge (+), and stream temperature (-). The negative relationship of temperature on travel time indicated that 1+ steelhead trout migrated downstream in less time when temperatures increased, which suggests the smolts were migrating downstream to avoid higher stream temperatures. The best model for travel time included both lunar phase and stream discharge, and was able to explain 51% of the variation in travel time. Travel rate (mi/d) in YR 2007 ranged from 0.5 – 8.3 mi/d, averaged 1.6 mi/d, and was significantly less than travel rate in YR 2005. Travel rate (transformed) was negatively related to lunar phase, which indicates that under higher moon illuminations, 1+ steelhead trout smolts probably spent more time feeding than migrating downstream.

Most (94%) of the 1+ smolts in YR 2007 showed positive growth, and on average gained 15 mm and 3.8 g. Travel time explained more of the variation in individual growth (delta FL, Wt; percent change in FL, Wt) than other variables tested, and was able to account for 85% of the variation in delta FL. However, lunar phase explained more of the variation in growth rate indices (AGR, SGRsc, RGR, etc) than other variables. All growth indices were positively related to travel time, stream discharge, and lunar phase, and negatively related to travel rate and water temperature. The positive relations indicate that 1+ smolts grew more when: 1) travel time increased, 2) stream discharge was higher, and 3) moon illuminations were higher. Thus, 1+ smolts delayed migration during higher stream discharges and higher moon illuminations in order to spend more time feeding. The negative relations indicate 1+ smolts decreased growth when: 1) traveling at a higher rate, and 2) stream temperatures increased. The negative relationship of growth and increasing stream temperatures is important because this supports the USEPA decision to list Redwood Creek as temperature impaired: we have direct evidence that high stream temperatures are negatively influencing 1+ steelhead trout growth.

As previously mentioned, far more 1+ steelhead trout emigrated past the lower trap than older, juvenile steelhead trout age-classes (2+). 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. 2006, among many others). However, the ratio of 1+ steelhead trout to 2+ steelhead trout (near 4:1 each study year) 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 (n = 10) collected in Redwood Creek, 30% of the adults entered the ocean as one-year-old juveniles; the most successful juvenile steelhead migrants to reach adulthood were 2+ steelhead trout. CDFG AFRAMP is currently collecting scale samples from adult steelhead 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 (Sparkman, 2007b, study 2i3) 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 that 1+ smolts are entering the ocean at age-1. I hypothesize that 1+ (and 0+) steelhead trout have changed their life history in Redwood Creek to limit the time spent in freshwater in order to avoid high, and at times, lethal stream temperatures. In YR 2006 we observed and documented lethal stream temperatures in upper Redwood Creek. Over-summer conditions in Redwood Creek could be limiting the production of older age class production (2+ 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 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 66 - 73%) than 1+ steelhead trout smolts in any given study year. With respect to the combined population of 1+ and 2+ steelhead trout emigrants each year, 2+ steelhead trout comprised 20 – 25% of the population.

The population abundance of 2+ steelhead trout in YR 2007 was slightly higher than YR 2006, much higher than YR 2005, and much less than YR 2004. The preliminary short term trend over years was negative, yet non-significant ($p > 0.10$). The 2+ steelhead trout population emigrating from upper Redwood Creek over the past eight years are showing a significant negative trend (Sparkman 2008). Whether the populations of 2+ steelhead trout smolts passing through lower Redwood Creek are also showing a true negative trend will take more study years to statistically determine.

Confidence intervals (and percent error) for the population 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 size for marking and subsequent recapture was lower. During the trapping period we routinely adjust trap configuration and install weir panels to increase the capture efficiency of 2+ steelhead trout. Additionally, we perform numerous mark/recapture trials, and when combined with altering trap configuration and paneling, are then able to produce a reliable population estimate.

In addition to differences in population abundance among study years, there were temporal differences in monthly and weekly emigration. In YR 2007, most of the 2+ steelhead trout smolts emigrated during June (61% of total), compared to June (56% of total) in YR 2006, May (43%) in YR 2005 and May (62%) in YR 2004. Depending upon study year, April-May, May-June, or June-July were the two most important months for emigration. Patterns in emigration in YRS 2006 and 2007 were unlike YRS 2004 and 2005 because more of the population emigrated during the middle of the trapping periods. For example, peak emigration in YRS 2006 and 2007 occurred in June, compared to late April/early May in YRS 2004 and 2005. Although I did not present such data, weekly population emigration in a given study year closely resembled the weekly catch distribution for that year. The pattern of 2+ steelhead trout migration by week in each study year, excluding YR 2004, was markedly similar to the pattern for 1+ steelhead trout population emigration, and may indicate these two age classes traveled downstream together in schools. Data collected at the upper trap also shows that the two age classes appear to have very similar weekly migration patterns (Sparkman 2008).

Average FL and Wt of 2+ steelhead smolts showed little variation each study year; the greatest difference between any two years was 4.1 mm and 2.8 g. Such small differences are unlikely to have biological meaning unless they affect survival to adulthood, which seems doubtful. The patterns in average weekly FL and Wt were surprisingly similar among study years. For each year, the average size was highest (except for YR 2005) in the beginning of the study, then decreased to the middle of the study period, and then increased until the end of the study. 2+ steelhead trout from upper Redwood Creek also exhibited this weekly pattern in size over a eight year study period (Sparkman 2008). The decrease in average FL and Wt by week during study year 2007 is typical of 2+ smolts in lower and upper Redwood Creek, and is not unusual because larger smolts frequently migrate earlier in the emigration period compared to smaller smolts (Quinn 2005). 2+ steelhead trout smolts in the nearby Mad River, Humboldt County, California also emigrated at a larger size in the beginning of the migration period (Sparkman 2002).

The percentage of 2+ steelhead trout showing parr characteristics was zero each study year, and indicated that 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 (93.9%) in YR 2007 was less than previous years, however, the greatest difference among any study year was 4.4 percentage points. In YR 2007 6.1% of the 2+ steelhead trout were classified as pre-smolts, compared to 3.2% for the previous three year average. Although the percentages of smolt and pre-smolts in YR 2007 were significantly different than the previous three year average (more pre-smolts and less smolts in YR 2007), such differences are unlikely to be biologically meaningful because the 2+ pre-smolts in YR 2007 could easily change to smolts when entering or residing in the estuary.

My latest analysis of trapping data (n = 8 years) in upper Redwood Creek showed that smolt percentages in a given year were negatively related to 2+ steelhead trout population size, and negatively related to stream temperature (Sparkman 2008). 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 shows that 62% of the variation in smolt percentages over eight study years can be attributed to the variation in stream temperatures (Sparkman 2008). 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 lower trap in Redwood Creek (RM 4) has consistently captured efficiency trial fish each study year. Additionally, 2+ steelhead trout from upper Redwood Creek have been observed in the estuary of Redwood Creek every year since the beginning of our smolt trapping studies (Dave Anderson, pers. comm. 2008). 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. The time required for one 2+ steelhead trout released from upper Redwood Creek to travel to the trap in lower Redwood Creek equaled 7 d in YR 2005; in YR 2004, the time required to travel from the upper trap to the lower trap ranged from 2 – 35 d, and averaged 13 d (n = 7); and in YR 2007 travel time for one pit tagged 2+ steelhead trout was 18.5 d. Although sample size was very small in YR 2007, 2+ steelhead trout are growing as they migrate downstream; the individual in YR 2007 grew 12 mm (9.6% change) and 5.1 g (23.4% change). Future trapping efforts will try to increase the sample size of recaptured 2+ steelhead trout for travel time experiments by increasing the sample size of releases from upper Redwood Creek.

Although there seems to be few studies that specifically look at steelhead smolt to adult survival, steelhead life history studies in a British Columbia stream (Keogh River) show there is a positive linear relationship between out-migrating 2+ smolts and returning adult steelhead (Ward and Slaney 1988, Ward 2000, Ward et al. 2002). Ward (2000) cites other authors who report similar positive linear relationships between smolts and adults along the British Columbia coast as well (eg Smith and Ward 2000). Survival from smolt to adult can be variable, and may range from an average of 15% (during 1976-1989) to an average of 3.5% (during 1990-1995) (Ward 2000). Ward and Slaney (1988), reporting on data from the Keogh River for 1978 – 1982 cohorts, determined survival from smolt to adult ranged from 7% to 26%, and averaged 16%. Meehan and Bjornn (1991) reported steelhead smolt to returning adult survival can be a relative high ranging from 10 – 20% in streams that are coastal to a low survival of 2% in streams where steelhead must overcome dams and travel long distances to reach spawning grounds. It is difficult to make specific inferences about 2+ steelhead 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 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 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. Catches in YR 2007, for example, equaled 44 (highest value in 4 consecutive years); catches in YR 2006 equaled 36; catches in YR 2005 equaled 9; and in YR 2004 catches equaled 37. Cutthroat trout catches over four years (126 individuals) were about 99.9% less than total juvenile steelhead trout catches (119,147individuals).

A high percentage of the catch in YR 2007 occurred in July (48% of total), as did catches in YR 2006 (50% of total). In YR 2004 the most important month was May (49% of total), and in YR 2005 there was no discernable peak month because the months of April – May each accounted for 22% of the total catch. For the second time in the our monitoring program in Redwood Creek, we performed mark/recapture trials with cutthroat trout to determine the population size of emigrating cutthroat trout aged-1 and older. We found that a very low number (N = 85) of cutthroat trout (at the population level) migrated downstream in YR 2007. Uncertainty to the point estimate was estimated at 33%, which is most likely due to small sample sizes for capture and subsequent mark/recapture experiments. The low trap catch and population estimate was not due to poor trapping efficiencies because the average weekly trapping efficiency was 34%. An obvious obstacle to determining population estimates with lower error terms occurs when any given species at age are in low numbers. In these cases, it may be more useful to think of the estimate in terms of the upper confidence interval; such that we are 95% sure that the estimate is below this value (UCL = 113 individuals for cutthroat trout). Whether the estimate is 85 or 113 isn’t as important, in this case, as knowing that very low numbers are emigrating from the majority of the Redwood Creek basin, upstream of the confluence with Prairie Creek. Similar to juvenile coho salmon, the Prairie Creek basin is probably the biggest contributor to cutthroat trout populations in Redwood Creek based upon this study, and various studies in Prairie Creek (Walter Duffy, pers. comm. 2008).

Most of the cutthroat trout passing through lower Redwood Creek emigrated during June and July, which accounted for 92% of the total population estimate in YR 2007, and 88% in YR 2006. All cutthroat trout that were captured were in a smolt stage. An unknown number or percentage of cutthroat trout will residualize in the stream for varying years, and not out-migrate to the estuary and ocean; thus the low trap catches (and population estimate) may not necessarily reflect a low population size in Redwood Creek. However, if there were large numbers present, we would probably catch much more than we do, as they re-distribute or migrate downstream. For example, juvenile salmonid trapping efforts in Prairie Creek consistently capture hundreds of cutthroat trout during spring/early summer as they migrate downstream (Roelofs and Klatte 1996, Roelofs and Sparkman 1999, Walter Duffy, pers. comm. 2008).

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 older juvenile steelhead trout (1+ and 2+) migrated through lower Redwood Creek than cutthroat trout as evidenced by trap catches. In the four study years, for example, the ratio of 1+ and 2+ steelhead trout combined catches to cutthroat trout catches each year ranged from 197:1 to 272:1, and averaged 223:1. In other words there was, on average, 223 times more 1+ and 2+ steelhead trout (combined) captured than cutthroat trout. Ratios are even higher when juvenile steelhead trout population (1+ SH, 2+SH) data was used instead of catch data (YR 2006, 588 1+ and 2+SH:1 cutthroat trout; YR 2007, 592 1+ and 2+ SH: 1 cutthroat trout); thus it seems very unlikely that low numbers of cutthroat trout could produce a significant portion of the juvenile trout captures. Therefore, we considered the percentage of 0+ cutthroat trout included in the 0+ steelhead trout catch to be low and negligible.

We used three characteristics to identify coastal cutthroat trout: upper maxillary that extends past the posterior portion of the eye, slash marks on the lower jaws, and hyoid teeth; spotting is 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 not observed any hybrids in the four 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 (Sparkman 2008).

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.

Few 0+ coho salmon were captured by the trap in lower Redwood Creek in four consecutive study years (total catch = 656 individuals). 0+ coho salmon were captured in every month of each study year; the most important month for trap catches was June in YR 2007 (47% of total), June (33% of total) in YR 2006, July in YR 2005 (38%), and July (35%) for YR 2004. The low catches of 0+ coho salmon in lower Redwood Creek is contrasted by often high catches in Prairie Creek. For example, trap catches of 0+ coho salmon in 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).

In YR 2007 we successfully determined the population size of emigrating 0+ coho salmon for the second time during our monitoring studies. The population estimate equaled 1,057 individuals in YR 2007, and 508 in YR 2006; monthly population peaked in June (54% of total) in YR 2007, and June (45% of total) in YR 2006. The total population estimates were very low, and indicated that relatively few young-of-year coho salmon were emigrating through lower Redwood Creek, upstream of the confluence with Prairie Creek.

The average size of 0+ Coho migrants in YR 2007 was greater than averages in previous study years. The greatest difference among years was 5.6 mm, and 0.45 g; whether these differences are biologically meaningful is unknown. Growth in YR 2007 from 6/11 – 8/5 equaled 0.34 mm/d, which was comparable to the group growth rate for 0+ Chinook salmon (0.35 mm/d) in YR 2007, and 0.32 mm/d for 0+ steelhead trout in YR 2007. Average weekly FL and Wt significantly increased over each study period, and showed growth was taking place.

0+ coho salmon migrating through lower Redwood Creek indicate that these fish were moving downstream to rear. If the young-of-year coho 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.

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 four years equaling less than 215 individuals. Similar to 0+ coho salmon, the low catches of 1+ coho salmon in lower Redwood Creek was contrasted by much higher catches in Prairie Creek. For example, trap catches of 1+ coho salmon in Prairie Creek from 1996 – 1999 ranged from 1,475 – 2,302, and averaged 1,965 per trapping season (Roelofs and Sparkman 1999). 1+ coho salmon in Redwood Creek had the most restricted temporal pattern to migration, such that few migrated downstream after June 10. The majority of catches occurred in May for any given study year, with weekly peaks occurring in late April/early May, May, or late May/early June.

The population of 1+ coho salmon in YR 2007 was the lowest of the four consecutive years, and 73% less than the previous three year average. As expected, the short term trend over the four years was negative, yet non-significant ($p > 0.10$). Similar to catch data, monthly population emigration peaked in May each study year, and May also accounted for the majority of emigration (ranged from 56 – 79% of total) each year. Population estimates for 1+ coho salmon should be viewed cautiously (due to relatively large error terms, 48 - 69%), and the proper context could be that we are 95% sure that the population during either study year was less than 900 individuals (upper 95% CI for YR 2004 estimate). Population abundances of less than 900 individuals can be considered very low (alarmingly so), particularly for a stream the size of Redwood Creek. Weekly population estimates peaked 5/21 – 5/27 in YR 2007, 6/4 – 6/10 in YR 2006, 5/7 – 5/13 in YR 2005, and 4/30 – 5/6 in YR 2004. Weekly population emigration in YRS 2004 - 2007 closely resembled the catch distribution each year.

The average size of 1+ coho salmon in four study years showed little variation, the greatest difference among years was 4.5 mm and 1.3 g. The average size in YR 2007 was lower than previous years, however, potential growth in the estuary could make up for any differences in size.

The reason(s) for the lack of sufficient numbers of 1+ coho salmon 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 (CDFG 1995). Although not in large numbers, pink salmon have been historically observed in the San Lorenzo River, Sacramento River and tributaries, Klamath River, Garcia River, Ten Mile River, Lagunitas River, Russian River, American River, Mad River, and once in Prairie Creek, which is tributary to Redwood Creek at RM 3.7. Pink salmon were observed spawning in the Garcia River in 1937, and the Russian River in 1955 (CDFG 1995). 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).

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. It is hard to say if the parents of the pink salmon were stays 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 CDFG, pink salmon are considered to be "probably extinct" in California (CDFG 1995). However, the HCPB does state that "more efforts need to be conducted to prove (or disprove) that reproducing populations exist anywhere in California" (CDFG 1995). Based upon our trapping data in upper and lower Redwood Creek, it appears that 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), steelhead trout (at least three age classes), coho salmon (two age classes), and cutthroat trout (one year old and older). The abundance of 0+ Chinook salmon and 2+ steelhead trout in YR 2007 was greater than abundance in YRS 2006 and 2005, and less than abundance in YR 2004; 1+ steelhead trout abundance in YR 2007 was greater than abundance in YR 2005, yet less than abundance in YRS 2004 and 2006; and 1+ coho salmon abundance in YR 2007 was lower than YRS 2004 – 2006. 0+ steelhead trout catches in YR 2007 were much higher than previous study years, which could be attributable to: 1) an increase in adult numbers upstream of the trap site, 2) higher trapping efficiency in YR 2007, 3) difference in the percentage of 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 were captured at the lower trap for the second consecutive year, which 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 must be rearing in reaches below RM 4 and in the estuary, thus lower Redwood Cr and the estuary are also important for young-of-year fish, in addition to older, juvenile age classes.

The preliminary population trend of 0+ Chinook salmon, 1+ steelhead trout, 2+ steelhead trout, and 1+ coho salmon over the four study years was non-significantly negative for each species at age. The population abundance of 0+ Chinook salmon in YRS 2004 – 07 occurred in years with peak streamflows capable of redd scour, which occur about every 1.2 years. Given enough study years, we are certain to determine abundance in years without scouring streamflows. 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 (1 year old). The number of 1+ coho salmon emigrating from areas upstream of the trap site was alarmingly low each study year (< 900 individuals). We determined population estimates for emigrating 0+ coho salmon and cutthroat trout (age-1 and older) for the second time in the salmonid monitoring history of Redwood Creek; each estimate showed very low abundances in YRS 2006 and 2007.

Most of the 0+ Chinook salmon, 1+ steelhead trout, and 2+ steelhead trout migrated downstream during May and June in YR 2007. Currently 1+ and 2+ steelhead trout appear to migrate downstream together, based upon weekly catch and population distributions. Most of the 0+ coho salmon migrated downstream during June and July in YRS 2006 and 2007, which contrasts the migration of 1+ coho salmon. 1+ coho salmon migrated downstream in larger numbers during May and June in YR 2007,; and by mid to late June emigration ceased. Cutthroat trout migrated downstream in greater numbers in June and July in YRS 2006 and 2007.

The population of 0+ Chinook salmon emigrants in YR 2007 (as well as previous years) consisted of both fry and fingerlings, with far more fingerlings emigrating than fry. The first smaller peak, and the second and third larger peaks (one for fry, the other two for fingerlings) in 0+ Chinook salmon migration (separated by nine and eleven weeks) in YR 2007 do not indicate two distinct runs of adult Chinook salmon spawned in Redwood Creek because of vast differences in the average size of migrants in each peak. The larger migrants associated with the second and third peak were likely to have been fry born at the same time as the fry that made up the first peak that reared for a longer time in the stream prior to capture.

Pit tagged 0+ Chinook salmon and 1+ steelhead trout released from upper Redwood Creek were recaptured 29 miles downstream at the second trap in lower Redwood Creek for the third, consecutive study year. Travel time for 0+ Chinook salmon in YR 2007 (n = 245 recaptures) ranged from 2.5 – 29.5 d, averaged 10.7 d, and was greater on average than travel time in YRS 2005 and 2006. Travel time in YR 2007 was positively related to size (FL, Wt) at time of recapture (Time 2). 0+ Chinook salmon travel rate in YR 2007 ranged from 1.0 – 11.6 mi/d, and averaged 4.0 mi/d. I could not successfully model travel rate because model assumptions were not met. Given the high number of recaptures (n = 245), I may be able to model travel rate by stratifying the data by month. Average travel rate in YR 2007 was less than averages for YRS 2005 and 2006. The recapture of pit tagged 0+ Chinook salmon per release group was variable. Individuals from the same release group were recaptured on the same day and in contrast, multiple recaptures from the same release group could be on different days. The greatest range in travel time for multiple recaptures from a single release group was 26 days.

Travel time for 1+ steelhead trout (n = 18 recaptures) in YR 2007 ranged from 3.5 – 55.5 d, averaged 29.5 d, and was greater than YRS 2005 and 2006; travel rate in YR 2007 was less than YRS 2005 and 2006. The best model for describing travel time included lunar phase and average stream discharge; both lunar phase and stream discharge had a positive relationship with travel time. Travel time was also inversely related to stream temperatures, which suggests 1+ steelhead smolts were migrating at a faster rate in order to avoid higher stream temperatures encountered during downstream migration. Travel rate (transformed) was also inversely related to lunar phase. Neither travel time or travel rate were related to the size of the smolt in YR 2007.

Most (73%) of the recaptured pit tagged 0+ Chinook salmon showed positive growth in FL, and 79% showed positive growth in Wt. Twenty-seven percent showed no change in FL, 19% showed no change in Wt, and about 2% lost Wt. Growth was positively related to travel time, and negatively related to travel rate. Based upon three years of consecutive data, the main working hypothesis concerning 0+ Chinook salmon smolts and growth in Redwood Creek is that fish grow more when they take more time to migrate downstream. By taking more time to migrate downstream, the fish have more time to forage for food and convert the food to growth.

Most (94%) of the recaptured pit tagged 1+ steelhead trout smolts showed positive growth in FL, and 89% showed positive growth in Wt. Six percent showed no change in

FL, and 11% showed no change in Wt. Growth in YR 2007 was greater than growth in YR 2006, and data from both years showed significant relationships with travel time (+) and travel rate (-). In YR 2007, 1+ steelhead trout growth was also related to stream discharge (+), lunar phase (+), and stream temperature (-). The relationship of increasing stream temperatures and reduced growth rates offers direct biological, supporting evidence for listing Redwood Creek as sediment and temperature impaired by the USEPA. Our data showed stream temperatures negatively affected growth, which in turn may prevent 1+ steelhead trout from attaining a size that was more favorable for survival to adulthood. Additionally, stream temperatures during summer months may increase the level of stress for a given individual, thus minimizing the amount of energy left for growth. Although steelhead trout smolts showed reduced growth rates with increasing stream temperatures, there is the chance for 1+ steelhead trout to gain additional size in the estuary, given that the estuary is able to at least temporarily support groups of 1+ steelhead trout smolts prior to ocean entry. Past and current research and monitoring of juvenile salmonid populations in the estuary by Redwood National Park (David Anderson, pers. comm. 2008) should provide pertinent information. To date, it appears that the estuary is a main limiting factor to anadromous salmonid survival and growth in Redwood Creek. Future fisheries work in Redwood Creek will address these issues 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 in order to provide a basin wide perspective on fisheries in Redwood Creek (author, Walter Duffy pers. comm. 2008, and David Anderson, pers. comm. 2008).

RECOMMENDATIONS

This study is one of the few studies that is designed to document smolt abundance and population trends of the California Coastal Chinook salmon ESU, Southern Oregon/Northern California Coasts Coho salmon ESU, Northern California Steelhead Trout ESU, and Southern Oregon/California Coasts Coastal Cutthroat Trout ESU over a relatively long time period. With respect to the Chinook salmon ESU 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 (10+) 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.

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

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

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

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

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

ACKNOWLEDGEMENTS

I thank the California Department of Fish and Game AFRAMP and the Fisheries Restoration Grant Program (Project No. P0610531) for funding this study. I would also like to thank the California Cooperative Fishery Research Unit, Humboldt State University Foundation, and CDFG AFRAMP for their assistance in managing the grant contract. I am particularly thankful to Joe Hufford for access to his property, and for his continued interest in salmon and steelhead in Redwood Creek. I thank Don Chapman for his interest in the study and for his helpful comments. I would also like to thank Catherine Stone for her constructive review. Lastly, and by no means in the least, I thank the dedicated field crew (Becky Dutra, Paula Whitten, Bret Diehl, Rod Park, Jason Crews, Luke Walker, among others) who counted and examined every fish we captured and marked, for removing debris from the livebox in the evenings and nights, for releasing marked fish upstream of the trap site at night, for helping me monitor the trap during high flow events, and for their positive attitudes.

LITERATURE CITED

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

Beamer EM, and K Larson. 2004. The importance of Skagit Delta habitat on the growth of wild ocean-type Chinook in Skagit Bay: implications for delta restoration. Web page:http://www.skagitcoop.org/Importance%20of%20delta%20rearing%20on%20bay%20growth.pdf, 6 p.

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

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

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

Busacker GP, IRA R Adelman, and EM Goolish. 1990. Growth. Pages 363 – 387 *in* CB Schreck and PB Moyle, editors. Methods in Fish Biology. American Fisheries Society, Bethesda, Maryland.

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

Cannata S, R Henly, J Erler, J Falls, D McGuire, and J Sunahara. 2006. Redwood Creek watershed assessment report. Coastal Watershed Planning and Assessment Program and North Coast Watershed Assessment Program. California Resources Agency and California Environmental Protection Agency, Sacramento, CA. 166 p.

Carl LM, and MC Healey. 1984. Differences in enzyme frequency and body morphology among three juvenile life history types of Chinook salmon (*Oncorhynchus tshawytscha*) in the Nanaimo River, British Columbia. Canadian Journal of Fisheries and Aquatic Sciences 41:1070-1077.

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

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

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

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

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

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

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

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

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

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

Federal Register. 1999a. Endangered and Threatened Species: Threatened status for two Chinook Salmon Evolutionarily Significant Unit in California. Final Rule. Federal Register, Washington D.C. 64: 50933 – 50415.

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

Federal Register. 2000. Endangered and Threatened Species: Threatened status for one steelhead Evolutionarily Significant Unit in California. Federal Register, Washington D.C. 65: 36704 – 36094.

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

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

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

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

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

Healey MC. 1980. Utilization of the Nanaimo River estuary by juvenile Chinook salmon, *Oncorhynchus tshawytscha*. Fishery Bulletin Vol. 77, No. 3, 653-668.

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

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

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

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

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

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

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

Madej MA, C Currens, V Ozaki, J Yee, and DG Anderson. 2006. Assessing possible thermal rearing restrictions for juvenile coho salmon (*Oncorhynchus kisutch*) through thermal infrared imaging and in-stream monitoring, Redwood Creek, California. Canadian Journal of Fisheries and Aquatic Sciences 63:1394-1396.

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

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

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

McCubbing D, and B Ward. 2003. Adult steelhead trout and salmonid smolt migration at the Keogh River, B.C., during winter and spring 2003. Habitat Conservation Trust Fund, Contract Number: CBIO4051. Province of British Columbia, Ministry of Water, Land, and Air Protection, Biodiversity Branch, Aquatic Ecosystem Science Section, Vancouver, B.C. 51 p.

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

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

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

Murphy ML and WR Meehan. 1991. Stream ecosystems. Pages 17-46. in WR Meehan (ed). Influences of forest and rangeland management on salmonid fishes and their habitats. Special Publication 19, American Fisheries Society. Bethesda, MD.

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

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

Negus, MT. 2003. Determination of smoltification in juvenile migratory rainbow trout and Chinook salmon in Minnesota. North American Journal of Fisheries Management 23:913-927.

Nickelson TE. 1986. Influences of upwelling, ocean temperature, and smolt abundance on marine survival of coho salmon (*Oncorhynchus kisutch*) in the Oregon production area. Canadian Journal of Fisheries and Aquatic Sciences 43:527-535.

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

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

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

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

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

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

___________________________________. 2007. Redwood Creek Watershed Analysis. In house data.

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

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

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

Rowe TA. 2003. Downstream Migrant Trapping Report: Horse Linto Creek and Willow Creek. U.S.D.A. Forest Service, Lower Trinity Ranger Station, Willow Creek, California, USA.

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

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

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

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

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

Smith SG, WD Muir, EE Hockersmith, RW Zabel, RJ Graves, CV Ross, WP Connor, and BD Arnsberg. 2003. Influence of river conditions on survival and travel time of Snake River subyearling Fall Chinook Salmon. North American Journal of Fisheries Management 23:939-961.

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

Solazzi MF, SL Johnson, B Miller, T Dalton, and KA Leader. 2003. Salmonid Life-Cycle Monitoring Project 2002 Monitoring Program Report Number OPSW-ODFW-2003-2, Oregon Department of Fish and Wildlife, Portland, Oregon; 25 p.

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

Sparkman MD. 1997. Fry emergence and gravel permeability of Chinook (*Oncorhynchus tshawytscha*) and coho salmon (*O. kisutch*) spawning redds in Prairie Creek, Humboldt County, CA. Senior thesis, Humboldt State University, Fisheries Program, Arcata, CA. 50 pps.

____________ 2002. Mad River juvenile steelhead downstream migration study, Humboldt County, Ca. CDFG S-RAMP, 2002 Annual report, project 2a3:32 p.

____________ 2004a. Upper Redwood Creek juvenile salmonid downstream migration study, study year 2003. California Department of Fish and Game, Anadromous Fisheries Resource Assessment and Monitoring Program. Annual Report 2003, study 2a5: 89 p.

____________ 2004b. Negative influences of predacious, egg-eating worms (*Haplotaxis ichthyophagous*) and fine sediments on coho salmon, (*Oncorhynchus kisutch*), in natural and artificial redds. Master's thesis. Humboldt State University, Arcata, CA. 55 pps.

____________ 2006. Upper Redwood Creek juvenile salmonid downstream migration study, a five-year summary report. California Department of Fish and Game, Anadromous Fisheries Resource Assessment and Monitoring Program. Annual Report 2i4: 87 p.

____________ 2007. Upper Redwood Creek juvenile salmonid (smolt) downstream migration study, study year 2006. California Department of Fish and Game, Anadromous Fisheries Resource Assessment and Monitoring Program, 2006 Annual Report, 2a5: 131 p.

____________ 2008. Upper Redwood Creek juvenile salmonid (smolt) downstream migration study, study year 2007. California Department of Fish and Game, Anadromous Fisheries Resource Assessment and Monitoring Program, 2006 Annual Report, 2a5: 136 p.

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

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

Teel DJ, GB Milner, GA Winans, and WS Grant. 2000. Genetic population structure of life history types in Chinook Salmon in British Columbia, Canada. Transactions of the American Fisheries Society 129:194-209.

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

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

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

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

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

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

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

[USGS] United States Geological Service. 2007. Surface water data for California: monthly streamflow statistics. Web page *http://water.usgs.gov/ca/nwis/monthly?*

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

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

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

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

Ward BR, PA Slaney, AR Facchin, and RW Land. 1989. Size-based survival in steelhead trout (*Oncorhynchus mykiss*): back-calculated lengths from adults' scales compared to migrating smolts at the Keogh River, British Columbia. Canadian Journal of Fisheries and Aquatic Sciences Vol. 46, pgs 1853-1858.

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

PERSONAL COMMUNICATIONS

Anderson, David. 2000 - 2008. Redwood National and State Parks, Fisheries Biologist, Orick, California.

Chapman, Don W. 2000 - 2008. McCall, Idaho.

Chesney, Bill. 2006. California Department of Fish and Game, Associate Fisheries Biologist, Yreka, Ca.

Duffy, Walter G. 2008. California Cooperative Fishery Research Unit Project Leader, U.S. Geological Survey, Humboldt State University, Arcata, CA.

Holden, Baker. 2005. Redwood National and State Parks, Fisheries Biologist Orick, CA.

Law, Phil. 2003. California Department of Fish and Game, Biometrician, Belmont, CA.

Madej, Mary Ann. 2005 - 2008. United States Geological Survey, Research Geologist, Arcata, CA.

Monday, Scott. 2004. California Department of Fish and Game, Fisheries Biologist, 1031-A South Main St, Ft. Bragg, CA. 95437

O'Neil, Christine. 2007. Hydrologic technician, United States Geological Survey, California Water Science Center.

Ozaki, Vicki. 2004 - 2007. Redwood National Park Service, Geologist. Arcata, CA. 95519.

Peters, Charlotte. 2001. Redwood Creek Watershed Map. Information Services, California Department of Fish and Game, Eureka, CA.

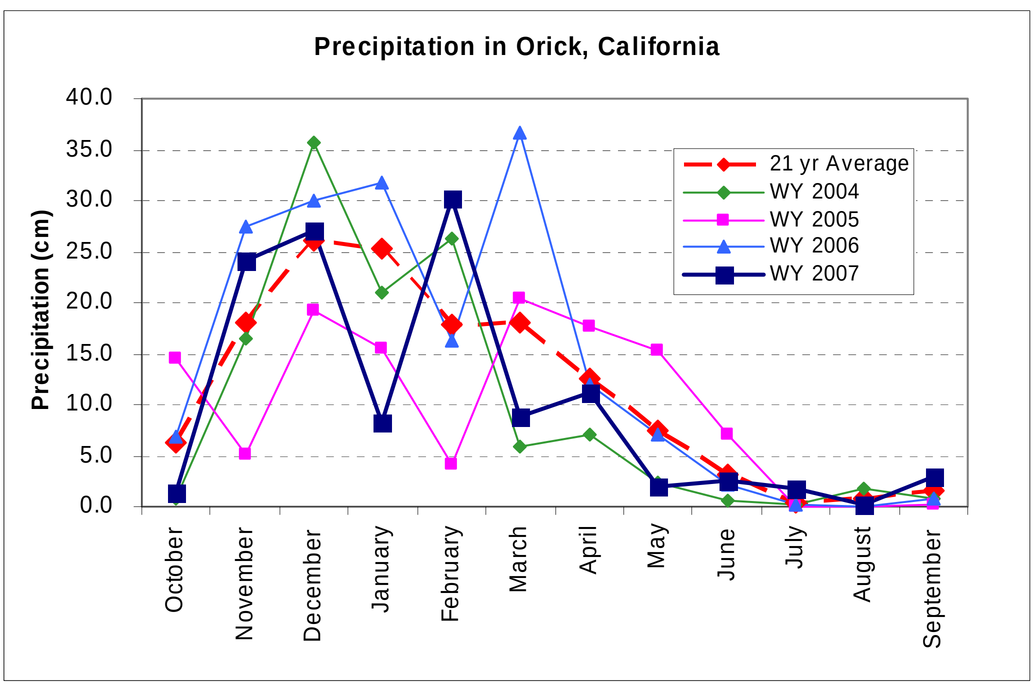
Stover, Marlin. 2000. Upper Redwood Creek long time resident and property owner. Redwood Valley, Humboldt County, California.

APPENDICES

Appendix 1. Comparison of 21 year average rainfall (cm) (Historic) with average rainfall in WYS 2004 – 2007, lower Redwood Creek, Humboldt County, CA.

	Monthly Precipitation (cm)*				
Month	Historic	YR 2004	YR 2005	YR 2006	YR 2007
October	6.2	0.8	14.4	6.8	1.4
November	18.0	16.5	5.1	27.5	24.2
December	26.1	35.8	19.2	30.0	27.1
January	25.4	21.0	15.5	31.8	8.2
February	17.8	26.3	4.1	16.3	30.3
March	18.1	5.9	20.3	36.6	8.7
April	12.5	7.1	17.6	11.9	11.2
May	7.5	2.4	15.3	7.0	2.0
June	3.2	0.5	7.0	2.2	2.5
July	0.5	0.1	0.0	0.1	1.7
August	0.8	1.8	0.0	0.0	0.1
September	1.5	0.7	0.2	0.8	2.9
Total:	137.7	119.0	118.8	171.0	120.5
Average:	11.5	9.9	9.9	14.2	10.0
SEM**	2.7	3.5	2.3	4.0	3.2

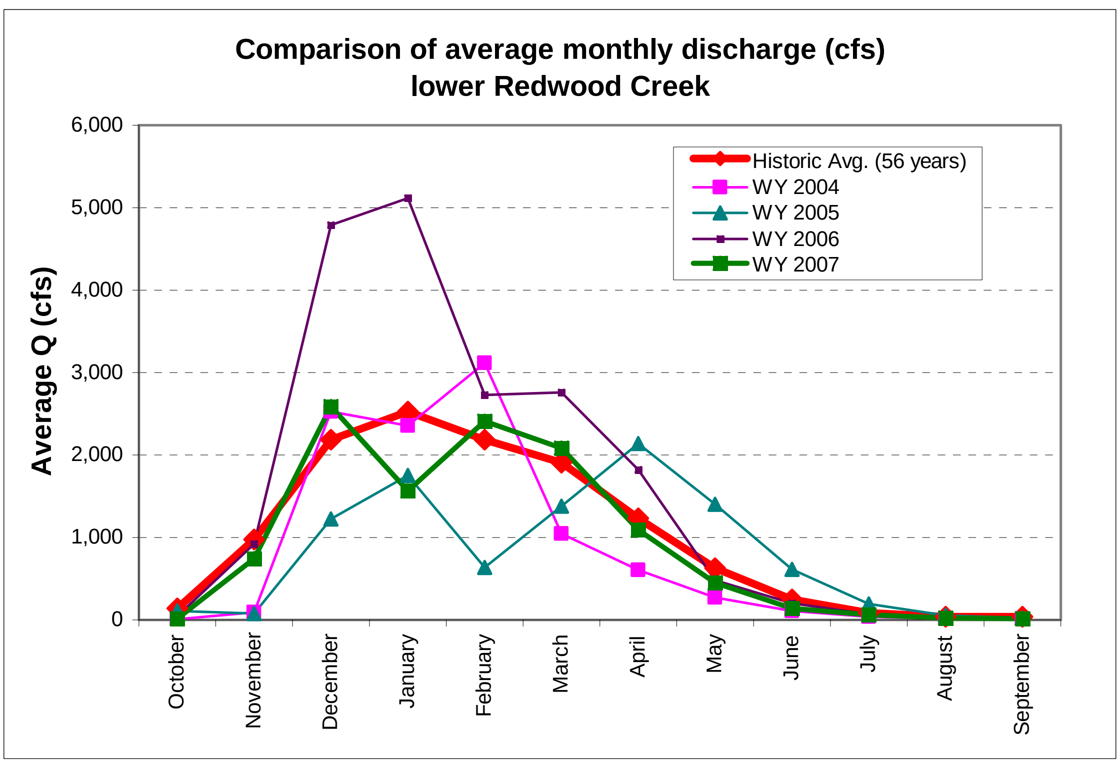
* Data courtesy of V. Ozaki (RNP, pers. comm. 2007).
** Standard Error of Mean



* Data courtesy of V. Ozaki (pers. comm. 2007)

Appendix 2. Comparison of 56 year average monthly discharge (historic) with monthly discharge in WYS 2004 – 07 (Orick Gaging Station, USGS 2007), lower Redwood Creek, Humboldt County, CA.

	Monthly Stream Discharge (cfs) in Lower Redwood Creek				
Month	Historic	YR 2004	YR 2005	YR 2006	YR 2007
October	137	8	111	44	13
November	977	90	74	919	745
December	2,187	2,526	1,223	4,788	2,588
January	2,526	2,356	1,749	5,119	1,567
February	2,185	3,113	638	2,666	2,407
March	1,904	1,050	1,379	2,762	2,086
April	1,232	602	2,138	1,741	1,094
May	630	271	1,400	472	449
June	251	109	613	184	138
July	86	41	195	61	65
August	40	19	56	20	26
September	36	9	25	12	13
Average:	1,016	850	800	1,566	933



Appendix 3. 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.

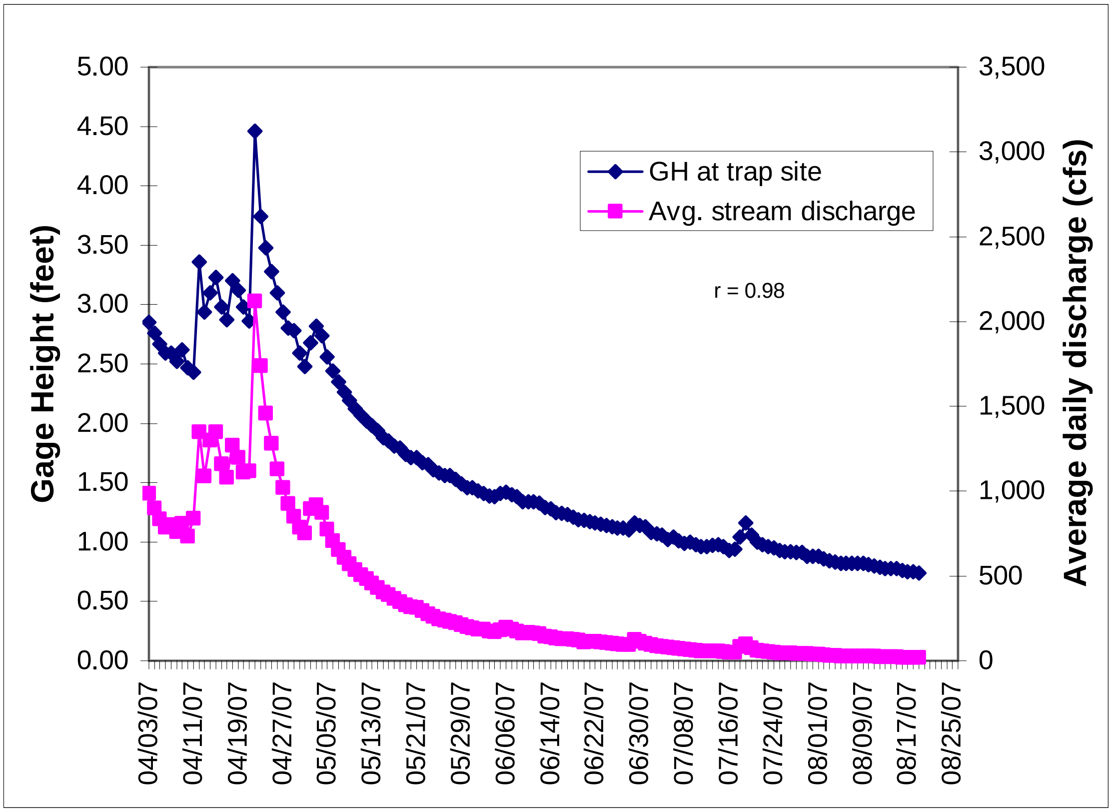
Coho Salmon

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 4. Graphical representation of daily stream gage height (ft.) at trap site and average daily streamflow (cfs) measured at Orick gaging station (USGS 2007), lower Redwood Creek, Humboldt County, CA.



Appendix 5. Descriptive statistics of size at time 1 (T1) and time 2 (T2), change in size (FL, Wt), percent change in size (FL, Wt), absolute growth rate (FL, Wt), relative growth rate (FL, Wt) and specific growth rate scaled (FL, Wt) for pit tagged 0+ Chinook salmon recaptured (n = 245) at the lower trap in Redwood Creek in YR 2007, Humboldt County, CA.

	Descriptive Statistics			
Variable	Min.	Max.	Avg. (median)	SEM**
Size at T1				
FL mm	67	80	71.9 (71.0)	0.19
Wt g	3.0	5.9	3.96 (3.9)	0.04
Size at T2				
FL mm	68	90	75.9 (76.0)	0.25
Wt g	3.2	7.7	4.63 (4.51)	0.05
Change in				
FL mm	0	17	3.9 (3.0)	0.24
Wt g	-0.39	3.31	0.68 (0.51)	0.05
% change in				
FL mm	0.00	25.37	5.48 (4.23)	0.35
Wt g	-8.48	106.8	18.41 (6.71)	1.30
AGR*				
FL mm	0.00	0.76	0.29 (0.33)	0.01
Wt g	-0.12	0.15	0.05 (0.05)	0.03
RGR*				
FL mm	0.000	0.011	0.004 (0.004)	0.002
Wt g	-0.021	0.044	0.013 (0.014)	0.007
SGR*				
FL mm	0.00	1.00	0.397 (0.430)	0.018
Wt g	-2.21	3.65	1.181 (1.288)	0.061

* Abbreviations are the same as in Table 32.
** SEM = standard error of mean.

Appendix 6. Release groups, sample sizes, and recaptures of pit tagged 1+ steelhead trout released from upper Redwood Cr, and recaptured in lower Redwood Cr, Humboldt County, CA., 2007.

Pit Tagged 1+ Steelhead Trout			
Release Group	Sample Size	No. of Recaptures	Percent Recapture
4/06/07	12	1	8.33
4/11/07	19	0	0.00
4/13/07	20	1	5.00
4/19/07	6	0	0.00
4/26/07	25	1	4.00
5/01/07	30	1	3.33
5/08/07	30	0	0.00
5/11/07	30	2	6.67
5/15/07	30	5	16.67
5/22/07	30	2	6.77
5/27/07	13	0	0.00
5/29/07	30	1	3.33
5/31/07	30	0	0.00
6/04/07	30	1	3.33
6/10/07	30	2	6.67
6/14/07	30	1	3.33
6/19/07	30	0	0.00
6/24/07	24	0	0.00
6/26/07	20	0	0.00
7/08/07	4	0	0.00
7/10/07	1	0	0.00
7/13/07	3	0	0.00
7/17/07	1	0	0.00
7/20/07	4	0	0.00
7/23/07	1	0	0.00
7/27/07	1	0	0.00
Sum:	484	18	

Appendix 7. Descriptive statistics of size at time 1 (T1) and time 2 (T2), change in size (FL, Wt), percent change in size (FL, Wt), absolute growth rate (FL, Wt), relative growth rate (FL, Wt) and specific growth rate scaled (FL, Wt) for pit tagged 1+ steelhead trout recaptured (n = 18) at the lower trap in Redwood Creek in YR 2007, Humboldt County, CA.

	Descriptive Statistics			
Variable	Min.	Max.	Avg. (median)	SEM**
Size at T1				
FL mm	68	115	83.9 (85.0)	2.71
Wt g	3.5	19.1	6.98 (6.55)	0.18
Size at T2				
FL mm	83	121	99.1 (99.5)	2.89
Wt g	6.0	21.0	10.77 (10.16)	1.02
Change in				
FL mm	0.0	29.0	15.2 (15.0)	20.7
Wt g	0.0	10.1	3.80 (3.06)	0.65
% change in				
FL mm	0.00	38.24	18.74 (19.74)	2.65
Wt g	0.00	165.35	65.49 (60.00)	11.64
AGR*				
FL mm	0.00	0.73	0.470 (0.490)	0.042
Wt g	0.00	0.22	0.111 (0.103)	0.014
RGR*				
FL mm	0.000	0.010	0.006 (0.006)	0.0006
Wt g	0.000	0.039	0.019 (0.021)	0.0026
SGRsc*				
FL mm	0.000	0.912	0.521 (0.571)	0.050
Wt g	0.000	2.414	1.381 (1.505)	0.169

* Abbreviations are the same as in Table 32.
** SEM = standard error of the mean.

Appendix 8. Results of linear regressions using travel time (d), travel rate (mi/d), average water temperature (°C), average stream discharge (cfs), and average lunar phase on various growth indices for pit tagged 1+ steelhead trout recaptured (n = 18) at the lower trap in Redwood Creek, Humboldt County, CA., YR 2007.

Variables		Regression Output (Results)			
Dependent (Y)*	Independent (X)	p value	Adj. or R2	Slope Sign	Power of test
Delta FL	Travel Time	*0.000001*	0.85	Positive	1.00
Delta FL	Travel Rate	*0.002*	0.45	Negative	0.92
Delta FL	Water Temperature	*0.001*	0.48	Negative	0.95
Delta FL	Stream Discharge	*0.003*	0.43	Positive	0.90
Delta FL	Lunar Phase	*0.003*	0.43	Positive	0.90
Delta FL**	Lunar Phase, Stream Discharge	*0.00001*	0.74	Positive, Positive	0.99
Delta WT	Travel Time	*0.000003*	0.75	Positive	1.00
Delta WT	Travel Rate	*0.01*	0.33	Negative	0.76
Delta WT	Water Temperature	*0.0002*	0.60	Negative	1.00
Delta WT	Stream Discharge	*0.0001*	0.59	Positive	0.99
Delta WT	Lunar Phase	*0.03*	0.27	Positive	0.64
Delta WT**	Lunar Phase, Stream Discharge	*0.00002*	0.73	Positive, Positive	0.98
% Change FL	Travel Time	*0.000001*	0.83	Positive	1.00
% Change FL	Travel Rate	*0.003*	0.42	Negative	0.89
% Change FL	Water Temperature	*0.007*	0.38	Negative	0.83
% Change FL	Stream Discharge	*0.01*	0.32	Positive	0.73
% Change FL	Lunar Phase	*0.002*	0.45	Positive	0.92
% Change FL**	Lunar Phase, Stream Discharge	*0.00001*	0.75	Positive, Positive	0.99
% Change Wt	Travel Time	*0.000001*	0.78	Positive	1.00
% Change Wt	Travel Rate	*0.02*	0.31	Negative	0.71
% Change Wt**	Water Temperature	*0.006*	0.38	Negative	0.83
% Change Wt**	Stream Discharge**	*0.005*	0.36	Positive	0.86
% Change Wt	Lunar Phase	*0.01*	0.32	Positive	0.74
% Change Wt**	Lunar Phase, Stream Discharge	*0.000006*	0.77	Positive, Positive	0.86
AGR FL	Travel Time	*0.01*	0.31	Positive	0.72
AGR FL	Travel Rate	*0.0006*	0.53	Negative	0.98
AGR FL	Water Temperature	*0.03*	0.27	Negative	0.62
AGR FL	Stream Discharge	0.11	0.15	Positive	0.36
AGR FL	Lunar Phase	*0.00002*	0.69	Positive	1.00
AGR FL	Lunar Phase, Stream Discharge	*0.0001*	0.67	Positive, Positive	0.94
AGR Wt	Travel Time	*0.002*	0.45	Positive	0.93
AGR Wt	Travel Rate	*0.002*	0.46	Negative	0.93
AGR Wt	Water Temperature	*0.001*	0.49	Negative	0.96
AGR Wt	Stream Discharge	*0.006*	0.38	Positive	0.84
AGR Wt	Lunar Phase	*0.0005*	0.54	Positive	0.98
AGR Wt	Lunar Phase, Stream Discharge	*0.0001*	0.67	Positive, Positive	0.94
SGRsc FL	Travel Time	*0.03*	0.25	Positive	0.59
SGRsc FL	Travel Rate	*0.001*	0.49	Negative	0.96
SGRsc FL	Water Temperature	0.08	0.18	Negative	0.42
SGRsc FL	Stream Discharge	0.27	0.08	Positive	0.19
SGRsc FL	Lunar Phase	*0.000005*	0.74	Positive	1.00
SGRsc FL	Lunar Phase, Stream Discharge	*0.00004*	0.70	Positive, Positive	0.97
SGRsc Wt	Travel Time	*0.009*	0.35	Positive	0.79
SGRsc Wt	Travel Rate	*0.002*	0.47	Negative	0.94
SGRsc Wt	Water Temperature	*0.02*	0.28	Negative	0.65
SGRsc Wt	Stream Discharge	0.12	0.14	Positive	0.34
SGRsc Wt	Lunar Phase	*0.000003*	0.76	Positive	1.00
SGRsc Wt	Lunar Phase, Stream Discharge	*0.00002*	0.74	Positive, Positive	0.99

Appendix 8 Continued:

RGR FL	Travel Time	*0.02*	0.31	Positive	0.72
RGR FL	Travel Rate	*0.001*	0.49	Negative	0.96
RGR FL	Water Temperature	0.05	0.21	Negative	0.50
RGR FL	Stream Discharge	0.18	0.11	Positive	0.26
RGR FL	Lunar Phase	*0.000006*	0.73	Positive	1.00
RGR FL	Lunar Phase, Stream Discharge	*0.00005*	0.70	Positive, Positive	0.96
RGR Wt	Travel Time	*0.002*	0.46	Positive	0.94
RGR Wt	Travel Rate	*0.004*	0.41	Negative	0.88
RGR Wt	Water Temperature	*0.02*	0.29	Negative	0.67
RGR Wt	Stream discharge	0.08	0.18	Positive	0.41
RGR Wt	Lunar Phase	*0.0001*	0.62	Positive	1.00
RGR Wt	Lunar Phase, Stream Discharge	Test assumptions not met, results unreliable			

* Abbreviations are the same as in Table 32. *P values* in italics indicate statistical significance for that test.
** Transformed with log(x+1)