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2007 ANNUAL REPORT

UPPER REDWOOD CREEK
JUVENILE SALMONID (SMOLT) DOWNSTREAM MIGRATION STUDY
2000 - 2007 Seasons
PROJECT 2a5

Prepared by

Michael D. Sparkman
Northern Region

Anadromous Fisheries Resource Assessment and Monitoring Program

August 26, 2008

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ABSTRACT

Juvenile anadromous salmonid trapping was conducted for the eighth consecutive year in upper Redwood Creek, Humboldt County, California during the spring/summer emigration period (March – August). The purpose of the study is to describe juvenile salmonid out-migration and estimate smolt population abundances for wild 0+ Chinook salmon, 1+ coho salmon, 1+ steelhead trout, and 2+ steelhead trout using mark/recapture methods. The long term goal is to monitor the status and trends of out-migrating juvenile salmonid smolts in upper Redwood Creek in relation to watershed conditions and restoration activities in the basin; and to provide data needed for Viable Salmonid Population (VSP) Analysis.

The trap operated 127 day/nights out of 129 possible, and captured 15,823 0+ Chinook salmon, zero 1+ Chinook salmon, 68,573 0+ steelhead trout, 5,036 1+ steelhead trout, 525 2+ steelhead trout, 2 cutthroat trout, zero 0+ pink salmon, and for the first time in eight consecutive years, 6 0+ coho salmon. The total trap catch equaled 89,965 individuals. Catches in YR 2007 were markedly less than the average of the previous seven years, and the greatest reduction (84%) occurred for 0+ Chinook salmon. Average weekly trapping efficiency was 24% for 0+ Chinook salmon, 15% for 1+ steelhead trout, and 15% for 2+ steelhead trout. Trapping efficiency of 0+ Chinook salmon was inversely related to stream discharge and stream gage height. The total 0+ Chinook salmon population estimate with 95% confidence intervals in YR 2007 equaled 68,283 (59,378 - 77,189), and was 2.6 times greater than emigration in YR 2006 and 76% less than emigration for the previous seven year average. The large decrease in YR 2007 most likely reflected a large decrease in the number of adult spawners upstream of the trap site since no streambed mobilization from flood flows occurred after reproduction. The population estimate for 1+ steelhead trout equaled 34,431 (29,697 - 39,165), and was 1.3 times higher than emigration in YR 2006 and 11% less than emigration for the previous seven year average. 2+ steelhead trout population emigration equaled 2,861 (2,196 - 3,525) and was 1.5 times greater than emigration in YR 2006 and 47% less than emigration for the previous seven year average. 0+ Chinook salmon, 1+ steelhead trout, and 2+ steelhead trout showed a negative trend over eight study years, however, significance was only detected with 1+ steelhead trout and 2+ steelhead trout.

With respect to successful watershed restoration, we expect: 1) stream temperatures to decrease in the summer, 2) the size of 0+ Chinook salmon migrants to not be limited by smolt population abundance, 3) a change in the age class structure of steelhead migrants to favor older, larger smolts, and 4) an increase in smolt population abundances.

[1/] This paper should be referenced as: Sparkman MD. 2008. Upper Redwood Creek juvenile salmonid (smolt) downstream migration study, study year 2007. CDFG AFRAMP, 2007 Annual Report 2a5: 136 p.

INTRODUCTION

This report presents results of the eighth consecutive year of juvenile salmonid downstream migration trapping in upper Redwood Creek, Redwood Valley, Humboldt County, California during the spring/summer emigration period. The study began in YR 2000, and was funded by the Redwood Creek Landowners Association (RCLA). Study years 2001 – 2007 have been a cooperative effort between the California Department of Fish and Game Anadromous Fisheries Resource Assessment and Monitoring Program (AFRAMP) (formerly Steelhead Research and Monitoring Program) and RCLA. In addition, the Fisheries Restoration Grant Program has assisted in funding this study from YR 2005 to the present. I would like to continue this study for a longer period of time (>15 yrs) in order to more fully address biological and environmental variability, and to determine the status and trends of smolt production in upper Redwood Creek.

The initial impetus for the study was to determine how many wild salmon and steelhead smolts were emigrating from upper Redwood Creek. Prior to this study, no information about smolt emigration and population estimates from upper Redwood Creek existed; this also applied to the remainder of mainstem Redwood Creek as well. Scientific studies which quantified anadromous salmonids within the Redwood Creek watershed were primarily limited to the estuary (juveniles) and Prairie Creek (adults and juveniles), which is tributary to lower Redwood Creek at river mile (RM) 3.7.

Redwood Creek is a difficult stream to monitor adult salmon and steelhead populations because the adult fish migrate upstream during late fall, winter and early spring. Thus, when the adults are present, the stream flow is often high and unpredictable, which limits the reliability and usefulness of any adult weir. Additionally, the stream flow during this time period often carries large amounts of suspended sediments, which render visual observations of adult fish (both live and carcass) and redds (eg spawning surveys) unreliable and unlikely for long term monitoring. 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 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 (Schmidt et al. 1996, Roper and Scarnecchia 1999, Ward 2000, Sharma and Hilborn 2001, Ward et al. 2002, Bill Chesney pers. comm. 2005), 2) redd gravel conditions (Cederholm et al. 1981, Holtby and Healey 1986, Hartman and Scrivener 1990), 3) in-stream habitat quality and watershed health (Tripp and Poulan

1986, Hartman and Scrivener 1990, Hicks et al. 1991, Bradford et al. 2000, Sharma and Hilborn 2001, Ward et al. 2002), 4) restoration activities (Everest et al. 1987 *in* Hicks et al. 1991, Slaney et al. 1986, Tripp 1986, McCubbing and Ward 1997, Solazzi et al. 2000, Cleary 2001, Ward et al 2002, McCubbing 2002, Ward et al. 2003, Roni et al. 2006), 5) over-winter survival (Scrivener and Brown 1993 *in* McCubbing and Ward 1997, Quinn and Peterson 1996, Solazzi et al. 2000, McCubbing 2002, Ward et al. 2002, Giannico and Hinch 2003), and 6) future recruitment to adult populations (Holtby and Healey 1986, Nickelson 1986, Ward and Slaney 1988, Ward et al. 1989, Unwin 1997, Ward 2000).

This paper will present the results of trapping in study year 2007 with comparisons to the average of the previous seven study years (YRS 2000 - 2006) and YR 2006.

Site Description

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

Geology

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

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

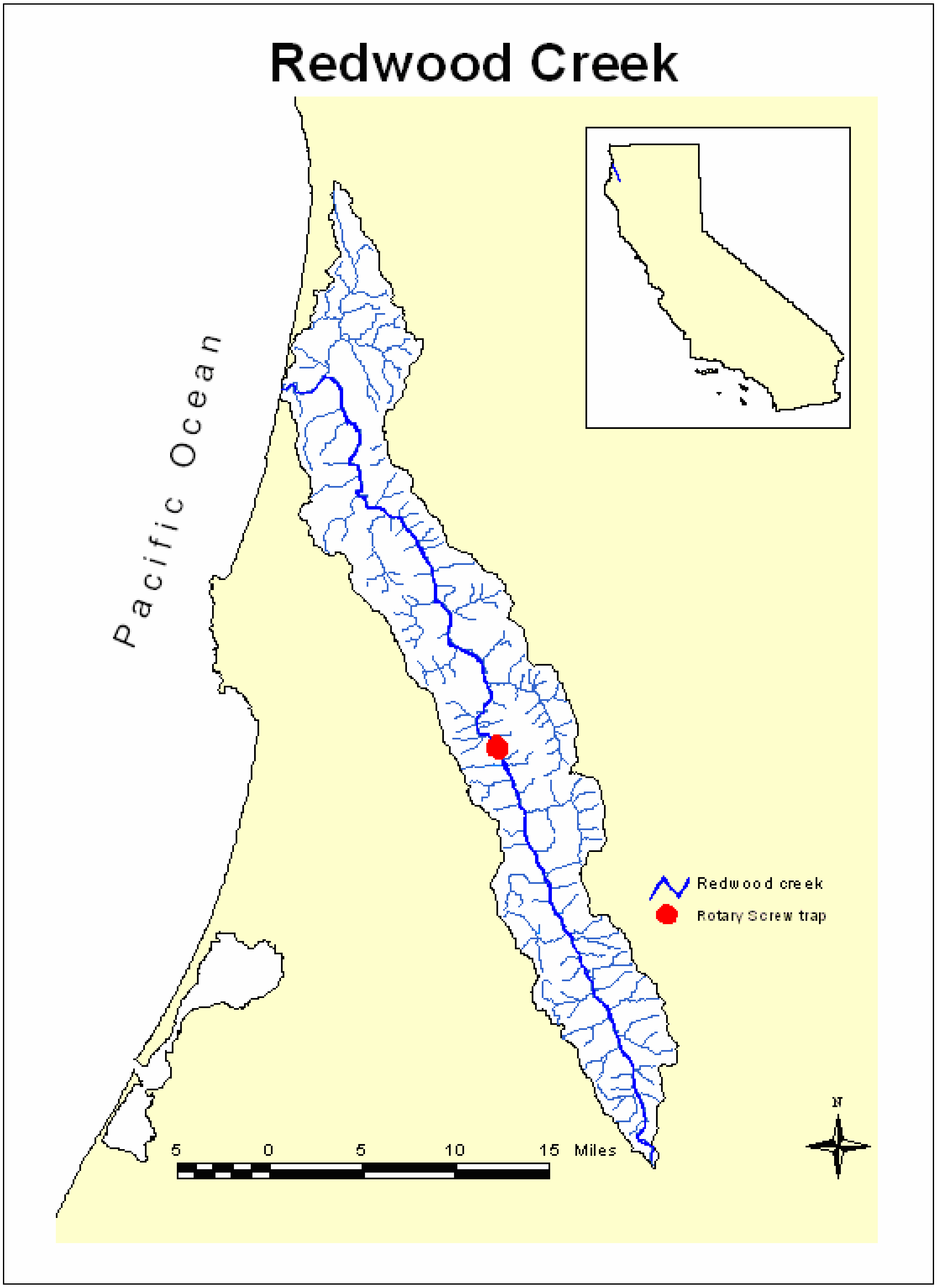

Figure 1. Redwood Creek watershed with rotary screw trap location (RM 33) in Redwood Valley, Humboldt County, CA., (scale is slightly inaccurate due to reproduction process; Charlotte Peters pers. comm. 2001).

Climate and Annual Precipitation

The climate of Redwood Creek basin varies dependent upon location within the watershed and season. Coastal areas have a moderate climate due to proximity to the ocean, and differ from inland areas (i.e. upper Redwood Creek) which experience higher and lower temperatures. Summers are typically cool and moist on the coast, and hot and dry inland. Ambient air temperatures in Redwood Valley often exceed 32 ^{o}C (or 90 ^{o}F) during summer months. Upper Redwood Creek experiences cold temperatures during the winter, and snowfall is common. In study year 2007, snowfall occurred as late as May 3rd. Rainfall in upper Redwood Creek is influenced by orographic effects, and can fall in considerable amounts.

A weather station (Davis Vantage Pro Weather Station) is located at the Hinz family residence in Redwood Valley, about 5.25 mi downstream of the trap site. Rainfall records cover the period from 1986 to the present to total 22 years (Vicki Ozaki pers. comm. 2007). Annual precipitation (by WY) ranged from 90 cm (35.4 in.) to 250 cm (98.4 in.), and averaged 181.2 cm (71.3 in.). Most (96%) of the rainfall in Redwood Creek occurs from October through May**,** with peak monthly rainfall normally occurring in December and January (Appendix 1). However, in some years relatively large amounts of rainfall may occur in November, February (WY 2007), April, and May (eg. YR 2005) as well. Rainfall in WY 2007 (199 cm) was the tenth highest on record, and about 18 cm (7 in.) greater than the 22 year average (Appendix 1).

The 22 year average monthly rainfall during the majority of the trapping season (April – July) totaled 26.5 cm (10.4 in.) (Table 1). Total monthly rainfall during this period of trapping in YR 2007 (25.3 cm or 10. in.) was about 4% less than the historic average and 5% less than the average of the previous seven study years. Rainfall in April 2007 accounted for 60% of the total rainfall during the majority of the trapping period (Table 1). Rainfall in July, 2007 (2.5 cm) was the second highest in 22 years of record.

Table 1. Comparison of 22 year average monthly rainfall (Historic) and monthly rainfall during the majority of the trapping period, Redwood Valley, Humboldt County, California.

	Rainfall* (centimeters)		
Month	Historic Average	Average of previous 7 study years (2000-06)	YR2007
Apr.	13.8	16.2	15.2
May	8.9	6.6	5.0
June	3.3	3.9	2.6
July	0.4	0.0	2.5
Total:	26.5	26.8	25.3

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

Stream Discharge

A USGS/CDWR gaging station (Blue Lake O'Kane, #11481500) is located about 8.4 miles upstream of the trap site on Redwood Creek. Stream flow records cover the periods of 1953 – 1958, 1972 – 1993, and 1997 – 2006 to total 36 years (USGS 2007). Following the pattern of rainfall, most of the high flows occur in the months of November - April, and typically peak in February; low flows usually occur from July - October (Appendix 2, USGS 2007). However, in WY 2007, average monthly flow peaked in March. Low flows in WY 2007 occurred in October and July - September. Using all years' data, mean monthly discharge in upper Redwood Creek was 234 cfs (6.6 m^3/sec), and ranged from 8 - 555 cfs (Appendix 2, USGS 2007). Average monthly discharge in WY 2007 equaled 203 cfs (5.7 m^3/sec) and was 13% less than the historic discharge, and 4% less than the previous seven year average by (Appendix 2, USGS 2007).

The 36 year average monthly discharge during the majority of the trapping season (April - July) equaled 139 cfs (3.9 m^3/sec) (Table 2). Average monthly discharge from April – July, 2007 (119 cfs) was 14% less than the historic average, and 18% less than the previous seven year average (Table 2, data from USGS 2007).

Table 2. Comparison of 36 year average monthly discharge (Historic), average monthly discharge for the previous seven years, and monthly discharge in YR 2007 in upper Redwood Creek (O'Kane station) during the majority of the trapping period (USGS 2007).

	Average Discharge (cfs)		
Month	Historic	Previous 7 study years (2000-06)	YR 2007
Apr.	306	320	286
May	162	189	140
June	66	57	32
July	21	17	16
Ave:	139	146	119

Overstory

The overstory in the Redwood Creek watershed is predominately second and third growth Redwood (*Sequoia sempervirens*) and Douglas Fir (*Pseudotsuga menziesii*), mixed with Big Leaf Maple (*Acer macrophyllum*), California Bay Laurel (*Umbellularia californica*), Incense Cedar (*Calocedrus decurrens*), Cottonwood (*Populus* spp.), Manzanita

(*Arctostaphylos* spp.), Oak (*Quercus* spp.), Tan Oak (*Lithocarpus densiflorus*), Pacific Madrone (*Arbutus menziesii*), and Red Alder (*Alnus rubra*).

Understory

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

Redwood Creek History (Brief)

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

Redwood Creek has been listed as sediment and temperature-impaired under section 303(d) of the Clean Water Act (CWA 2002; SWRCB 2003; USEPA 2003).

Federal ESA Species Status

Chinook (King) salmon (*Oncorhynchus tshawytscha*), coho (Silver) salmon (*O. kisutch*), steelhead trout (*O. mykiss*), and cutthroat trout (*O. clarki clarki*) are known to inhabit Redwood Creek. This study also shows that pink salmon (*O. gorbuscha*) are present in Redwood Creek. Chinook salmon (KS) of Redwood Creek belong to the California

Coastal Chinook Salmon Evolutionarily Significant Unit (ESU), and are listed as "threatened" under the Federal Endangered Species Act (Federal Register 1999a). The definition of threatened as used by National Oceanic and Atmospheric Administration (NOAA) and the National Marine Fisheries Service (NMFS) is "likely to become endangered in the foreseeable future throughout all or a significant portion of their 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 in Redwood Creek was most likely the fall/early winter-run Chinook salmon.

Purpose

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

1) Determine the species composition and temporal pattern of downstream migrating juvenile salmonids, and enumerate species out-migration.
2) Determine population estimates for downstream migrating 1+ steelhead trout, 2+ steelhead trout, 0+ Chinook salmon, 1+ coho salmon, and cutthroat trout.
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 and potential stress.
7) Statistically analyze data for significance and trends.
8) Compare data between study years.

METHODS AND MATERIALS

Trap Operations

A modified E.G. Solutions (5 foot diameter cone) rotary screw trap was deployed in upper Redwood Creek (RM 33) on March 22, 2007 at the same location as in previous study years. Due to gravel/sand deposits during winter months in YRS 2005 and 2006, the habitat type changed from a moderately high gradient riffle to a run.

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 March 22 through July 10, except for two missed days (March 28 and April 22).

During periods of reduced stream flows, rock type weirs and weir panels were used with the rotary screw to: 1) keep the trap's cone revolutions relatively high, and 2) maintain good trap efficiencies by directing the fish into the cone area. The weir panels were set to fall down under any unexpected, high stream flows. Plastic drop cloths were used to cover the weirs in June and early July to further increase flow into the cone area.

Beyond July 10, stream flows were too low to operate the rotary screw trap, and a fyke net was deployed on July 10 about 20 m upstream of the screw trap's position. Normally by mid to late July we remove the rotary screw trap and install a pipe trap to finish the study. However, due to the decrease in channel gradient, a fyke net was deployed instead of the pipe trap. Weir panels were placed immediately upstream of the fyke net to funnel all migrating fish into the net and livebox.

The trapping season in YR 2007 was discontinued on July 29 when the catch distribution for each species at age reached zero, or when relatively few individuals were caught in consecutive days.

The YR 2007 trapping season can be characterized with relatively few high flow events, and 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 carefully removed debris (e.g. alder cones, leaves, sticks, detritus, varying amounts of filamentous green algae, etc) from within the livebox nearly every night of trapping to reduce trap mortalities the following morning. The trap's livebox was emptied at 09:00 every morning by 2 - 4 technicians. 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. Plumbing inside the ice chest consisted of two PVC pipes: one that served to dissipate stream water into the ice chest, and the other to drain excess water. 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.

Each individual fish was counted by species and age, and observed for trap efficiency trial marks. Random samples of each species at age (eg 0+ KS, 0+ SH, etc.) were netted from the ice chest for enumeration and biometric data collection.

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), 0+ coho salmon (0+ CO), 1+ and greater cutthroat trout (CT), 1+ steelhead trout (1+ SH), and 2+ and greater steelhead trout (2+ SH). 0+ steelhead trout were only measured for fork length. A 350 mm measuring board (± 1 mm) and an Ohaus Scout ll digital scale (± 0.1 g) were used in the study. Fork lengths were taken every day of trap operation, and fork length frequencies of 0+ and older steelhead trout 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 - 5 times per week; and 0+ coho salmon, 1+ cutthroat trout, and 2+ steelhead trout weights were taken almost 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 157 m downstream of the trap site, and aged 1 and older fish were transported 170 m downstream of the trap site and released into the river.

Developmental Stages

We visually determined developmental stages (e.g. parr, pre-smolt, smolt) for every 1+ steelhead trout, 2+ steelhead trout, 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. Smolts are also known to easily shed scales.

Discerning developmental stages is subjective; however, I attempted to minimize observer bias by individually training (and checking) each crew member and having all crew members follow the same protocol. 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 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, and 2+ steelhead trout using stratified and non-stratified mark-recapture methods described by Carlson et al. (1998). Sample sizes for marking 0+ coho salmon and cutthroat trout were too low to determine a population estimate. 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 two to six times a week for 0+ Chinook salmon and 1+ steelhead trout, and two to five times a week for 2+ steelhead trout. Trials for 1+ cutthroat trout were unsuccessful due to very low captures during the trapping period (n = 2). Trap efficiency data was combined (pooled by week) and run through the equation to determine the weekly estimate (for a complete description of estimation methods and model assumptions see Sparkman 2004a, study 2a5). The Carlson et al. (1998) model and my methods were (favorably) peer reviewed 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). Clips for 2+ steelhead trout were stratified by week such that marked fish of one group (or week) would not be included in the following week(s) calculations (no out of strata captures occurred in YR 2004, 2005, 2006, and 2007). I did not stratify clips for 0+ Chinook and 1+ steelhead trout because four years of data (when I did stratify clips) showed that nearly all of the recaptures (99.4%) occurred in the correct strata. Clip types for 1+ and 2+ steelhead were kept on different time schedules to aid in identifying the correct age group of the recaptured fish; if there was any doubt or question, we would re-measure the fish, and count it for the appropriate age group. 0+ Chinook salmon and 1+ steelhead trout were given upper caudal fin clips, and 2+ steelhead trout were given upper or lower caudal 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). Fin clipped 0+ Chinook salmon were released in fry habitat 260 m upstream of the trap, and clipped 1+ and 2+ steelhead were released into a pool 160 m upstream of the trap. Fin clipped 0+ Chinook salmon, 1+ steelhead and 2+ steelhead trout were released upstream of the trap site at night. We released the fish at night either manually or by using a live cage with a battery operated lever system that opened the trap door at any given time (eg 2200). Night releases generally occurred from 2000 – 2300.

Additional Experiments

<u>Re-migration</u>

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 YRS 2004

- 06). 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 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 to be later caught at the lower trap (Sparkman 2008b) or estuary (David Anderson, pers. comm. 2007). 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 (Seth Ricker, pers. comm. 2005; this study in YR 2006). 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 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 show growth; if the tag had a negative impact upon the juveniles, then 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%).

Delayed Mortality

We conducted several delayed mortality tests for captured 0+ Chinook salmon (n = 36 tests), 0+ steelhead trout (n = 11 tests), 1+ steelhead trout (n = 45 tests), and 2+ steelhead trout (n = 45 tests) throughout the trapping period to insure that our methods were not harming fish during and after processing. Fish were held in mesh cages (live cars) in the stream during each type of test. Fin clip tests were for fish that were anesthetized and given a partial fin clip; some fin clip test fish were also measured for FL and Wt due to small sample sizes**.** Total sample size was 362 for 0+ Chinook salmon, 200 for 0+ steelhead trout, 329 for 1+ steelhead trout, and 133 for 2+ steelhead trout. Test durations were 24 - 36 hrs for 0+ Chinook salmon, 0+ steelhead trout, and 2+ steelhead trout; and 36 hrs for 1+ steelhead trout.

Handling tests were for fish that were anesthetized and measured for FL, or FL and WT. Total sample size was 98 for 0+ Chinook salmon, 270 for 0+ steelhead trout, 5 for 1+ steelhead trout, and 7 for 2+ steelhead trout. The duration of tests was 24 – 36 hrs for each species at age. There was one test in which 2+ steelhead trout were held for 60 hours.

Pit tag tests were for fish that were anesthetized, measured for FL (mm) and Wt (g), tagged with a pit tag, and given a partial upper caudal fin clip (secondary mark). Total sample size was 696 for 0+ Chinook salmon, 484 for 1+ steelhead trout, and 48 for 2+ steelhead trout. The duration of each test ranged from 10 – 36 hrs, with 36 hrs being most common.

Pit Tag Retention

We did not perform any pit tag retention tests in YR 2007 because in YR 2006 we found retention was 100% over a 24, 34, and 48 hr period. Technicians did not observe any potential pit tagged fish (presence of clip and scar from surgery) without pit tags.

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 March 23 – July 29, 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 (Ave. = 14.46 and 14.40 ^{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; and attached to the rotary screw trap via 1/8" diameter wire rope. Probes were set to record stream temperatures (^{o}C) every 30 minutes and recorded about 6,162 measurements per probe over the course of the study. The shallowest stream depths during which measurements were taken (in August) were about 2 - 3 feet. The maximum weekly average temperature (MWAT) and maximum weekly maximum temperature (MWMT) for YRS 2001 - 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 regression and correlation (for temporal component) were used to test for influences of average daily stream temperature, average daily discharge (O'Kane gage, USGS 2005), stream gage height (at trapping site), lunar phase and trapping day (temporal variable) on daily catches of all juvenile salmonids combined and for each species at age. Regression and correlation models did not include any combination of the independent variables (eg average temperature, average daily discharge, gage height, and trapping day) in a given model or test because they were highly correlated with one-another (Correlation, $p = 0.000001$, r ranged from 0.84 – 0.95). Regression and correlation were also used to test for influences of stream temperature, stream discharge and stream gage height averaged by week, and trapping week number on the weekly catches of all species combined, and for each species at age; weekly trapping efficiencies for 0+ Chinook salmon, 1+ steelhead trout, and 2+ steelhead trout were also regressed on weekly catches for a given species at age.

Regression (and correlation) was also used to test for influences of stream temperature, stream discharge, and stream gage height averaged by week, and trapping week number on population emigration by week for 0+ Chinook salmon, 1+ steelhead trout, and 2+ steelhead trout. Once again, independent variables were not combined together in the models due to high correlations (Correlation, $p < 0.00001$, r ranged from 0.84 – 0.95).

Linear correlation was used to determine if weekly trapping efficiencies for 0+ Chinook salmon, 1+ steelhead trout, and 2+ steelhead trout changed over time (weeks). Regression was used to test for influences of physical variables (average weekly gage height and average weekly stream discharge) on weekly trapping efficiencies for a given species at age. As in previous tests, gage height and stream discharge were not combined together in the models due to high correlation ($p < 0.001$, $r = 0.95$).

Linear correlation slope and equation line were used to determine if the population size of a given species at age was increasing or decreasing over the eight years of study. Linear regression was used to test the relationship of peak winter flows during egg incubation in spawning redds on the subsequent population size of 0+ Chinook salmon by coding high, bedload mobilizing flows as 1 (for population estimates in YRS 2003, 2005, and 2006) and non-bedload mobilizing flows as 0 (for population estimates in YRS 2000 - 2002, 2004, and 2007) (Zar 1999). Flows considered great enough to mobilize the bedload in upper Redwood Creek (> 5,000 cfs) were identified by Redwood National Park Hydrologists and Geologists (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 FL data and weekly population estimates. The percentage of juvenile Chinook salmon per size class each week was then 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 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.

Descriptive statistics were used to characterize the mean FL (mm) and Wt (g) of each species at age on a study year and weekly basis. Linear correlation was used to test if average FL and Wt by season (study year) changed over time (study year). Regression was used to test for influences of a species total catch (0+SH) or population estimate (0+KS, 1+SH, 2+SH) on average FL and Wt per season for the current eight years of data collection (seven years for 0+ Chinook salmon). Data for 0+ Chinook salmon in YR 2003 was omitted from analysis because so few measurements were taken due to the year class failure in 2003. Additionally, the majority of measurements were taken in June and did not include the smaller fry that normally emigrate in late March, April, and May.

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 $\geq$ 25 (week 3/26 - 4/01) and the last weekly average in the season (7/02 - 7/08) with a sample size $\geq$ 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 98. 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 rate for 0+ steelhead trout was also determined using this method.

Linear correlation was also used to test if the average weekly FL and Wt of each species at age (excluding 0+ steelhead weight) increased over the study period in YR 2007 and for the previous six year average for Chinook salmon, and previous seven year average for 0+ and older steelhead trout. 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 YR 2007 with the six year average for 0+ Chinook salmon (excludes YR 2003), and seven year average for 0+ (excludes Wt), 1+, and 2+ steelhead trout.

Chi-square was used to test if the percentages of Chinook salmon fry and fingerlings in YR 2007 differed from the previous seven year average. The percentage of fry and fingerlings in YR 2007 was also tested for randomness by assuming that a random occurrence of the two designations would be 50/50 or 1:1. Chi-square was also used to test for differences in the proportions of pre-smolt and smolt designations for captured 1+ steelhead trout and 2+ steelhead trout in YR 2007 with the previous seven year average. Parr stage was not included in the test for 2+ steelhead trout because in YR 2007 none of the 2+ steelhead trout were classified as parr (NCSS 97).

Regression was used to investigate relationships between: 1) 0+ steelhead trout catches (in year x) with 1+ steelhead trout population estimates the following year (or year x + 1) and with 2+ steelhead population estimates two years later (or year x + 2), and 2) 1+ steelhead trout population estimate (in year x) on the next year's 2+ steelhead trout population estimate (in year x + 1).

Descriptive statistics were used to characterize FL, Wt, travel time (d), travel rate (mi per d), and various growth indices (Delta FL and Wt, Percent Change in Growth, Absolute Growth Rate, Specific Growth Rate scaled, 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 (Delta FL and Wt, 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 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. Stream temperature and stream discharge were not included together in any regression models because they were highly correlated ($p < 0.001$); as were stream temperature and lunar phase for 1+ steelhead trout ($p < 0.05$). 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 in YR 2007 compared to the previous six year average (YRS 2001-2006). Study year 2000 was omitted from analysis because the temperature probe was not deployed over the majority of the trapping period, and encompassed only two months. Linear correlation was used to test if average daily stream temperature per study year changed over study years 2001 – 2007. Linear 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; the same test was applied to the previous six year average. Regression was used to test if average daily stream temperature was influenced by the gage height of the stream. Regression was also used to examine the relationship of the daily and monthly stream discharge on average daily or monthly stream temperature for YR 2007; and the relationship of average discharge during each trapping season on average stream temperature each season ($n = 7$) (excluding YR 2000).

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 6 - 8 data points (eg. population or catch trend analysis, regressions of population size on average FL and Wt by year, etc) was set at 0.10, and for tests with more than eight data points, alpha was set at 0.05. Bonferroni correction factors were applied to alpha when appropriate (NCSS 97).

RESULTS

The rotary screw trap operated from 3/22/07 - 7/10/07 and trapped 108 day/nights out of a possible 110. The fyke net operated from 7/11/06 - 7/29/07 and trapped 19 day/nights out of a possible 19. The trapping rate in YR 2007 was 98% compared to 97% for the previous seven year average (ranged from 92 - 99%). Days missed trapping in YR 2007 occurred in March (n = 1) and April (n = 1).

Species Captured

Juvenile Salmonids

Species captured in YR 2007 included: juvenile Chinook salmon (*Oncorhynchus tshawytscha*), juvenile steelhead trout (*O. mykiss*), coastal cutthroat trout (*O. clarki clarki*), and for the first time in eight consecutive years, 0+ coho salmon (*O. kisutch*) (Appendix 5). A total of 89,965 juvenile salmonids were captured in YR 2007 (Figure 2).

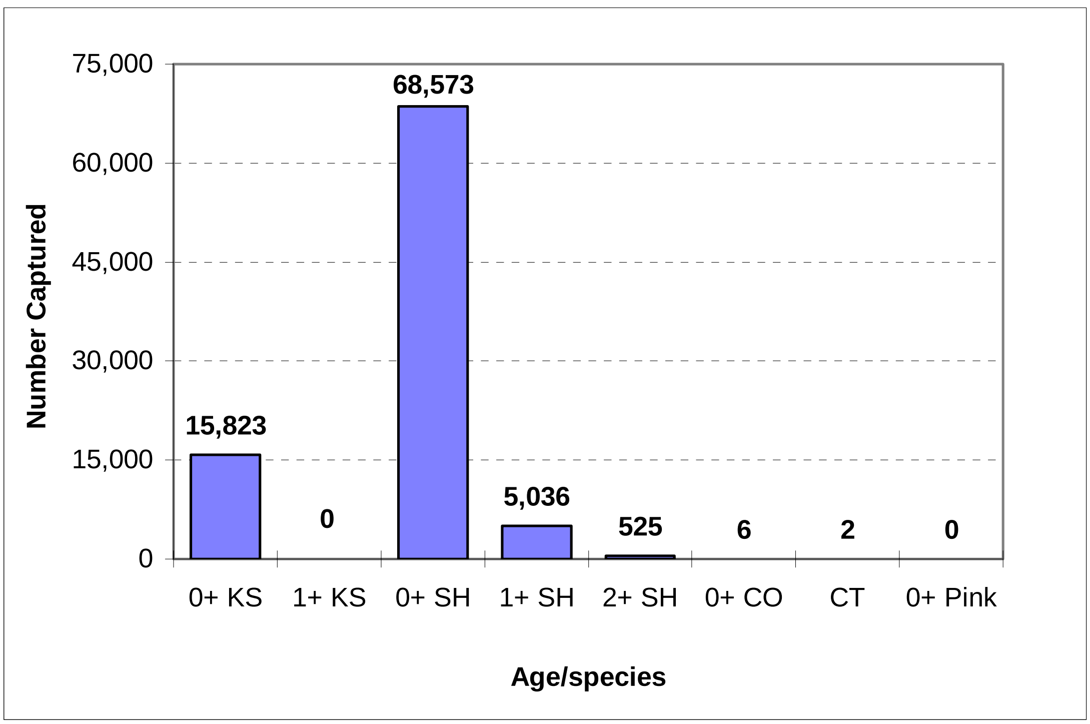

Figure 2. Total juvenile salmonid trap catches (n = 89,965) from March 23 through July 29, 2007, upper Redwood Creek, Redwood Valley, Humboldt County, CA. Numeric values above columns represent actual catches. 0+ KS = young-of-year Chinook salmon, 1+ KS = age 1 and older Chinook salmon, 0+ SH = young-of-year steelhead trout, 1+ SH = age 1 and older steelhead trout, 2+ SH = age 2 and older steelhead trout, 0+ CO = young-of-year coho salmon, CT = cutthroat trout, 0+ Pink = young-of-year pink salmon.

The total trap catch of juvenile salmonids in YR 2007 was 1.6 times higher than catches in YR 2006, and much less (54%) than trap catches for the previous seven year average (Table 3). Aside from 1+ Chinook salmon and 0+ pink salmon catches, the greatest reduction (84%) in trap catches in YR 2007 occurred with 0+ Chinook salmon. 0+ steelhead trout made up a higher percentage (76%) of the total catch in YR 2007 than other juvenile salmonids. (Table 3).

Table 3. Comparison of juvenile salmonid trap catches in YR 2007 with YR 2006 and the previous seven year average catch, upper Redwood Creek, Humboldt County, Ca.

	Actual Catches			
Age/species*	YR 2006	Previous seven year average	YR 2007	Percent reduction in YR 2007**
0+ KS	4,830	98,367	15,823	83.9
1+ KS	0	10	0	100.0
0+ SH	48,759	86,318	68,573	20.6
1+ SH	3,201	10,147	5,036	50.4
2+ SH	400	948	525	44.6
CT	3	4	2	50.0
0+ Pink	0	3	0	100.0
0+ CO	0	0	6	No Reduction
Total:	57,193	195,797	89,965	54.1

* Age/species definitions are the same as in Figure 2.
** Comparisons are with the previous seven year average (YRS 2000-06).

Miscellaneous Species

The trap captured several species besides anadromous salmonids in YR 2007, including: coast range sculpin (*Cottus aleuticus*), sucker (*Catostomidae* family), three-spined stickleback (*Gasterosteus aculeatus)*, juvenile (ammocoete) lamprey and adult Pacific Lamprey (*Entosphenus tridentatus*) (Table 4). Adult Pacific lamprey catches in YR 2007 were greater than catches in YR 2006, and the previous seven year average.

Amphibian catches in YR 2007 included: coastal (Pacific) giant salamander (*Dicamptodon tenebrosus*), rough skinned newt (*Taricha granulosa granulosa*), yellow legged frog (*Rana muscosa*), and tailed frog tadpole (*Ascaphus truei*) (Table 4). Numerous and at times, countless, aquatic invertebrates were also captured in the trap.

Table 4. Miscellaneous species captured in YR 2007 compared to catches in YR 2006 and the previous seven year average catch, upper Redwood Creek, Humboldt County, CA.

	Actual Catches		
Species Captured	YR 2006	Previous seven year average	YR 2007
Prickly Sculpin	3	5	0
Coast Range Sculpin	16	82	9
Sucker	15	8	9
3-Spined Stickleback	79	96	21
Brown Bullhead	0	1	0
Adult Pac. Lamprey	25	34	40
Juvenile Lamprey	648	1,970	547
Pac. Giant Salamander	185	122	121
Painted Salamander	0	1	1
Rough Skinned Newt	12	27	6
Red-Legged Frog	0	1	0
Yellow-Legged Frog	8	13	12
American Bullfrog	0	0	0
Tailed Frog*	61	16	4

* Includes both adult and tadpole stages.

Juvenile Salmonid Captures

Catches of 0+ Chinook salmon, 0+ steelhead trout, 1+ steelhead trout, and 2+ steelhead trout in YR 2007 were variable over time, with apparent multi-modal catch distributions for each species at age.

0+ Chinook salmon daily catches in YR 2007 (n = 15,823) ranged from 0 – 1,142 individuals, and averaged 123 fish per day. The previous seven year daily catch ranged from 0 - 10,700 and averaged 762 per day. Daily 0+ Chinook salmon captures in YR 2007 expressed as a percentage of total 0+ Chinook salmon catch in YR 2007 (n = 15,823) ranged from 0.0 – 7.2%, and averaged 0.8%. The peak catch in YR 2007 occurred 6/05/07 (n = 1,142).

0+ steelhead trout daily catches in YR 2007 (n = 68,573) ranged from 0 – 3,660 individuals, and averaged 532 per day. The previous seven year daily catch ranged from 0 - 6,993 individuals and averaged 659 per day. Daily 0+ steelhead captures in YR 2007 expressed as a percentage of total 0+ steelhead catch in YR 2007 (n = 68,573) ranged from 0.0 - 5.3% and averaged 0.8%. The peak catch in YR 2007 occurred 6/05/07 (n = 3,660).

1+ steelhead trout daily catches in YR 2007 (n = 5,036) ranged from 0 - 183, and averaged 39 per day. The previous seven year daily catch ranged from 0 - 727 individuals and averaged 78 per day. Daily 1+ steelhead trout captures in YR 2007 expressed as a percentage of total 1+ steelhead trout catch in 2007 (n = 5,036) ranged from 0.0 – 3.6% and averaged 0.8%. The peak catch in YR 2007 occurred on 5/08/07 (n = 183).

2+ steelhead trout daily catches in YR 2007 (n = 525) ranged from 0 - 22, and averaged four individuals per day. The previous seven year daily catch ranged from 0 - 45 individuals and averaged seven per day. Daily 2+ steelhead trout captures in YR 2007 expressed as a percentage of total 2+ steelhead trout catches in YR 2007 (n = 525) ranged from 0.0 – 4.2%, and averaged 0.7%. The peak catch in YR 2007 occurred on 6/21/07 (n = 22).

Days Missed Trapping

Two days were not trapped during the course of the study due to a high flow event on 3/28/07, and when a log jammed the trap's cone on 4/22/07. Days missed trapping did not influence the total catch or population estimate of any species at age to any large degree (Table 5).

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 = 2 d) during the emigration period of March 23 through July 29 (as a percentage of total without missed days in parentheses), upper Redwood Creek, Humboldt County, CA., 2007.

Age/spp.*	Catch	Population Level
0+ KS	41 (0.26%)	678 (1.00%)
0+ SH	0 (0.00%)	-
1+ SH	23 (0.46%)	131 (0.38%)
2+ SH	5 (0.95%)	23 (0.81%)

* 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

Trap catches of 0+ Chinook salmon by month in YR 2007 were much lower than the previous seven year average catch by month; however, the pattern of monthly catches was similar (Figure 3).

The majority of 0+ Chinook salmon catches in YR 2007 occurred in May and June (n = 13,934 or 88.1% of total catch), as did the majority of catches for the previous seven year average (n = 71,449 or 72.6% of total average catch).

The correlation of 0+ Chinook salmon catches with study years indicated a non-significant negative relationship (n = 8, p = 0.13, r = 0.58, slope is negative, power = 0.32).

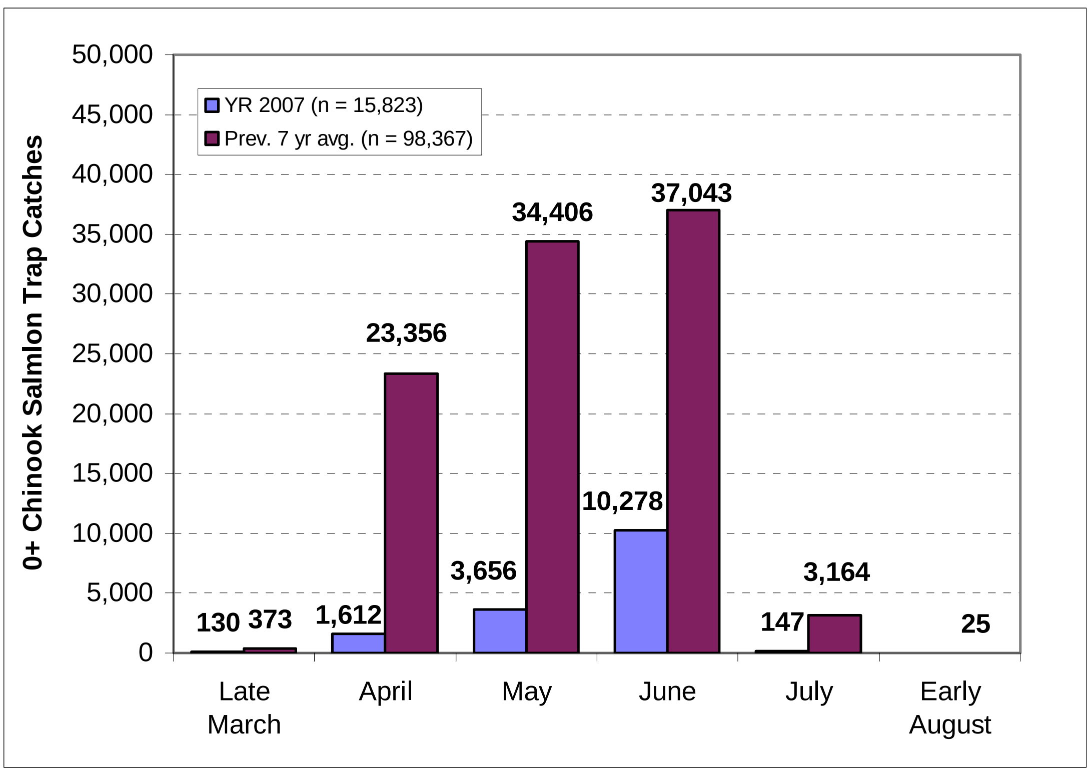

Figure 3. Comparison of total 0+ Chinook salmon trap catches by month in YR 2007 with the previous seven year average, upper Redwood Cr, Humboldt County, CA. Numeric values represent actual catches.

0+ Steelhead Trout

Trap catches of 0+ steelhead trout by month in YR 2007 were lower than the previous seven year average catch by month, except for catches in June (Figure 4). Low catches occurred during late March and April because most of the fry had not yet emerged from redds.

The majority of 0+ steelhead trout catches in YR 2007 occurred in May and June (n = 60,542 or 88.3% of total catch), compared to catches in June and July (n = 59,951 or 69.5% of total) for the previous seven year average. June was the month with the highest catches for both YR 2007 and the previous seven year average. The biggest reduction in catches in YR 2007 occurred in July (n =18,620 less individuals, or 70% reduction).

The linear correlation of 0+ steelhead trout trap catches with study years indicated a non-significant negative relationship (n = 8, p = 0.42, r = 0.33, slope is negative, power = 0.08) (Appendix 6). The line of best fit using a polynomial relationship showed a negative trend over the eight study years, and was able to correlate 63% of the variation in trap catches to study years (Appendix 6).

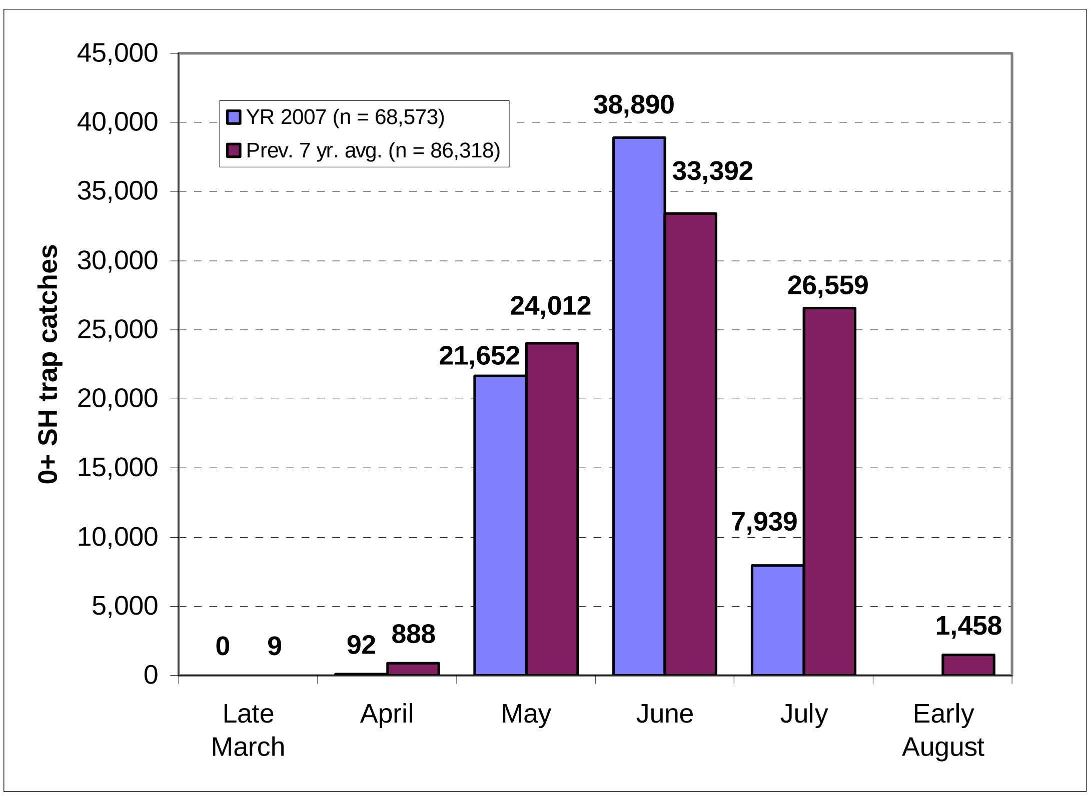

Figure 4. Comparison of total 0+ steelhead trout trap catch by month in YR 2007 with the previous seven year average, upper Redwood Creek, Humboldt County, CA. Numeric values above columns represent actual catches.

1+ Steelhead Trout

Trap catches of 1+ steelhead trout by month in YR 2007 were much lower than the previous seven year average catch by month, except for catches in June (Figure 5). The majority of 1+ steelhead trout catches in YR 2007 occurred in May and June (n = 4,098 or 81.4% of total catch), compared to the majority of catches in April and May (n = 7,688 or 75.8% of total) for the previous seven year average. The highest catches occurred in May for both YR 2007 and the previous seven year average.

The correlation of 1+ steelhead trout trap catches (transformed) with study years indicated a significant negative relationship (n = 8, p = 0.03, r = 0.76, slope is negative, power = 0.66).

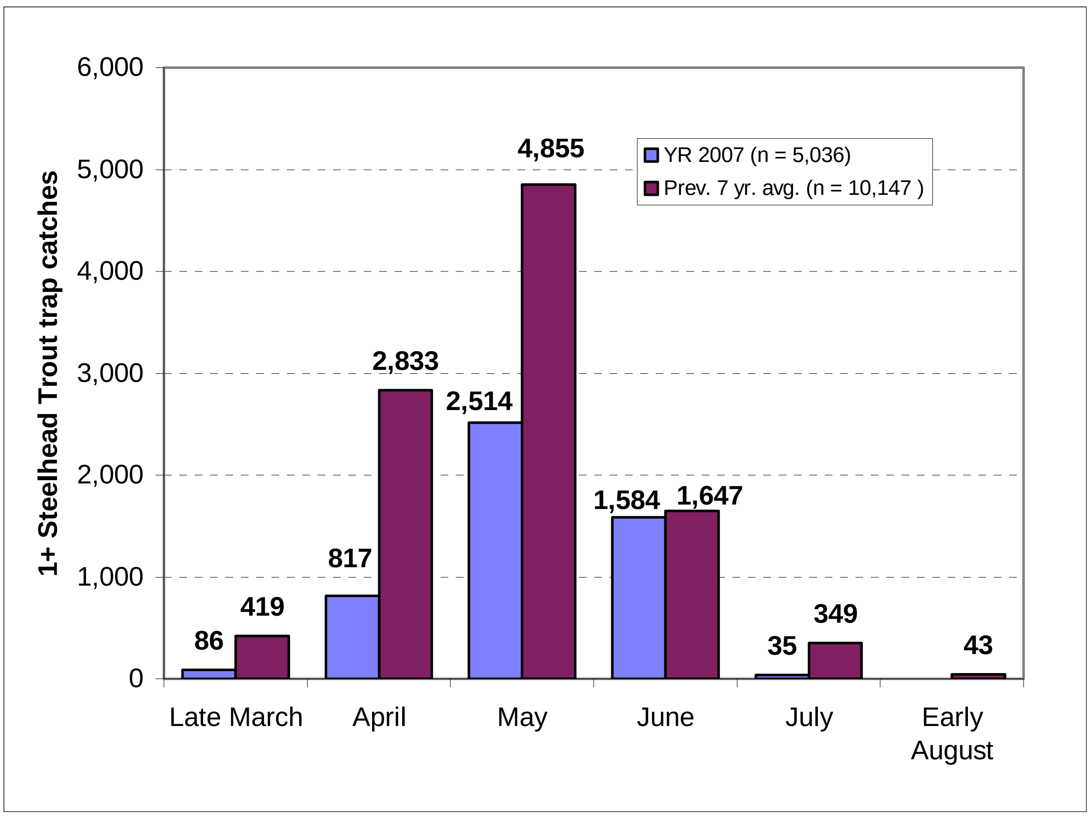

Figure 5. Comparison of total 1+ steelhead trout catches by month in YR 2007 with the previous seven year average, upper Redwood Creek, Humboldt County, CA. Numeric values represent actual catches.

2+ Steelhead Trout Catches

Trap catches of 2+ steelhead trout by month in YR 2007 were lower than the previous seven year average catch by month except for the month of June (Figure 6). The majority of 2+ steelhead trout catches in YR 2007 occurred in May and June (n = 329 or 62.7% of total catch), compared to April and May (n = 655 or 69.1% of total) for the previous seven year average. The highest monthly catch in YR 2007 occurred in June compared to May for the previous seven year average.

The correlation of 2+ steelhead trout trap catches with study years indicated a non-significant negative relationship (n = 8, p = 0.16, r = 0.55, power = 0.28).

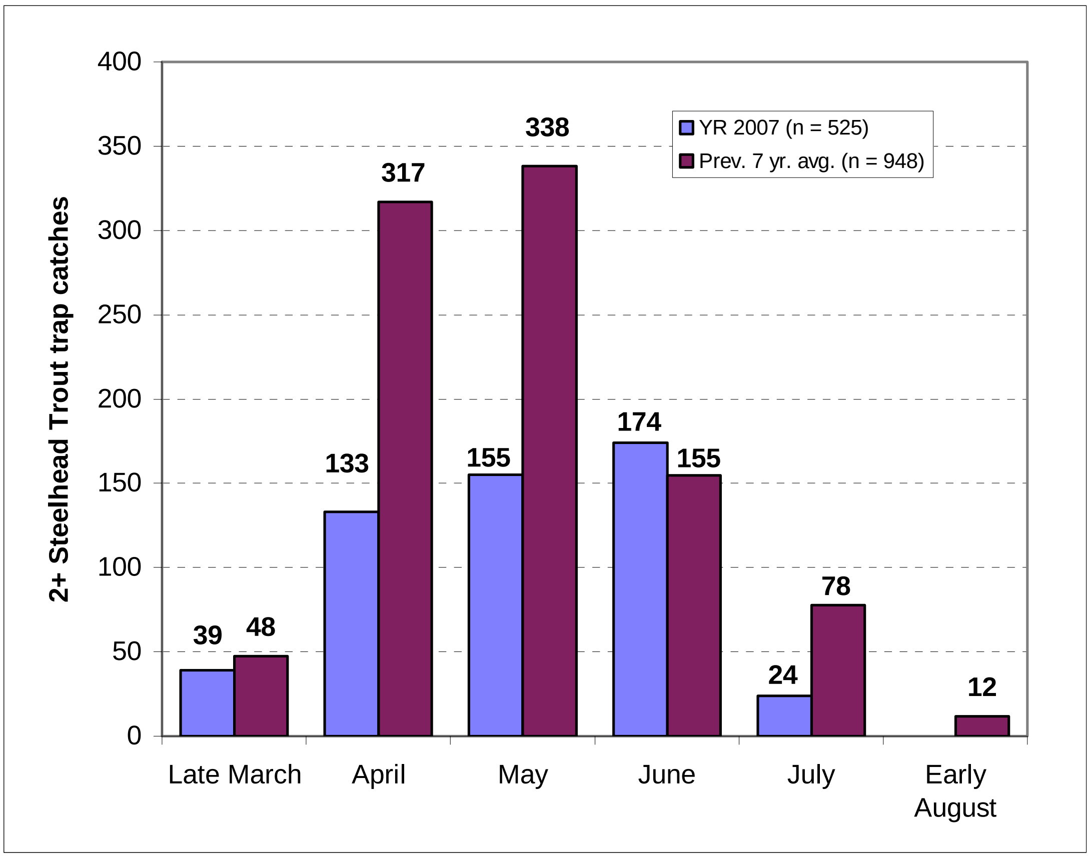

Figure 6. Comparison of total 2+ steelhead trout trap catches by month in YR 2007 with the previous seven year average, upper Redwood Creek, Humboldt County, CA. Numeric values represent actual catches.

Linear Relations of Catch with Stream Temperature, Stream Discharge, Stream Gage Height, and Time (trapping day or trapping week number)

By Day

The total number of juvenile salmonids captured by day (transformed) was positively related (weakly) to trapping day number (Correlation, $p < 0.001$, $r = 0.30$, positive slope, power = 0.94), average daily water temperature (Regression, $p < 0.01$, $R^2 = 0.07$, positive slope, power = 0.88), and the transformed daily discharge (Regression, $p < 0.001$, $R^2 = 0.10$, positive slope, power = 0.97). Regressions of lunar phase or gage height on total catches violated regression assumption tests, and results were not valid [even with log(x+1) transformations]. Regressions of average daily water temperature, daily discharge, lunar phase, and gage height on daily catches of 0+ KS, 0+ SH, 1+ SH and 2+ SH each violated regression assumptions, and results were not valid.

Although statistical tests were not warranted for any species at age, some generalizations can be made from the corresponding scatter plots (not given) of average stream temperature and stream gage height (which can also represent stream discharge, see Appendix 7) on daily catches. The majority of daily trap catches occurred during average daily stream temperatures of 6.4 – 18.1 ^{o}C for Chinook salmon (99% of total 0+KS catch), 9.5 – 21.0 ^{o}C for 0+ Steelhead trout (99% of total 0+SH catch), 6.4 – 18.1 ^{o}C for 1+ Steelhead trout (99% of total 1+SH catch), and 6.4 to 19.1 ^{o}C for 2+ steelhead trout (98% of total 2+SH catch). The peak catch occurred during an average daily steam temperature of 14.8 ^{o}C for 0+ Chinook (n = 1,142), 14.2 ^{o}C for 0+ steelhead trout (n = 3,660), 13.8 ^{o}C for 1+ steelhead trout (n = 183), and 17.9 ^{o}C for 2+ steelhead trout (n = 22). The peak catch of 0+ Chinook salmon consisted of fingerlings (100%), and the peak catch of 0+ trout was mostly comprised (60%) of emergent fry (Avg. FL < 34 mm). The two peaks in 0+ Chinook salmon catches occurred during small increases in gage height (0.24 and 0.74 in.). Most of the peaks in 0+ steelhead trout catches were associated with the slowly descending limb of the hydrograph; however, a peak catch on July 19th occurred when the stream dropped 1.2 inches. Most of the peaks in 1+ steelhead trout catches also occurred during the slowly descending limb; however, a peak catch on June 7th occurred when the stream dropped 0.36 inches. 2+ SH showed more variation than younger age classes: two peaks in catches occurred with a six and seven inch increase in gage height, and a third peak occurred with a small decrease (0.36 in.) in gage height. The largest peak in 2+ steelhead trout catches occurred when the stream was slowly dropping (descending limb of hydrograph).

By Week

The transformed weekly catches of 0+ Chinook salmon were not significantly related to week number (Correlation, $p > 0.05$, $r = 0.40$, positive slope) or stream temperature (Regression, $p > 0.05$, $R^2 = 0.16$, positive slope). Transformed weekly catches were negatively related to gage height (Regression, $p < 0.05$, $R^2 = 0.32$, negative slope), negatively related to stream discharge (Regression, $p < 0.05$, $R^2 = 0.36$, negative slope), and positively related to trapping efficiencies (Regression, $p < 0.05$, $R^2 = 0.31$, positive slope) (Appendix 7).

The transformed catches of 0+ SH were positively related to week number (Correlation, $p < 0.01$, $r = 70$, positive slope), negatively related to gage height (Regression, $p < 0.00001$, $R^2 = 0.66$, negative slope), negatively related to stream discharge (Regression, $p < 0.000001$, $R^2 = 0.74$, negative slope), and positively related to stream temperature (Regression, $p < 0.01$, $R^2 = 0.46$, positive slope) (Appendix 7).

1+ steelhead trout weekly catches were not significantly related to any variable tested ($p > 0.05$ for each test) (Appendix 7). 2+ steelhead trout weekly catches were also not significantly related to any variable tested ($p > 0.05$ for each test) (Appendix 7).

Trapping Efficiencies

0+ Chinook Salmon

We fin clipped and released 3,269 young-of-year Chinook salmon upstream of the trap site during 48 efficiency trials over the course of trapping in YR 2007. The average number used in our weekly trials (includes 1 - 4 trials) equaled 203, and ranged from 6 - 381 (per week). Weekly trapping efficiencies in YR 2007 ranged from 3.4 – 48.3%, and averaged 23.8% (Table 6). Average weekly and seasonal (total number of recaptures/total number marked) trapping efficiencies in YR 2007 were much less than efficiencies for the previous seven year average (Table 6).

0+ Chinook salmon weekly trap efficiencies in YR 2007 significantly increased over time (Correlation, $p < 0.000001$, $r = 0.93$, positive slope, power = 1.00), were negatively related to the transformed gage height (Regression, $p < 0.0001$, $R^2 = 0.85$, negative slope, power = 1.00), and negatively related to average stream discharge (Regression, $p < 0.0001$, $R^2 = 0.77$, negative slope, power = 0.99).

Table 6. Comparison of 0+ Chinook salmon trapping efficiency in YR 2007 with the previous seven year average, Upper Redwood Creek, Humboldt County, CA.

	0+ Chinook salmon trap efficiency (percentage)		
	Weekly trapping efficiency		
Study Year	Range	Average	Seasonal
2007	3.4 - 48.3	23.8	26.4
2000-06	20.2 - 68.4*	43.0	42.1**

* Range in average weekly trapping efficiency per study year.
** Average of seasonal trap efficiencies.

1+ Steelhead Trout

We fin clipped and released 1,586 1+ steelhead trout upstream of the trap site during 48 efficiency trials over the course of trapping in YR 2007. The average number used in our weekly trials (includes 2 - 6 efficiency trials) equaled 110, and ranged from 13 - 191 (per week). Weekly trapping efficiencies in YR 2007 ranged from 10.7 – 21.5%, and averaged 14.9% (Table 7). Average weekly and seasonal (total number of recaptures/total number of marked releases) trapping efficiencies in YR 2007 were much less than efficiencies for the previous seven year average (Table 7).

1+ steelhead trout trap efficiencies in YR 2007 did not statistically change over time (Correlation, $p > 0.05$, negative slope, $r = 0.46$, power = 0.40). Trap efficiencies were also not statistically related to gage height (Regression, $p > 0.05$, positive slope, $R^2 = 0.23$, power = 0.44), or stream discharge (Regression, $p > 0.05$, positive slope, $R^2 = 0.22$, power = 0.43).

Table 7. Comparison of 1+ steelhead trout trapping efficiency in YR 2007 with the previous seven year average, Upper Redwood Creek, Humboldt County, CA.

	1+ Steelhead Trout Trap Efficiency (percentage)		
	Weekly trapping efficiency		
Study Year	Range	Average	Seasonal
2007	10.7 – 21.5	14.9	14.7
2000-06	13.6 – 42.3*	25.7	26.6**

* Range in the average weekly trapping efficiency per study year.
** Average of seasonal trap efficiencies.

2+ Steelhead Trout

We fin clipped and released 337 2+ steelhead trout upstream of the trap site during 45 efficiency trials over the course of trapping in YR 2007. The average number used in our weekly trials (includes 2 - 5 efficiency trials) was 23, and ranged from 9 - 47 (per week).

Weekly trapping efficiencies in YR 2007 ranged from 10.3 – 21.1%, and averaged 15.3% (Table 8). Average weekly and seasonal (total number of recaptures/total number marked) trapping efficiencies in YR 2007 were slightly less than efficiencies for the previous seven year average (Table 8).

Similar to 1+ steelhead trout trap efficiencies, 2+ steelhead trout trap efficiencies were not statistically related to time (Correlation, $p > 0.05$, negative slope, $r = 0.14$, power = 0.07), gage height (Regression, $p > 0.05$, positive slope, $R^2 = 0.02$, power = 0.07), or stream discharge (Regression, $p > 0.05$, positive slope, $R^2 = 0.00$, power = 0.06).

Table 8. Comparison of 2+ steelhead trout trapping efficiency in YR 2007 with the previous seven year average, Upper Redwood Creek, Humboldt County, CA.

	2+ Steelhead Trout Trap Efficiency (percentage)		
	Weekly trapping efficiency		
Study Year	Range	Average	Seasonal
2007	10.3 – 21.1	15.3	14.5
2000-06	10.9 – 26.2*	18.1	19.3**

* Range in the average weekly trapping efficiency per study year.
** Average of seasonal trap efficiencies.

Population Estimates

0+ Chinook Salmon

The population estimate (or production) of 0+ Chinook salmon emigrating from upper Redwood Creek in YR 2007 equaled 68,283 with a 95% CI of 59,378 – 77,189. Population estimate error (or uncertainty) equaled ± 13.0% or about 8,905 individuals. Population emigration in YR 2007 was 2.6 times greater than emigration in YR 2006 (N = 26,093, and 76.3% less than the previous seven year average ($Nav_7 = 288,619$).

Correlation of time (study year) on population estimates indicated a non-significant, negative relationship ($p = 0.13$, $r = 0.58$, power = 0.32) (Figure 7).

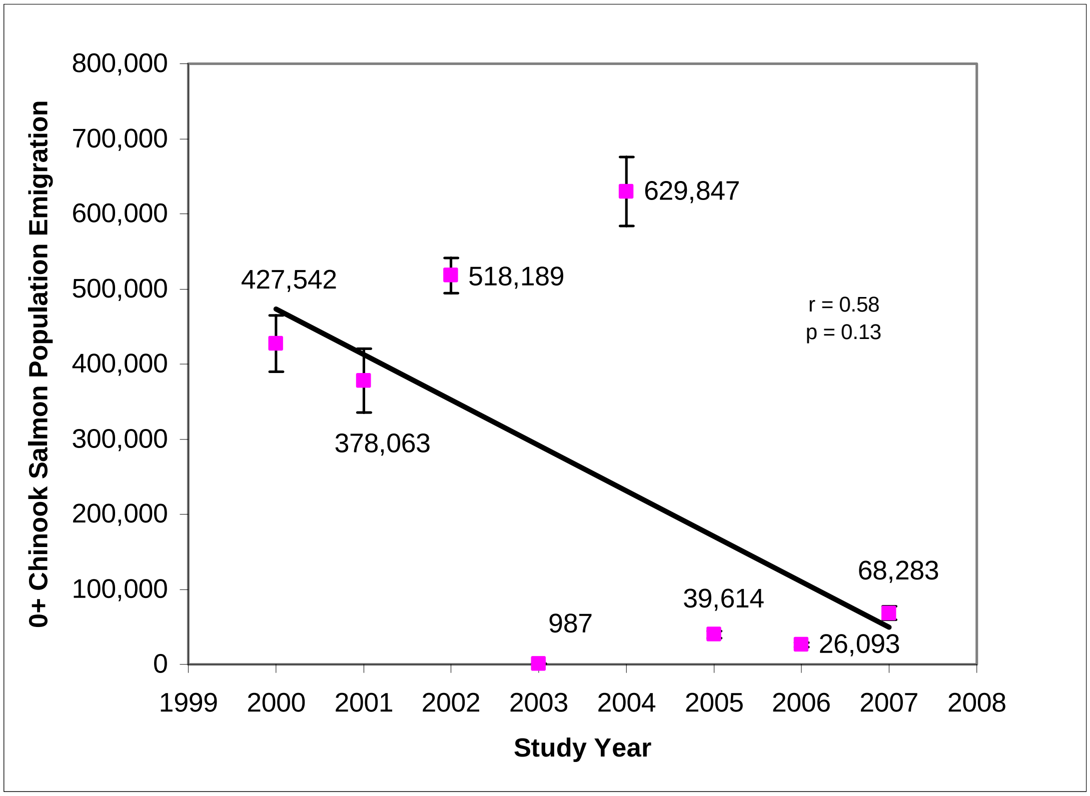

Figure 7. 0+ Chinook salmon population estimates (error bars are 95% confidence interval) in eight consecutive years. Lack of 95% CI for YRS 2003, 2005, 2006, and 2007 is due to scale of Y axis. Numeric values next to box represent number of individuals. Line of best fit is a regression line, with corresponding equation, correlation value (r), and p value.

Relationship of Potential Redd Scour with Population Emigration

There were no peaks in stream discharge (> 5,500 cfs) that were considered capable of scouring adult Chinook salmon redds for the YR 2007 cohort. The greatest peak occurred on 1/03/07 and equaled 2,780 cfs.

Using the regression equation modeled with data from YRS 2000-06 ($Y = -466178.9x + 488410.3$, where $x = 0$ for non bedload mobilizing flows, and $x = 1$ for bedload mobilizing flows), the expected population size of 0+ Chinook salmon in YR 2007 ($\hat{Y}$) equaled 488,410 individuals. The mark/recapture estimate of 68,283 in YR 2007 was 86% less than the expected value. Thus, the model failed to accurately predict the numbers emigrating in YR 2007.

The overall model including data from YR 2007 (and YRS 2000 – 06) remained significant ($p < 0.05$). Linear regression detected a significant negative relationship with bedload mobilizing flows during egg incubation (and embryogenesis) in spawning redds and the subsequent 0+ Chinook salmon population estimate for the eight consecutive study years ($p < 0.02$, $R^2 = 0.60$, slope is negative, and power = 0.71). The variation in peak stream flow (in this case, bedload mobilizing flow and non-bedload mobilizing flow) during redd incubation periods explained 60% of the variation in seasonal 0+ Chinook salmon population estimates (production).

The number of 0+ Chinook salmon (at population level) per mile, kilometer, and watershed acres upstream of the trap site in YR 2007 was about 76% less than values for the previous seven year average (Table 9).

Table 9. Estimated population of 0+ Chinook salmon per stream mile, stream kilometer, and watershed acreage upstream of the trap site, YRS 2000 - 2007.

Study Year	0+KS/mi	0+KS/km	0+KS/acre
2000	11,555	7,186	6.58
2001	10,218	6,354	5.82
2002	14,005	8,709	7.97
2003	27	17	0.01
2004	17,023	10,586	9.69
2005	1,071	666	0.61
2006	705	439	0.40
Average:	7,801	4,851	4.44
2007	1,845	1,148	1.05

0+ Chinook salmon population emigration by month in YR 2007 was severely reduced compared to emigration by month for the previous seven year average (Figure 8). The biggest reductions in YR 2007 occurred in April (78.7% or 87,091 individuals), and May (82.0% or 78,760 individuals).

The majority of 0+ Chinook salmon population emigration occurred in April and June in YR 2007 (70.6% of total) compared to April and May for the previous seven year average (71.6% of total) (Figure 8). Population emigration during April – June accounted for 96.0% of the total for YR 2007 compared to 96.2% of the total for the previous seven year average.

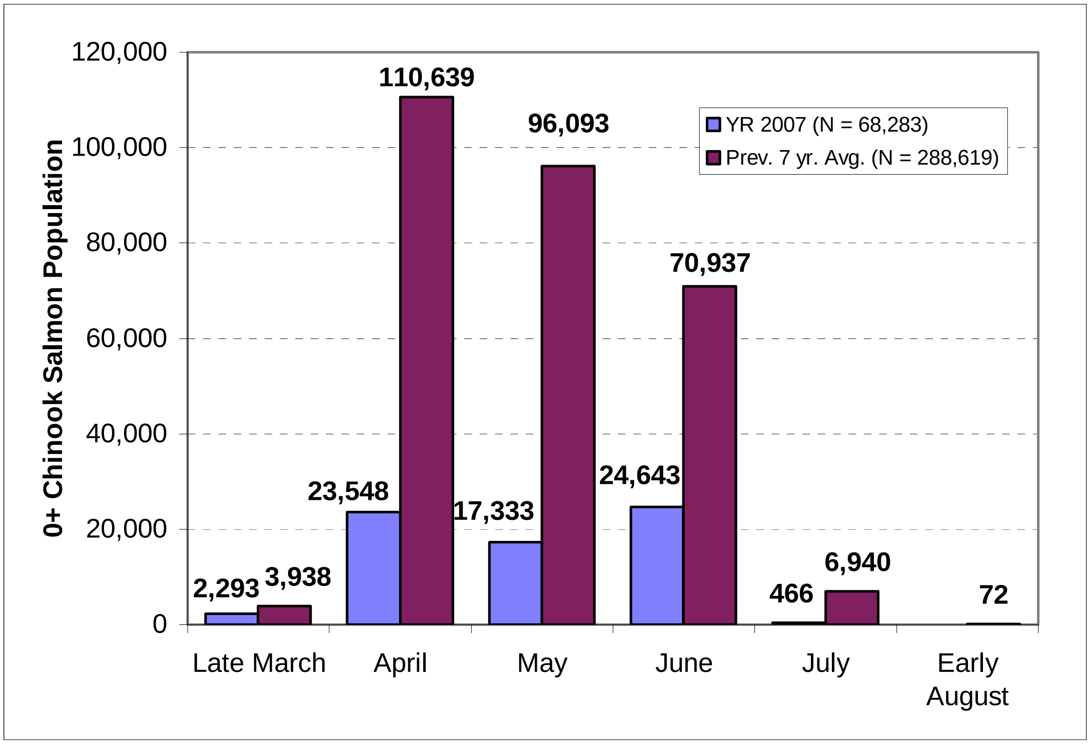

Figure 8. Comparison of 0+ Chinook salmon population emigration by month in YR 2007 with the previous seven year average, upper Redwood Creek, Humboldt County, CA. Numeric values above columns represent number of individuals.

The peak in weekly population emigration in YR 2007 occurred 6/04 – 6/10 (Table 10, Figure 9). For the eight years of data, two peaks occurred in April, one occurred in May, one occurred in late May/early June, and four peaks occurred in June (Table 10). The largest weekly peak occurred in YR 2004 (N = 165,782 individuals) and the smallest occurred in YR 2003 (N = 316 individuals) (Table 10). The average FL (mm) for 0+ Chinook salmon migrants during the two modes in emigration in YR 2007 equaled 38.1 mm for 4/09 – 4/15, and 58.7 mm for 6/04 – 6/10 (Figure 9).

Table 10. Date of peak weekly 0+ Chinook salmon population emigration by study year (number of individuals in parentheses).

Study Year	Date of peak in weekly out-migration (number in parentheses)
2000	5/28 - 6/03 (56,457)
2001	5/07 - 5/13 (79,848)
2002	6/04 - 6/10 (63,093)
2003	6/11 - 6/17 (316)
2004	4/09 - 4/15 (165,782)
2005	4/23 - 4/29 (9,059)
2006	6/18 - 6/24 (4,287)
2007	6/04 - 6/10 (12,564)

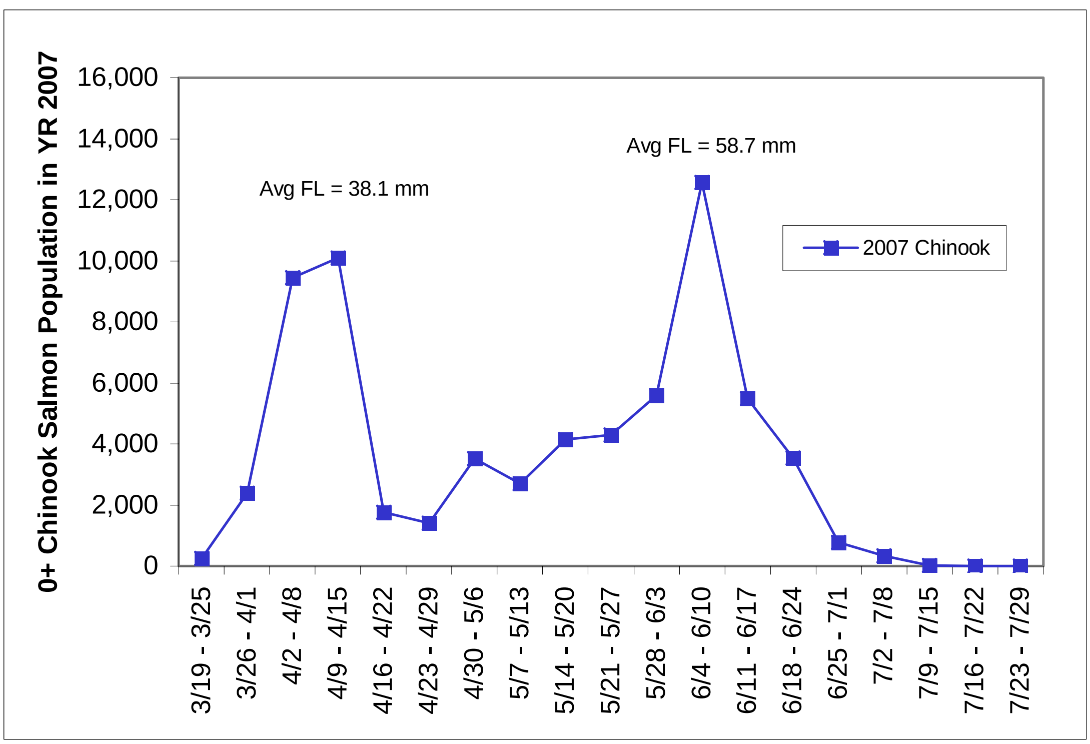

Figure 9. 0+ Chinook salmon population emigration by week in YR 2007, upper Redwood Creek, Humboldt County, CA.

The number and percentage of 0+ Chinook salmon migrants grouped into fry or fingerling categories varied among study years (Table 11). In YR 2007, 46% of the migrants were estimated as fry, and 54% were estimated as fingerlings. The previous seven year average (N = 288,619) consisted of 53% fry and 47% fingerlings. A statistically lesser proportion of fry and a higher proportion of fingerlings were present in YR 2007 compared to the previous seven year average (Chi-square, $p < 0.0001$). There was a significant, non-random distribution in the percentages of fry and fingerlings in YR 2007 as well (Chi-square, $p < 0.0001$).

The percentage of fry over study years was not influenced by emigrant population size, stream temperature, WY stream discharge, and average stream discharge during the trapping season (Regression, $p > 0.10$ for all tests).

Table 11. Comparison of the production of 0+ Chinook salmon partitioned into fry and fingerling categories each study year (percentage of total for each year in parentheses), upper Redwood Creek, Humboldt County, CA.

	0+ Chinook salmon production as:	
Study Year	Fry (FL < 45mm)	Fingerling (FL > 44 mm)
2000	139,316 (33)	288,226 (67)
2001	226,351 (60)	151,712 (40)
2002	245,024 (47)	273,165 (53)
2003	8 (1)	979 (99)
2004	434,400 (69)	195,447 (31)
2005	22,957 (58)	16,657 (42)
2006	10,390 (40)	15,703 (60)
7 yr avg.	154,064 (53)	134,555 (47)
2007	31,615 (46)	36,668 (54)

0+ Chinook salmon fry and fingerling migrants showed differences in abundance and migration timing in YR 2007 and for the previous seven year average (Figure 10). For the previous seven year average, fry migration generally occurred near the onset of trapping (except in YR 2001, juvenile Chinook salmon did not emigrate until 4/16), peaked during 4/9 – 4/15, and gradually diminished to low values by early June; fingerling migration began in early to mid April, reached peaks during 5/28 – 6/10, and gradually decreased to low values by late July (Figure 10). In YR 2007, fry (Avg. FL = 39.0 mm) migration also occurred near the onset of trapping, reached a peak value during the same week as for the previous seven year average (4/9 – 4/15), and decreased to low values by the end of May; fingerling (Ave. FL = 61.0 mm) migration began in late April/early May, reached a peak during the same week as for the previous seven year average (6/4 – 6/10), and descended to low values near the beginning of July (Figure 10). The noticeable two modes to the distributions for YR 2007 and the previous seven year average do not indicate two different runs of adult Chinook salmon entered upper Redwood Creek because of great differences in FL or Wt. For example, average FL for fry during 4/09/07 – 4/15/0 was 38.1 mm, compared to the average fingerling FL of 58.7 mm for 6/04/07 – 6/10/07. Had there been two runs of adults at different times, we would expect the FL's during 6/04 – 6/10 to be nearly the same as 4/09/07 – 4/15/07.

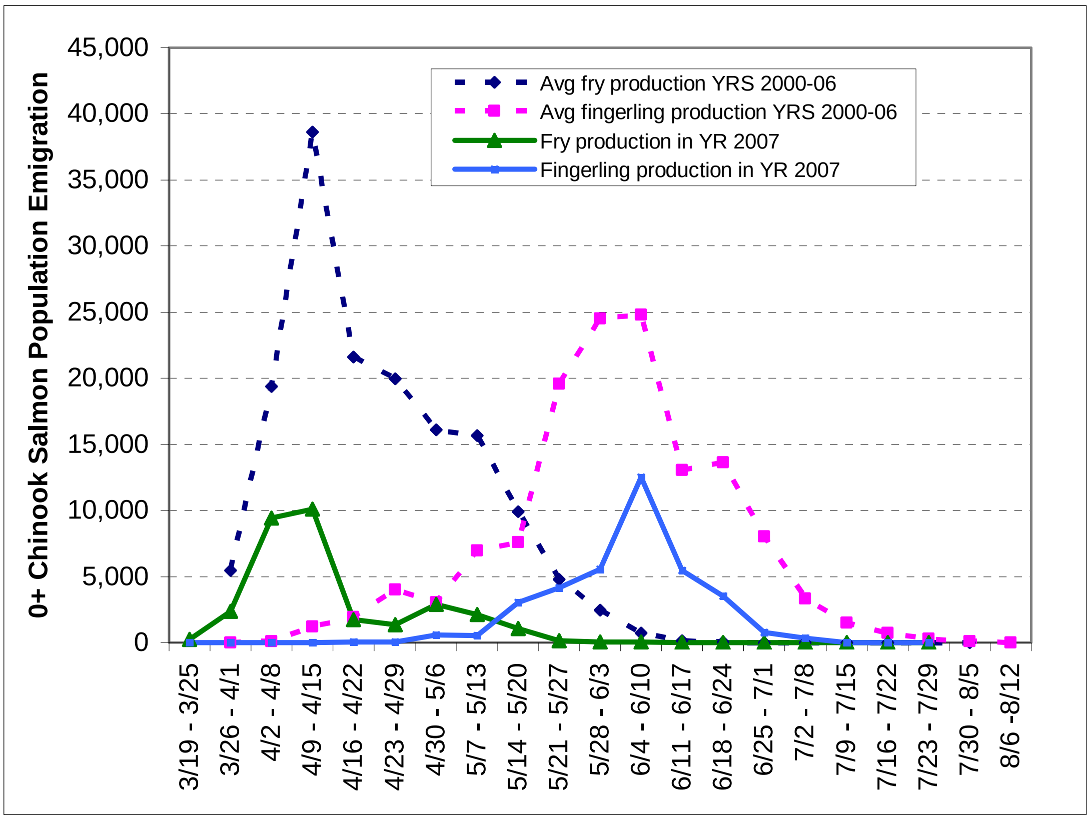

Figure 10. Comparison of 0+ Chinook salmon fry and fingerling abundance and migration timing in YR 2007 with previous seven year average, upper Redwood Creek, Humboldt County, CA.

<u>1+ Steelhead Trout</u>

The population estimate (or production) of 1+ steelhead trout emigrating from upper Redwood Creek in YR 2007 equaled 34,431 with a 95% CI of 29,697 – 39,165. Population estimate error (or uncertainty) equaled $\pm$ 13.8% or 4,734 individuals. Population emigration in YR 2007 was 32% higher than emigration in YR 2006 (N = 26,248), and 11% lower than the previous seven year average (N = 38,748).

Correlation of time (study year) on yearly population estimates showed a significant negative relationship ($p < 0.10$, $r = 0.70$, power = 0.52) (Figure 11).

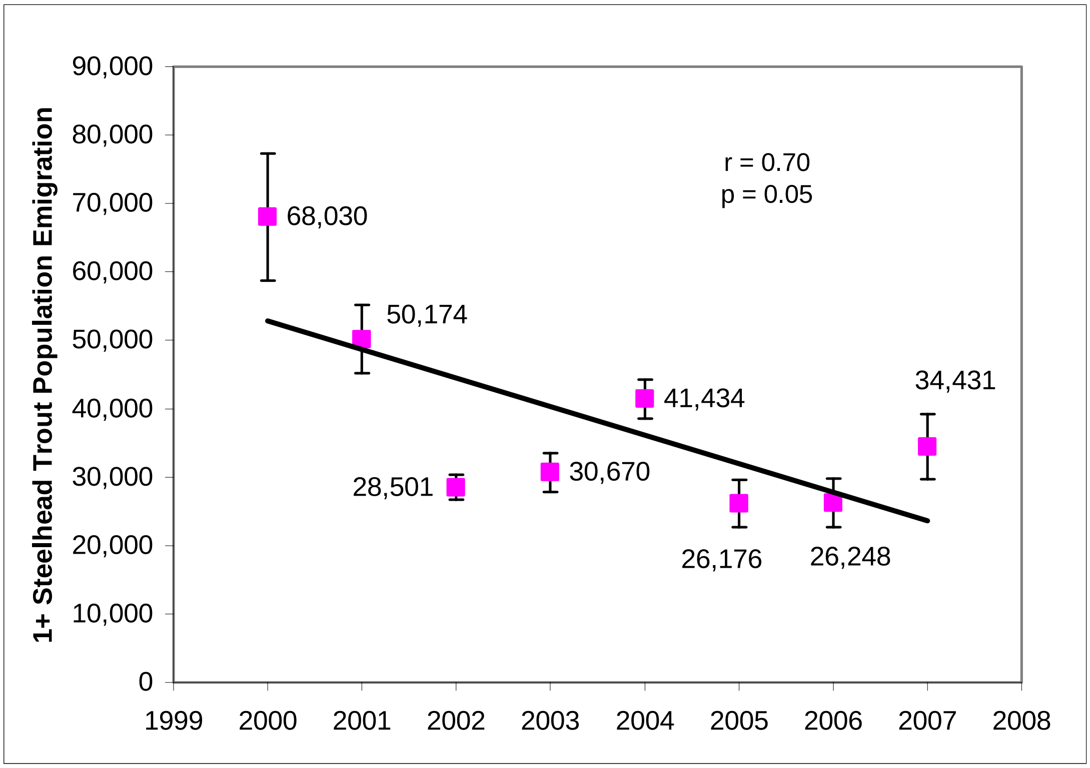

Figure 11. 1+ steelhead trout population estimates (error bars are 95% confidence interval) in eight consecutive years. Numeric values next to box represent number of individuals. Line of best fit is a regression line, with corresponding equation, correlation value (r), and p value.

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 11% less than values for the previous seven year average (Table 12). Highest values occurred in YR 2000 and lowest values occurred in YR 2005.

Table 12. Estimated population of 1+ steelhead trout per stream mile, stream kilometer, and watershed acreage upstream of the trap site, YRS 2000 - 2007.

Study Year	1+SH/mi	1+SH/km	1+SH/acre
2000	1,839	1,143	1.05
2001	1,356	843	0.77
2002	770	479	0.44
2003	829	515	0.47
2004	1,120	696	0.64
2005	707	440	0.40
2006	709	441	0.40
Average:	1,047	651	0.60
2007	931	579	0.53

1+ steelhead trout monthly population emigration in YR 2007 was less than monthly emigration for the previous seven year average, except for the month of June (Figure 12). Emigration peaked in May in YR 2007 (N = 16,724 or 49% of total) and for the previous seven year average (N= 17,015 or 44% of total) (Figure 12). In YR 2007, 28,947 individuals (or 84% of total) emigrated in May and June, compared to 26,704 (or 69% of total) migrants that emigrated in April and May for the previous seven year average. The largest reduction in emigration in YR 2007 occurred during April (N = 4,717 or 49% less than previous seven year average for April; emigration during late March and July in YR 2007 was also severely reduced (reduction of 74 – 90%). The pattern of emigration in YR 2007 was similar to the pattern for the previous seven year average (Figure 12).

The peak in 1+ steelhead trout weekly emigration in YR 2007 occurred during the same week as in YR 2000, and was the third highest in number (Table 13). For the eight study years, six peaks occurred during May and two peaks occurred during late April. The largest weekly peak occurred in YR 2000 (N = 16,244), and the smallest occurred in YR 2006 (N = 4,062) (Table 13).

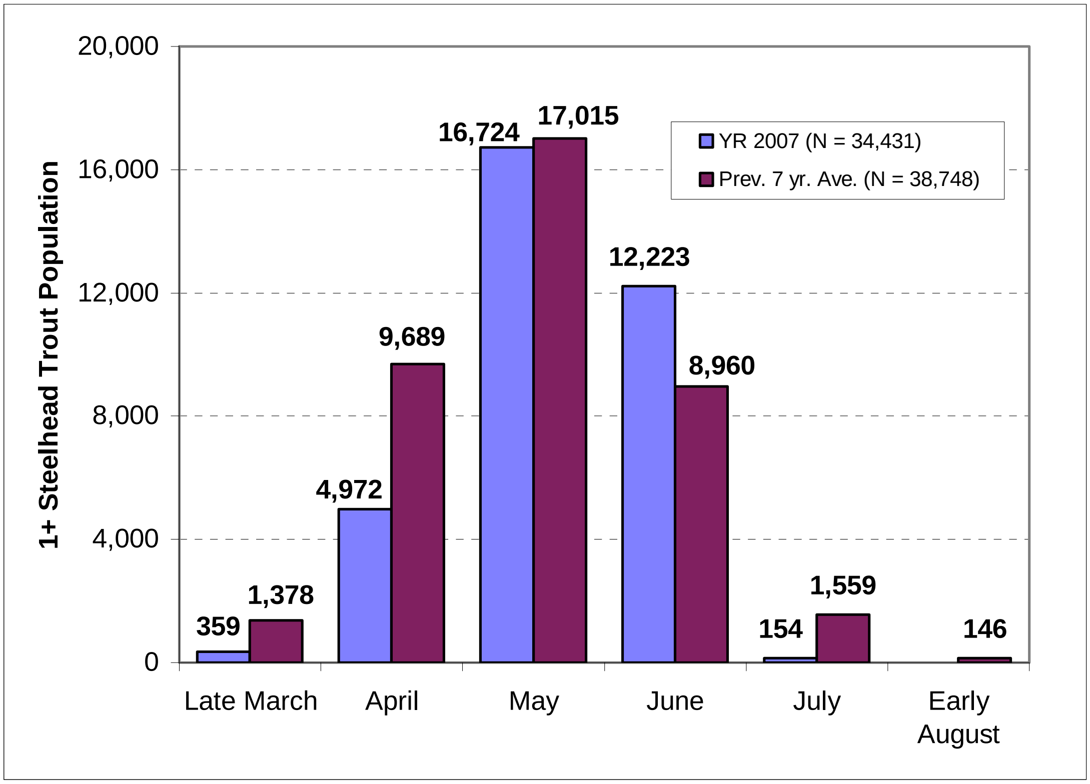

Figure 12. Comparison of 1+ steelhead trout population emigration by month in YR 2007 with the previous seven year average, upper Redwood Creek, Humboldt County, CA. Numeric values above columns represent number of individuals.

Table 13. Date of peak weekly 1+ steelhead trout population emigration by study year (number of individuals in parentheses).

Study Year	Date of peak in weekly out-migration (number in parentheses)
2000	5/07 - 5/13 (16,244)
2001	4/23 - 4/29 (6,963)
2002	5/14 - 5/20 (4,180)
2003	5/14 - 5/20 (4,483)
2004	5/14 - 5/20 (6,659)
2005	4/23 - 4/29 (4,834)
2006	5/21 - 5/27 (4,062)
2007	5/07 - 5/13 (6,777)

2+ Steelhead Trout

The population estimate (or production) of 2+ steelhead trout emigrating from upper Redwood Creek in YR 2007 equaled 2,861 with a 95% CI of 2,196 – 3,525 (Figure 13). Population estimate error (or uncertainty) equaled $\pm$ 23.2% or 665 individuals. Population emigration in YR 2007 was 53% greater than emigration in YR 2006 (N = 1,866), and 47% lower than the previous seven year average (N = 5,366).

Correlation of time (study year) on yearly population estimates showed a significant negative relationship ($p < 0.10$, $r = 0.64$, power = 0.40) (Figure 13).

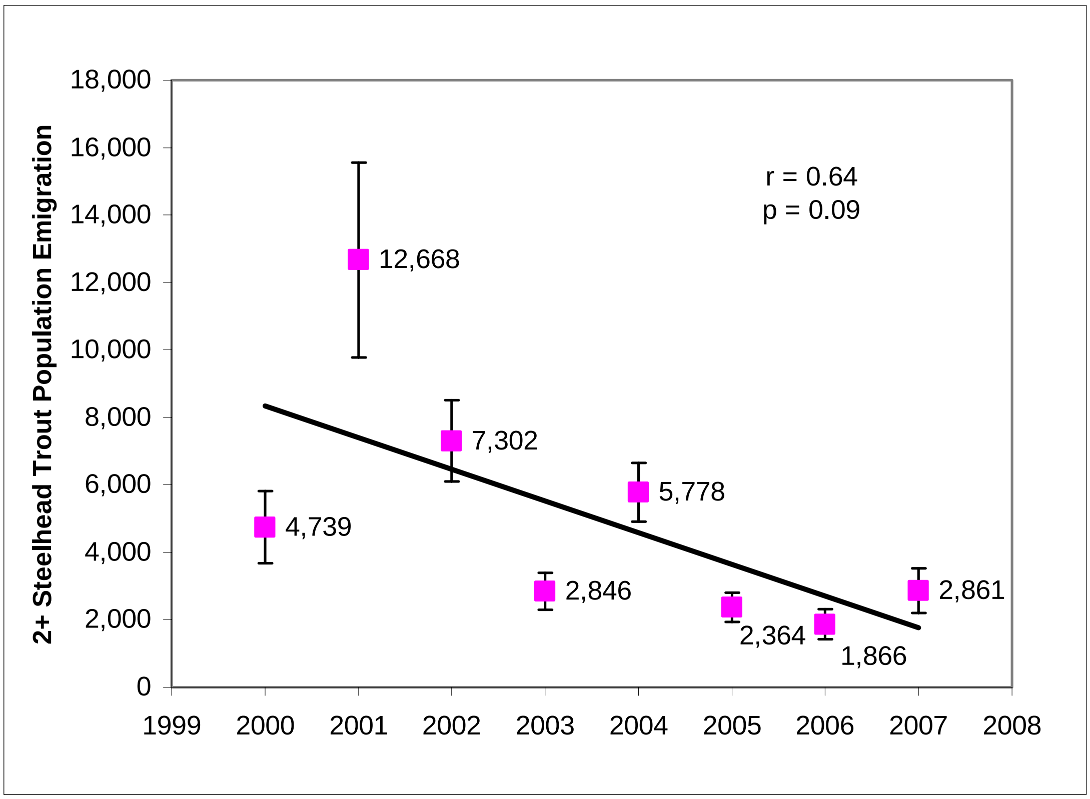

Figure 13. 2+ steelhead trout population estimates (error bars are 95% confidence interval) in eight consecutive years. Numeric values next to box represent number of individuals. Line of best fit is a regression line, with corresponding equation, correlation value (r), and p value.

The number of 2+ steelhead trout (at population level) per mile, kilometer, and watershed acreage upstream of the trap site in YR 2007 was about 47% less than values for the previous seven year average (Table 14). Highest values occurred in YR 2001 and lowest values occurred in YR 2006.

Table 14. Estimated population of 2+ steelhead trout per stream mile, stream kilometer, and watershed acreage upstream of the trap site, YRS 2000 - 2007.

Study Year	2+SH/mi	2+SH/km	2+SH/acre
2000	128	80	0.07
2001	342	213	0.19
2002	197	123	0.11
2003	77	48	0.04
2004	156	97	0.09
2005	64	40	0.04
2006	50	31	0.03
Average:	145	90	0.08
2007	77	48	0.04

2+ steelhead trout monthly population emigration in YR 2007 was less than monthly emigration for the previous seven year average, except for the month of June (Figure 14). Emigration peaked in June in YR 2007 (N = 1,185 or 41% of total) compared to April for the previous seven year average (N = 1,836 or 34% of total) (Figure 14). In YR 2007, 1,942 individuals (or 68% of total) emigrated in May and June, compared to 3,600 (or 67% of total) migrants that emigrated in April and May for the previous seven year average. The largest reduction in population emigration in YR 2007 occurred during April (1,124 individuals or 61% reduction); emigration during May and July in YR 2007 was also severely reduced (reduction of 57 – 91%).

The peak in 2+ steelhead trout weekly emigration in YR 2007 occurred early June (Table 15). For the eight study years, four peaks occurred during April, three peaks occurred during May, and one peak occurred in June. The largest weekly peak occurred in YR 2001 (N = 1,463), and the smallest occurred in YR 2003 (N = 363) (Table 15).

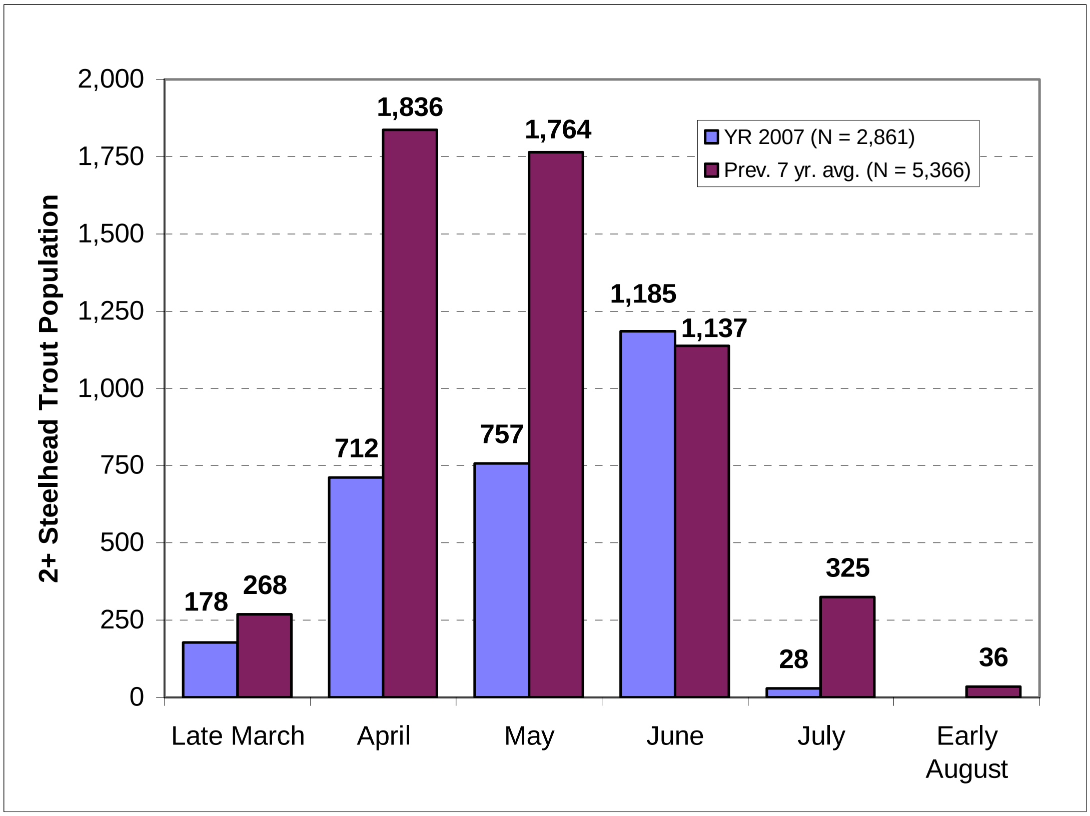

Figure 14. Comparison of 2+ steelhead trout population emigration by month in YR 2007 with the previous seven year average, upper Redwood Creek, Humboldt County, CA. Numeric values above columns represent number of individuals.

Table 15. Date of peak weekly 2+ steelhead trout population emigration by study year (number of individuals in parentheses).

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

Linear Relations of weekly population emigration for 0+ Chinook salmon, 1+ steelhead trout, and 2+ steelhead trout with Stream Gage Height, Stream Discharge, and Stream Temperature averaged by week, and Time (trapping week number)

The transformed 0+ Chinook salmon weekly population emigration was positively related to the stream discharge (cfs) (Regression, $p < 0.05$, $R^2 = 0.29$), and negatively related to stream temperature (Regression, $p < 0.05$, $R^2 = 0.35$) and week number (Correlation, $p < 0.01$, $r = 0.63$) (Appendix 8). The variation in stream temperature explained 35% of the variation in weekly population emigration.

1+ steelhead trout weekly population emigration was not significantly related to week number, gage height, stream discharge, or stream temperature (Regression, $p > 0.05$) (Appendix 8). 2+ steelhead trout weekly population emigration was also not significantly related to week number, gage height, stream discharge, or stream temperature (Regression, $p > 0.05$) (Appendix 8).

Age Composition of Juvenile Steelhead Trout

The following percentages represent maximum values for 1+ and 2+ steelhead trout because their population estimates were compared to catches of 0+ steelhead trout (ie the actual catches of 0+ steelhead trout are less than expected 0+ steelhead trout population out-migration). Far more 0+ steelhead trout migrated downstream than either 1+ or 2+ steelhead trout on a percentage basis (Table 16). In YR 2007, the ratio of 0+ steelhead trout to 1+ steelhead trout to 2+ steelhead trout equaled 24:12:1 compared to the previous seven year average ratio of 16:7:1. In YR 2006, the ratio was 26:14:1. The ratio of 1+ steelhead trout to 2+ steelhead trout was 12:1 in YR 2007, and 7:1 for the previous seven year average.

Table 16. Comparison of 0+ steelhead trout, 1+ steelhead trout, and 2+ steelhead trout percent composition of total juvenile steelhead trout downstream migration in YR 2007 with the previous seven year average, upper Redwood Creek, Humboldt County, CA.

	Percent composition of total juvenile steelhead trout out-migration		
Study Year	0+ steelhead*	1+ steelhead	2+ steelhead
2007	64.8	32.5	2.7
Prev. 7 yr Avg.	64.9	31.3	3.8
All years combined	66.0	30.0	4.0

* Uses actual catches instead of population estimate.

Relationships Between Juvenile Steelhead Age Classes

1+ steelhead trout population estimates (y variable, YRS 2001 - 2007) were not significantly related to the previous year's 0+ steelhead trout catches (x variable, YRS 2000 - 2006) (Regression, $p > 0.10$, $R^2 = 0.09$, slope sign is negative, power = 0.09); 2+ steelhead trout population estimates (y variable, YRS 2002 - 2007) were not related to 0+ steelhead trout catches in YRS 2000 – 2005 (x variable, Regression, $p > 0.10$, $R^2 = 0.09$, slope is negative, power = 0.08).

A significant positive relationship was found for the relationship of 1+ steelhead trout population estimates on the following year's 2+ steelhead population estimate ($p < 0.05$, $R^2 = 0.79$, slope is positive, power = 0.93).

We detected a significant, positive correlation between 1+ and 2+ steelhead trout population emigration by week in YR 2007 (correlation, $p < 0.05$; $r = 0.53$; power = 0.65), similar to past study years. The pattern of weekly outmigration for 1+ and 2+ steelhead trout tracked fairly well, such that when 2+ steelhead trout migration increased, decreased, or remained stable, so did 1+ steelhead trout migration for many (12/19 or 63%) of the weeks.

Fork Lengths and Weights

<u>0+ Chinook Salmon</u>

We measured (FL mm) 2,811 and weighed (g) 2,127 0+ Chinook salmon in YR 2007 (Table 17). Average FL in YR 2007 was about 7% less than the average FL in YR 2006; average Wt in YR 2007 was about 25% less than the average Wt in YR 2006 (Table 17). Average FL and Wt in YR 2007 was lower than the previous six year average (excludes YR 2003). The mode in YR 2007 was 40 mm for FL and 0.5 g for Wt, which corresponds to the size of fry in YR 2007.

Average FL and Wt did not significantly change over study years 2000 - 2002, and 2004 – 2007 (Correlation: FL, $p = 0.86$, $r = 0.08$, slope is positive, power = 0.05; Wt, $p = 0.84$, $r = 0.09$, slope is positive, power = 0.05). Using an adjusted alpha of 0.10 to account for low sample size ($n = 8$), linear regression detected a significant negative relationship of population size on average FL's ($p = 0.09$, $R^2 = 0.40$, power = 0.39), which suggests a density-dependent relationship. No significant relationship was found between average Wt and population size (Regression, $p = 0.10$, $R^2 = 0.39$, negative slope, power = 0.37)

Table 17. 0+ Chinook salmon population estimates, and average fork length (mm) and weight (g) for study YRS 2000 - 2007, upper Redwood Creek, Humblodt County, CA.

	0+ Chinook Salmon						
		Fork Length (mm)			Weight (g)		
Study Year	(N)*	n	Avg.	SEM**	n	Avg.	SEM**
2000	427,542	3,661	55.5	0.2	913	2.03	0.04
2001	378,063	2,719	51.9	0.2	778	1.73	0.04
2002	518,189	3,517	52.4	0.2	1,545	1.70	0.03
2003	987	573	67.3	0.3	499	3.43	0.05
2004	629,847	3,571	50.8	0.2	1,593	1.61	0.03
2005	39,614	2,489	60.4	0.3	1,751	3.09	0.05
2006	26,093	2,123	55.5	0.3	1,684	2.07	0.04
6 yr Avg.***			54.4	1.4		2.04	0.22
2007	68,283	2,811	51.6	0.2	2,127	1.55	0.03

* "N" denotes emigrant population size; "n" denotes sample size for FL and Wt.
** Standard error of mean.
***Average for FL and Wt does not include YR 2003.

0+ Chinook salmon average weekly FL's in YR 2007 were numerically close to values for the six year average during the first seven weeks of trap operation (Figure 15). Average FL for the first eight weeks in YR 2007 were representative of newly emerged fry and post emergent fry. Average weekly FL (mm) significantly increased over time (weeks) in YR 2007 and for the six year average (Correlation, $p < 0.0001$, $r = 0.97$ and 0.99, slope is positive, power = 1.0 for each test) (Figure 15). The increases in average FL over time indicate growth was taking place, and from 4/02/07 – 7/08/07 0+ Chinook salmon grew 0.34 mm/d. Growth in YR 2005 was 0.41 mm/d, and in YR 2006 equaled 0.36 mm/d. Kruskal-Wallis One-Way ANOVA on Ranks showed that the median weekly FL in YR 2007 (52.8 mm) was not significantly different than the median weekly FL of the six year average (55.0 mm) ($p = 0.67$).

Average weekly Wt's in YR 2007 were also numerically close to values for the six year average during the first seven weeks of trap operation (Figure 16). Average weekly Wt (g) significantly increased over time (weeks) in YR 2007 and for the six year average (Correlation, $p < 0.00001$, $r = 0.95$ and 0.98, power = 1.0) (Figure 16). The increases in average Wt over time show growth was taking place, and from 4/02/07 – 7/08/07 0+ Chinook salmon grew 0.03 g/d. Growth in YR 2005 was 0.05 g/d, and in YR 2006 equaled 0.04 g/d. Median weekly Wt (g) (1.58 g) in YR 2007 was not significantly different than the median weekly Wt (1.88 g) for the previous six year average (excludes YR 2003) (Kruskal-Wallis One-Way ANOVA on Ranks , $p = 0.37$).

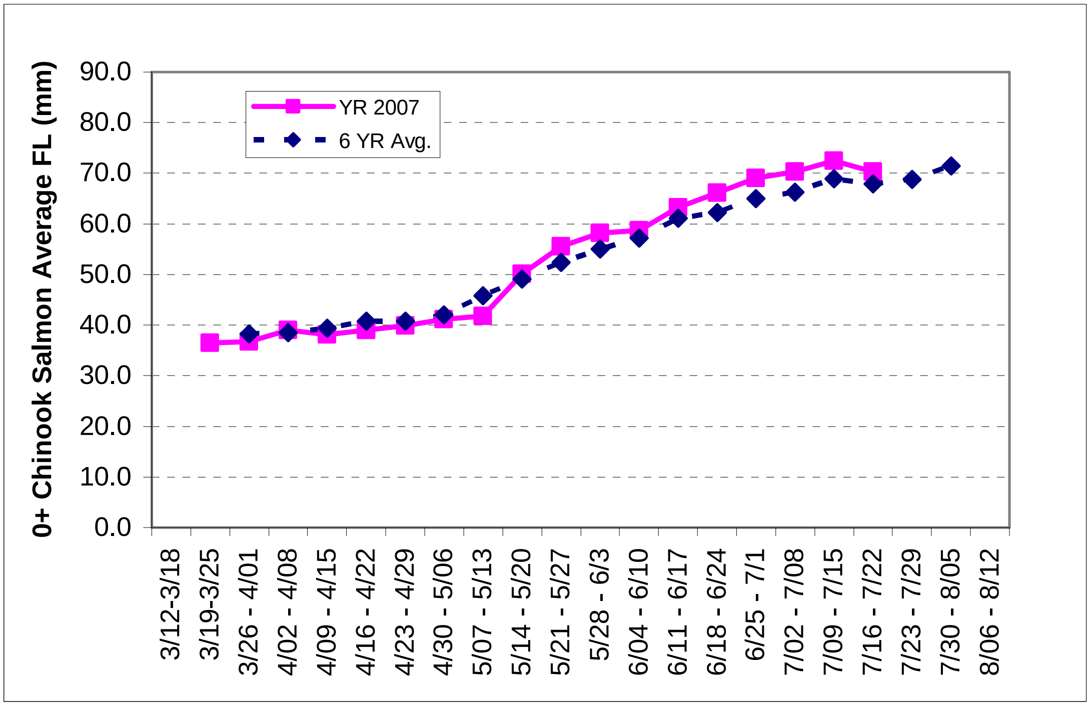

Figure 15. 0+ Chinook salmon average weekly fork lengths (mm) in YR 2007 and the average of six years, upper Redwood Creek, Humboldt County, CA.

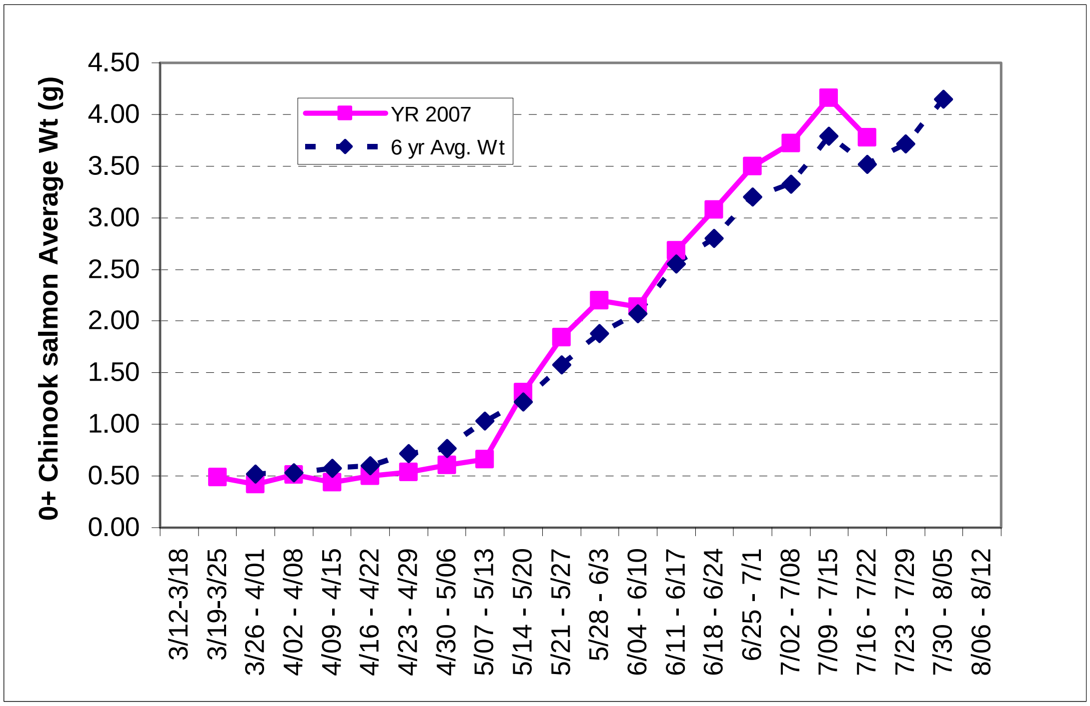

Figure 16. 0+ Chinook salmon average weekly weights (g) in YR 2007 and the average of six years, upper Redwood Creek, Humboldt County, CA.

0+ Steelhead Trout

We measured (FL mm) 2,672 0+ steelhead trout in YR 2007 (Table 18). Average FL in YR 2007 was 5.1% less than the previous seven year average (Table 18). The mode in FL in YR 2007 was 29 mm, which corresponded to the size of emergent fry.

The correlation of study years (n = 8) on average FL by season violated test assumptions, and results were not valid. Average FL by season was not linearly related to the number of steelhead trout captured each year (Regression, $p = 0.50$, $R^2 = 0.08$, power = 0.09).

Average weekly FL (mm) significantly increased over time (weeks) in YR 2007 (Correlation, $p < 0.001$, $r = 0.82$, power = 1.0) and for the previous seven year average (Correlation, $p < 0.00001$, $r = 0.96$, power = 1.0) (Figure 17). The increases in average FL over time show growth was taking place, and from 4/30/07 – 7/29/07 0+ steelhead trout grew 0.17 mm/d. Growth in YR 2006 was 0.22 mm/d. Median weekly FL (mm) (34.5 mm) in YR 2007 was not significantly different than median weekly FL (34.4 mm) for the previous seven year average (Kruskal-Wallis One-Way ANOVA on RANKS, p = 0.68).

Table 18. 0+ steelhead trout total catch and average fork length (mm) for study years 2000 - 2007, upper Redwood Creek, Humboldt County, CA.

	0+ Steelhead Trout						
		Fork Length (mm)			Weight (g)		
Study Year	(Catch)	n	Avg.	SEM*	n	Avg.	SEM*
2000	55,126	2,669	40.9	0.2	-	-	-
2001	102,408	1,136	39.0	0.3	-	-	-
2002	124,426	3,228	38.7	0.2	-	-	-
2003	102,954	3,338	38.5	0.2	-	-	-
2004	128,885	3,615	37.5	0.2	-	-	-
2005	41,671	3,661	42.3	0.2	-	-	-
2006	48,759	2,670	35.9	0.2			
7 yr Avg.			39.0	0.8		-	
2007	68,573	2,672	37.0	0.2	-	-	-

* Standard error of mean.

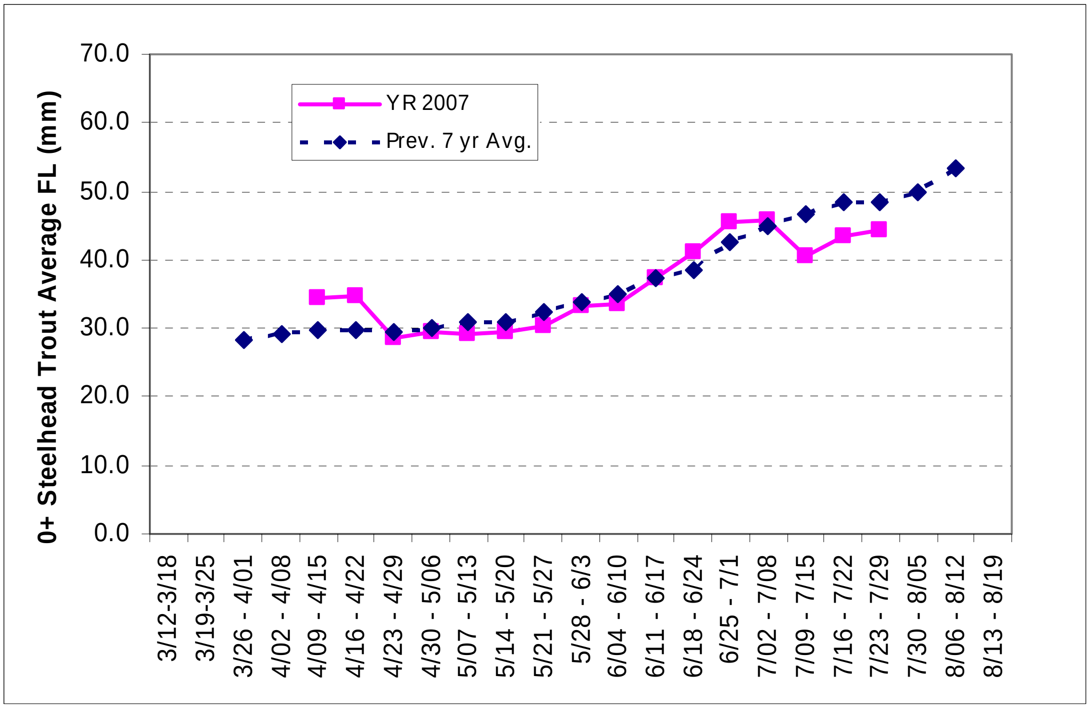

Figure 17. 0+ steelhead trout average weekly fork lengths (mm) in YR 2007 and the previous seven year average, upper Redwood Creek, Humboldt County, CA.

1+ Steelhead Trout

We measured (FL mm) 2,414 and weighed (g) 1,954 1+ steelhead trout in YR 2007 (Table 19). Average FL in YR 2007 was about 0.3% less than the average FL in YR 2006; average Wt in YR 2007 was about 0.9% less than the average Wt in YR 2006 Average FL and Wt in YR 2007 was less than values for the previous seven year average (Table 19). The modes in FL in YR 2007 were 85 and 90 mm, and the mode for Wt in YR 2007 was 10.1 g.

Average FL significantly decreased over study years 2000 - 07 (Correlation, $p < 0.05$, $r = 0.73$, slope is negative, power = 0.59); whereas average Wt did not (Correlation, $p > 0.10$, $r = 0.61$, slope is negative, power = 0.35). Linear regression detected a significant positive relationship of population estimate on average FL ($p < 0.05$, $R^2 = 0.63$, power = 0.76, n = 8), and a non-significant positive relationship for average Wt ($p > 0.10$, $R^2 = 0.33$, power = 0.30, n = 8).

Table 19. 1+ steelhead trout population estimates, and average fork length (mm) and weight (g) for study years 2000 - 2007, upper Redwood Creek, Humboldt County, CA.

	1+ Steelhead Trout						
		Fork Length (mm)			Weight (g)		
Study Year	(N)*	n	Avg.	SEM**	n	Avg.	SEM**
2000	68,030	2,721	92.4	0.2	1,455	8.29	0.09
2001	50,174	2,761	91.9	0.3	908	9.27	0.11
2002	28,501	3,049	86.7	0.3	1,356	7.79	0.14
2003	30,670	3,064	84.8	0.3	1,633	7.14	0.09
2004	41,434	3,191	85.7	0.3	1,441	7.57	0.10
2005	26,176	2,473	88.1	0.2	1,592	8.02	0.09
2006	26,248	1,961	85.7	0.3	1,683	7.48	0.09
7 yr Avg.			87.9	1.2		7.94	0.26
2007	34,431	2,414	85.4	0.3	1,954	7.41	0.09

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

The pattern of 1+ steelhead trout FL over time showed some similarity to the previous seven year average (Figure 18). Average weekly FL (mm) for 1+ steelhead trout in YR 2007 significantly increased over time (weeks) (Correlation, $p < 0.00001$, $r = 0.87$, slope is positive, power = 1.00), as did the weekly FL (mm) for the previous seven year average (Correlation, $p < 0.05$, $r = 0.45$, slope is positive, power = 0.52) (Figure 18). Median weekly FL in YR 2007 (85.6 mm) was not significantly different than the median weekly FL of the previous seven year average (87.9 mm) (Kruskal-Wallis One-Way ANOVA on Ranks, $p = 0.19$).

The pattern of 1+ steelhead trout Wt over time also showed some similarity to the previous seven year average (Figure 19). 1+ steelhead trout average weekly Wt (g) in YR 2007 significantly increased over time (weeks) (Correlation, $p < 0.0001$, $r = 0.83$, slope is positive, power = 1.00), as did the average Wt (g) by week for the previous seven year average (Correlation, $p < 0.05$, $r = 0.53$, slope is positive, power = 0.68) (Figure 19). Median weekly Wt in YR 2007 (7.32 g) was not significantly different than median weekly Wt for the previous seven year average (8.18 g) ($p = 0.14$).

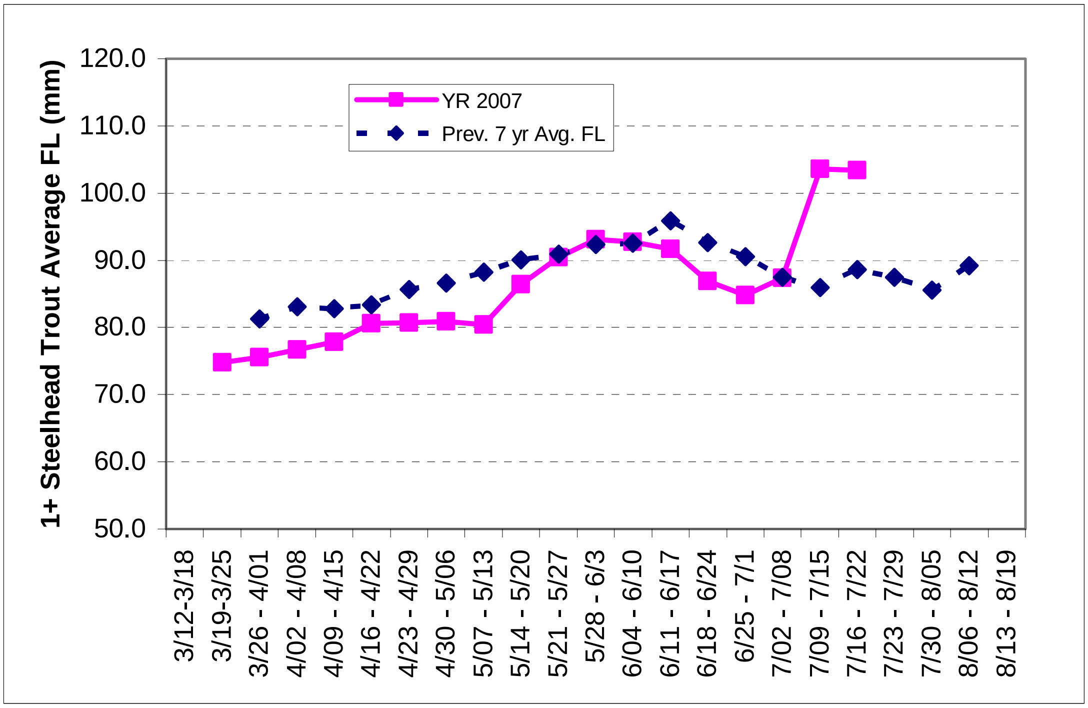

Figure 18. 1+ steelhead trout average weekly fork lengths (mm) in YR 2007 and the previous seven year average, upper Redwood Creek, Humboldt County, CA.

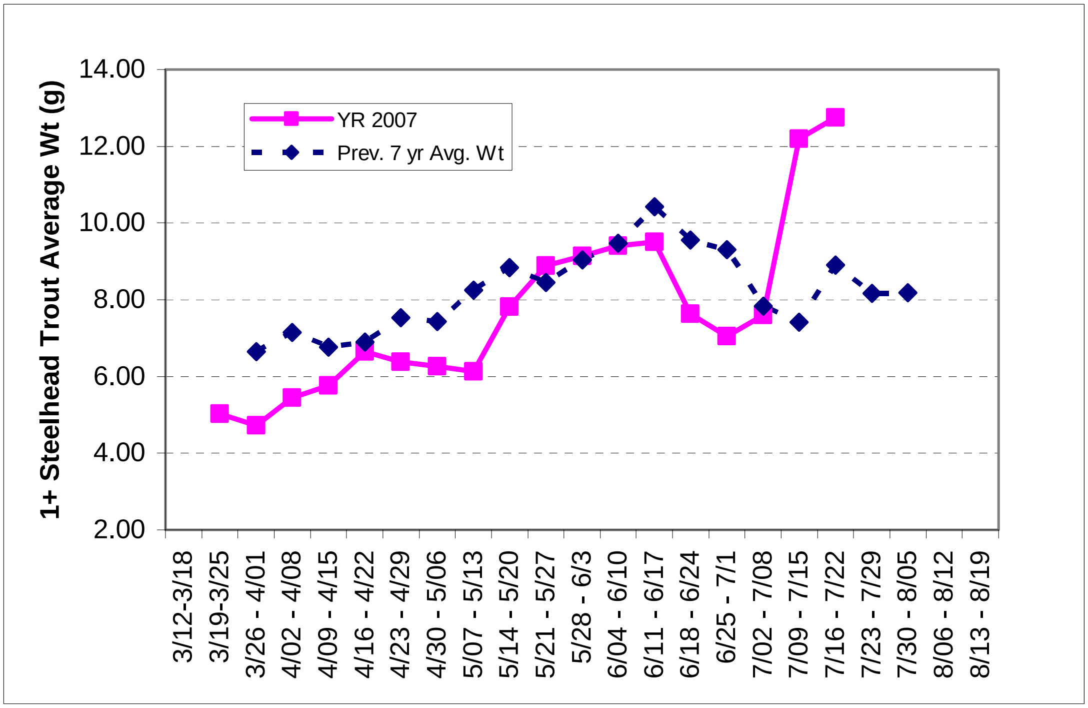

Figure 19. 1+ steelhead trout average weekly weights (g) in YR 2007 and the previous seven year average, upper Redwood Creek, Humboldt County, CA.

2+ Steelhead Trout

We measured (FL mm) 517 and weighed (g) 490 2+ steelhead trout in YR 2007 (Table 20). Average FL in YR 2007 was 8.2% less than average FL in YR 2006, and average Wt in YR 2007 was 21.1% less than average WT in YR 2006 (Table 20). The mode in FL in YR 2007 was 120 mm, and the modes for Wt in YR 2007 were 19.9 and 21.9 g. Average FL and Wt over study years 2000 - 2007 did not significantly change over time (Correlation: FL, $p > 0.10$, slope is negative, $r = 0.28$, power = 0.09; Wt, $p > 0.10$, $r = 0.36$, power = 0.12).

Average FL and Wt by season was not influenced by population size (Regression, FL: $p > 0.10$, $R^2 = 0.009$, slope is negative, power = 0.05; Wt: $p > 0.10$, $R^2 = 0.09$, slope is negative, power = 0.05).

Table 20. 2+ steelhead trout population estimates, and average fork length (mm) and weight (g) for study years 2000 - 2007, upper Redwood Creek, Humboldt County, CA.

	2+ Steelhead Trout						
		Fork Length (mm)			Weight (g)		
Study Year	(N)*	n	Avg.	SEM**	n	Avg.	SEM**
2000	4,739	710	164.4	0.6	480	49.12	0.61
2001	12,668	1,316	151.2	0.5	1,225	39.17	0.43
2002	7,302	1,528	147.5	0.6	1,463	37.87	0.51
2003	2,846	625	144.0	0.9	583	35.15	0.71
2004	5,778	1,277	144.1	0.7	1,244	35.44	0.47
2005	2,364	594	150.5	0.2	592	39.90	0.91
2006	1,866	396	159.8	1.4	391	44.86	1.06
7 yr Avg.			151.6	2.9		40.22	1.93
2007	2,861	517	146.7	1.1	490	35.40	0.75

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

The pattern in 2+ steelhead trout average weekly FL over the study period in YR 2007 was similar to the pattern for the previous seven year average (Figure 20). Highest values in YR 2007 occurred during the first nine weeks of trapping, and the lowest value occurred during 6/04/07 – 6/10/07 (Figure 20). 2+ steelhead trout average weekly FL (mm) significantly decreased over time (weeks) in YR 2007 (Correlation, $p < 0.0001$, $r = 0.83$, slope is negative, power = 1.00), as did the previous seven year average FL

(Correlation, $p < 0.05$, $r = 0.50$, slope is negative, power = 0.64). Median weekly FL in YR 2007 (144.7 mm) was not significantly different than the median weekly FL for the previous seven year average (150.4 mm) (Kruskal-Wallis One-Way ANOVA on Ranks, $p > 0.05$). Median weekly 2+ steelhead trout FL (144.7) in YR 2007 was significantly greater than median weekly 1+ steelhead trout FL (87.9 mm) in YR 2007 (Kruskal-Wallis One-Way ANOVA on Ranks, $p < 0.000001$).

The pattern in 2+ steelhead trout average weekly Wt over the study period in YR 2007 was very similar to the previous seven year average Wt (Figure 21). Highest values in YR 2007 occurred during the first nine weeks of trapping, and the lowest value occurred during 6/04/07 – 6/10/07 (Figure 21).

2+ steelhead trout average weekly Wt (g) significantly decreased over time (weeks) in YR 2007 (Correlation, $p < 0.0001$, $r = 0.83$, slope is negative, power = 1.00); as did the previous seven year average Wt (Correlation, $p < 0.05$, $r = 0.49$, slope is negative, power = 0.61) (Figure 21). Median weekly Wt in YR 2007 (35.84 g) was not significantly different than the median weekly Wt for the previous seven year average (38.48 g) (Kruskal-Wallis One-Way ANOVA on Ranks, $p > 0.05$). 2+ steelhead trout median weekly Wt (35.84 g) in YR 2007 was significantly greater than 1+ steelhead trout median weekly Wt (7.32 g) in YR 2007 (Kruskal-Wallis One-Way ANOVA on Ranks, $p < 0.000001$).

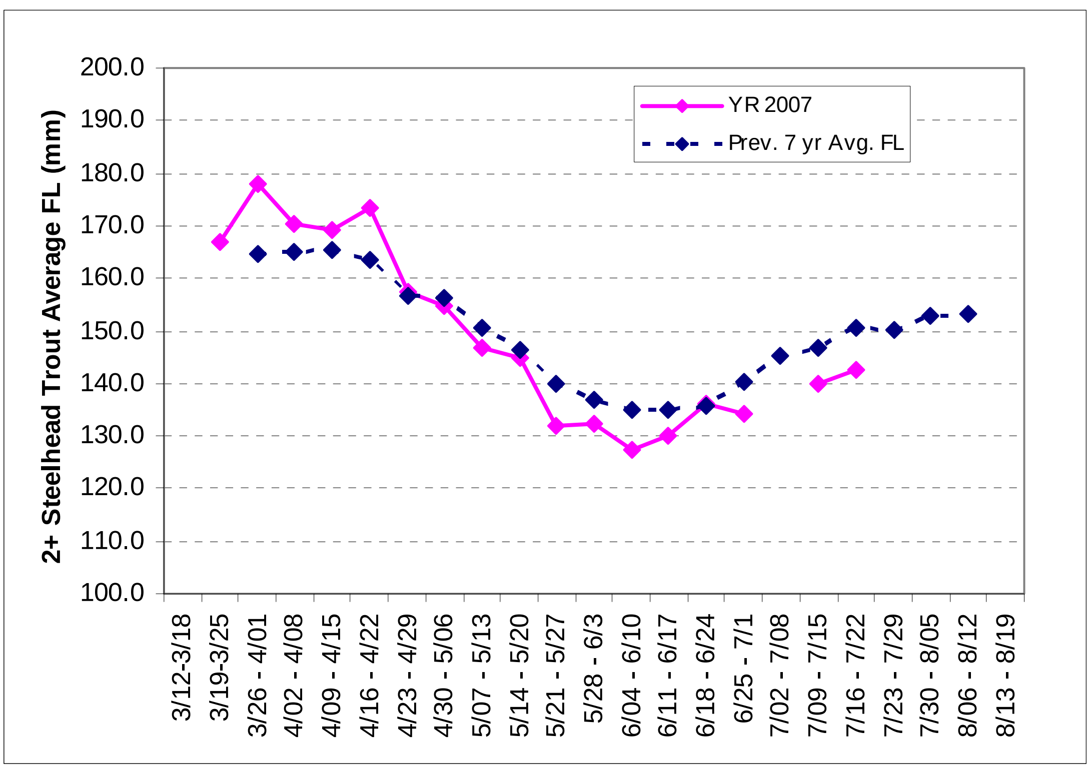

Figure 20. 2+ steelhead trout average weekly fork lengths (mm) in YR 2007 and the previous seven year average, upper Redwood Creek, Humboldt County, CA.

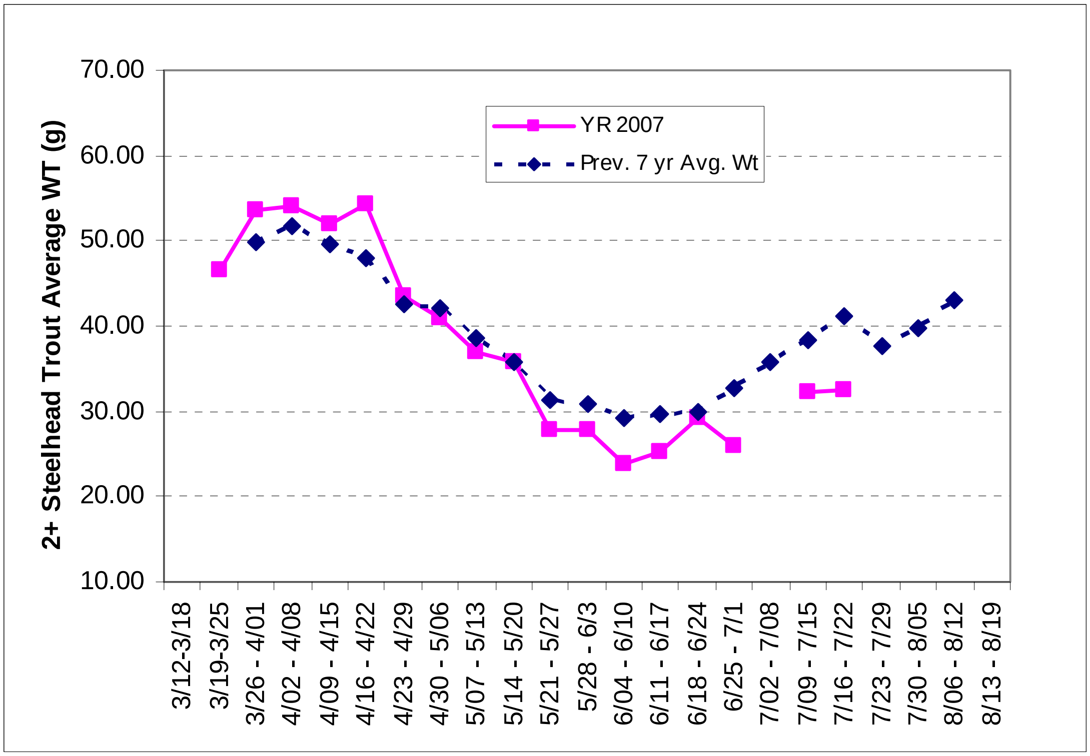

Figure 21. 2+ steelhead trout average weekly weights (g) in YR 2007 and the previous seven year average, upper Redwood Creek, Humboldt County, CA.

Developmental Stages

1+ and 2+ Steelhead Trout

There was an obvious non-random distribution of parr, pre-smolt, and smolt designations (developmental stages) for 1+ and 2+ steelhead trout captured in YR 2007 and for the previous seven year average (Table 21). A totally random distribution would equal 33.3% for each designation (parr, pre-smolt, smolt). The contingency test (2x2) showed there were significant differences in the proportions of parr, pre-smolt and smolt designations for 1+ steelhead in YR 2007 compared to the previous seven year average (Chi-square, $p < 0.000001$). There were statistically less parr and pre-smolts, and more smolts in YR 2007 compared to the previous seven year average. For 2+ steelhead trout, there were statistically less pre-smolts and more smolts compared to the previous seven year average (Chi-square, $p < 0.0001$).

Using data by year (not given), the percentage of 1+ steelhead trout smolts in a given study year was not related to population size, size of fish (FL, Wt), average monthly discharge during the trapping period, or average daily discharge during the trapping period (Regression, $p > 0.10$ for each test); however, 1+ steelhead trout smolt percentages were negatively related to average daily stream temperature during the trapping periods

(Regression, $p < 0.05$, $R^2 = 0.71$, power = 0.80). For 2+ steelhead trout, the percentage of smolts in a given year was inversely related to the transformed population abundance (Regression, $p < 0.01$, $R^2 = 0.75$, power = 0.94), and inversely related to average daily stream temperature at the trapping site (Regression, $p < 0.05$, $R^2 = 0.62$, power = 0.64). No statistical relationships were found with average monthly stream discharge, or average fish size (FL, WT) (Regression, $p > 0.10$ for each test). The combined percentage of pre-smolts and smolts for 1+ steelhead trout and 2+ steelhead trout in YR 2007 and for the previous seven year average was nearly 100% (Table 21).

Table 21. Developmental stages of captured 1+ and 2+ steelhead trout in YR 2007 and the previous seven year average, upper Redwood Creek, Humboldt County, CA.

	Developmental Stage (as percentage of total catch)					
	1+ Steelhead Trout			2+ Steelhead Trout		
Year	Parr	Pre-smolt	Smolt	Parr	Pre-smolt	Smolt
2007	0.1	10.1	89.8	0.0	1.0	99.0
7 yr Avg.*	3.1	54.9	42.0	0.1	18.3	81.6

* Study years 2000 – 2006.

Additional Experiments

Re-migration

In YR 2007, we did not recapture any of the pit tagged fish released in YR 2006 (Table 22), and in YR 2006 we did not recapture any of the 1+ and 2+ steelhead trout marked and released with elastomer (n = 183) 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 22). To date, we have found no evidence of 0+ Chinook salmon, 1+ steelhead trout, and 2+ steelhead trout re-migrating upstream of the trap site to be caught moving downstream the following year.

Table 22. Data for testing re-migration of 0+ Chinook salmon, 1+ steelhead trout, and 2+ steelhead trout, upper Redwood Cr, 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 23). Percent recapture per release group ranged from 0.0 – 67% (Table 23).

Initial fork lengths of recaptured juveniles ranged from 67 – 80 mm, and averaged 71.9 mm (Appendix 9). Time to travel the 29 miles between traps ranged from 2.5 – 29.5 d, and averaged 10.7 d (median = 8.5 d, mode = 3.5 d) (Table 24). Travel time in YR 2007 was greater than travel time in YRS 2005 and 2006 (Table 24). 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 24). 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).

Table 23. 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	

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 9). 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 24). 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 24). Growth values in YR 2007 were greater than values in YRS 2005 and 2006 (Table 24).

Table 24. 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 22). Travel rate (mi/d) was inversely related to change in Wt (transformed) (Regression, $p < 0.00001$, R2 = 0.66, power = 1.0).

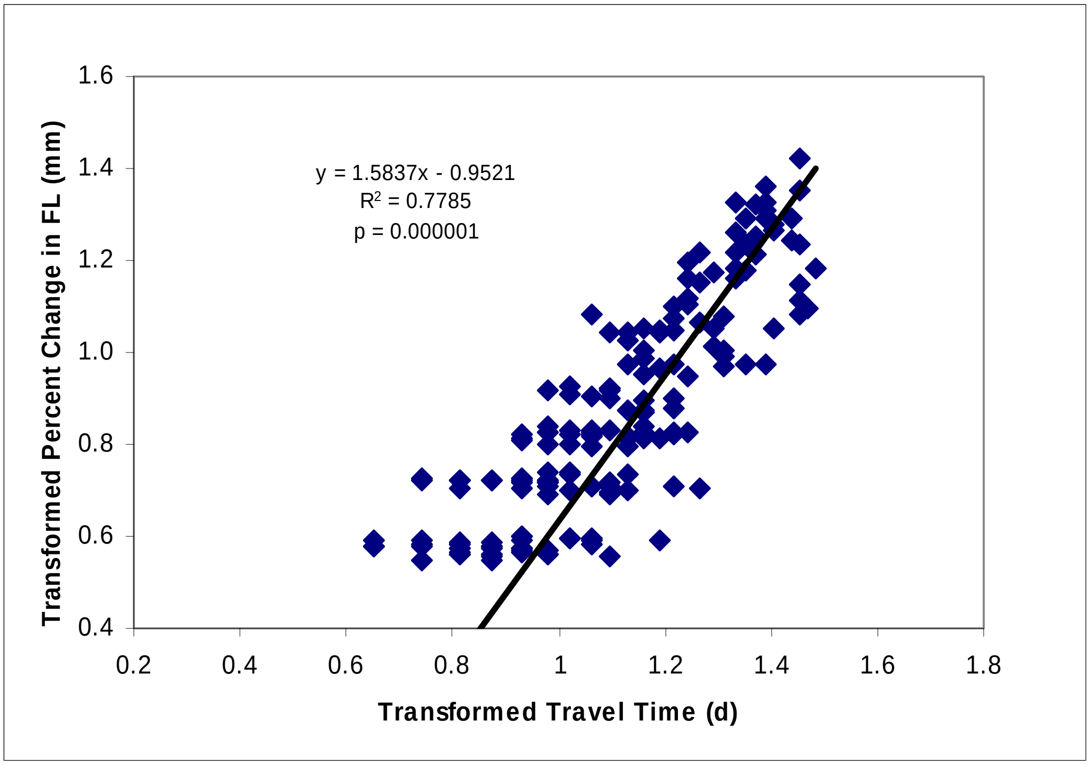

Figure 22. Linear regression of transformed travel time (d) on transformed percent change in FL (mm) for pit tagged 0+ Chinook salmon (n = 245) recaptured at the lower trap in Redwood Creek, Humboldt County, CA. 2007.

Separate growth statistics were determined for recaptured pit tagged 0+ Chinook salmon individuals showing only positive growth (Table 25). On average, the pit tagged Chinook salmon absolute growth rate equaled 0.402 mm per day for FL, and 0.066 g per day for Wt (Table 25).

Table 25. 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 24.
** 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 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 26).

Table 26. 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 10). Percent recapture per release group ranged from 0.0 – 16.7%, and averaged 2.6% (Appendix 10).

Initial fork lengths of recaptured juveniles (n =18) ranged from 68 – 115 mm, and averaged 83.9 mm (Appendix 11). 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 11). 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 11). Travel time in YR 2006 averaged 20.8 d, and travel time in YR 2005 (n = 5) averaged 12.4 d (Table 27). 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 (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 11, Table 27). 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 27). 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 27). Growth in YR 2007 was greater than growth in YR 2006 (Table 27).

Table 27. 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 24.
** 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 12). 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 12). The variation in travel time (d) explained 85% of the variation in delta FL (Figure 23).

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 12). 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 9, R^2 ranged from 0.62 to 0.74) (Appendix 12).

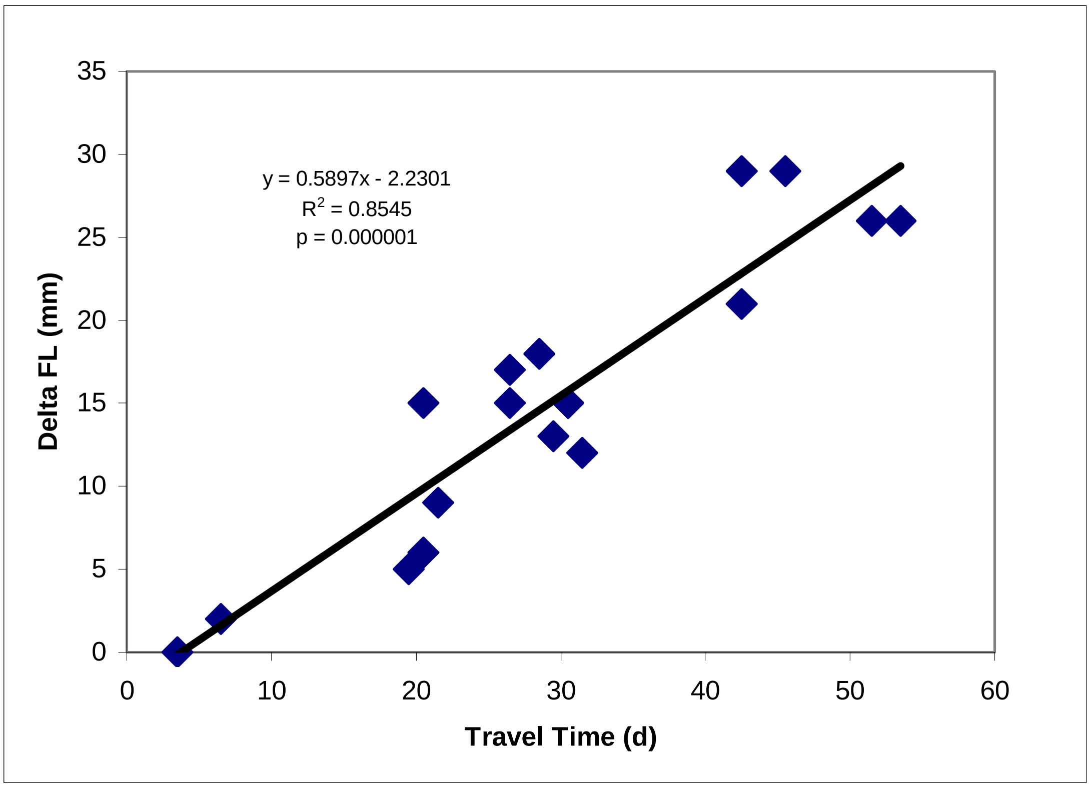

Figure 23. Linear regression of travel time (d) on change in FL (mm) for pit tagged 1+ steelhead trout (n = 18) recaptured at the lower trap in Redwood Creek, Humboldt County, CA., 2007.

2+ Steelhead Trout

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

Delayed Mortality

0+ Chinook Salmon

A total of 36 delayed mortality experiments were conducted with 0+ Chinook salmon (n = 1,155) in YR 2007, with an overall mortality of 0.43% (Appendix 13). No mortalities attributable to fin clipping or handling occurred, however, five of the 696 pit tagged fish (which also includes anesthetization, FL and Wt measurements, and a small partial upper caudal fin clip) died after being held for 24 – 36 hours. These five fish were noted as not recovering well (swimming poorly, changing color from silvery to dark) immediately after pit tag application (and prior to being held in the delayed mortality cage). The five fish that died collectively accounted for three out of 20 total pit tag groups, and was not considered indicative of delayed mortality over the entire season. Delayed mortality attributable to pit tagging over the entire season was considered to be less than 0.43%.

0+ Steelhead Trout

A total of 11 delayed mortality experiments were conducted with 0+ steelhead trout (n = 470) in YR 2007, with an overall mortality of 0.00% (Appendix 14). Average sample size per test equaled 43 individuals, and average test duration equaled 27 hours.

1+ Steelhead Trout

A total of 45 delayed mortality experiments were conducted with 1+ steelhead trout (n = 822) in YR 2007, with an overall mortality rate of 0.00% (Appendix 15). Average sample size per test equaled 18 individuals, and average test duration equaled 30 hours.

2+ Steelhead Trout

A total of 45 delayed mortality experiments were conducted with 2+ steelhead trout (n = 188) in YR 2007, with an overall mortality rate of 1.0% (Appendix 16). The two mortalities occurred in a total of two out of 45 test groups, and were not considered indicative of delayed mortality over the entire season. Delayed mortality over the season was considered less than 1.0%. If the 1.0% were applied to the total captures, then we estimated five fish could have died after being counted, measured etc.

Trapping Mortality

The mortality of fish that were captured in the traps and subsequently handled was closely monitored over the course of the trapping period. The trap mortality (which includes handling mortality) for a given age/species in YR 2007 ranged from 0.00 - 0.26%, and using all data, was 0.22% of the total captured and handled (Table 28). This level of trap mortality is very low, and considered negligible.

Juvenile salmonid trapping mortality in YR 2007 (0.22%) was much lower than the previous seven year average (0.48%) (Table 29).

Table 28. Trapping mortality for juvenile salmonids captured in YR 2007, upper Redwood Creek, Humboldt County, CA.

	Trap Mortality in YR 2007		
Age/spp.	No. captured	No. of mortalities	Percent mortality
0+ Chinook	15,823	15	0.09
0+ Steelhead	68,573	180	0.26
1+ Steelhead	5,036	3	0.06
2+ Steelhead	525	1	0.19
0+ Coho	6	0	0.00
Cutthroat trout	2	0	0.00
Overall:	89,965	199	0.22

Table 29. Comparison of trapping mortality of juvenile salmonids in seven consecutive study years, upper Redwood Creek, Humboldt County, CA.

	Trap Mortality		
Study Year	No. captured	No. of mortalities	Percent mortality
2000	191,761	934	0.49
2001	239,262	1,631	0.68
2002	361,433	1,480	0.41
2003	111,514	362	0.32
2004	352,860	1,192	0.34
2005	56,544	368	0.65
2006	57,193	128	0.22
Average (2000-06)			0.48

Stream Temperatures

The average daily (24 hr period) stream temperature from 3/25/07 – 7/29/07 was 14.4 ^{o}C (or 57.9 ^{o}F) (95% CI = 13.6 – 15.2 ^{o}C), with daily averages ranging from 6.4 – 22.1 ^{o}C (43.5 – 71.8 ^{o}F). In 2007, the average daily stream temperature exceeded 20 ^{o}C (68 F) for 17 d (13%) out of 127 d of record. Average daily stream temperatures during the trapping periods have significantly decreased over YRS 2001 – 07 (Correlation, $p < 0.10$, $r = 0.70$, negative slope, power = 0.42).

Average stream temperature during the trapping period in YR 2007 was the second lowest of the current seven consecutive years of data (Table 30). Average daily stream temperature during the trapping period for YRS 2001 – 2007 was inversely related to the average daily stream discharge during the trapping period (Regression, $p < 0.05$, $R^2 = 0.62$, slope is negative, power = 0.63).

Table 30. Average daily stream temperature (°C) (standard error of mean in parentheses) with minimum and maximum recorded stream temperature during the trapping period in YR 2007 and previous six years, upper Redwood Creek, Humboldt County, CA.

	Stream Temperature					
	Celsius			Fahrenheit		
Study Year	Avg.	Min.	Max.	Avg.	Min.	Max.
2001	16.3 (0.40)	5.7	28.2	61.3 (0.72)	42.3	82.8
2002	15.8 (0.39)	6.7	27.5	60.4 (0.71)	44.1	81.5
2003**	14.5 (0.46)	6.1	28.4	58.1 (0.82)	43.0	83.1
2004	15.8 (0.39)	6.7	28.8	60.4 (0.71)	44.1	83.8
2005**	13.5 (0.38)	6.2	25.8	56.4 (0.68)	43.2	78.4
2006**	14.9 (0.45)	5.7	29.5	58.8 (0.82)	42.3	85.1
6 Yr. Avg.*	15.1 (0.42)	5.7	28.8	59.3 (0.74)	42.3	83.8
2007	14.4 (0.39)	5.7	25.5	57.9 (0.70)	42.3	77.9

* YR 2000 excluded due to incomplete coverage during trapping period.
** Data truncated to 8/5 for equal comparison among study years.

Average monthly stream temperatures during the majority of the trapping season (April – July) in YR 2007 ranged from 9.5 – 20.3 °C (49.1 – 68.5 °F) (Table 31). Highest stream temperatures occurred in the later part of the trapping season (June and July) each study year. Median monthly temperatures were not significantly different (Kruskal-Wallis One –Way ANOVA on RANKS, $p > 0.05$). Average monthly temperatures in YRS 2001 – 2007 were inversely related to average monthly discharge (Regression, $p < 0.01$, $R^2 = 0.81$, negative slope, power = 0.95).

Table 31. Average monthly stream temperature (°C) (°F in parentheses) at the trap site in study years 2001 - 2007, upper Redwood Creek, Humboldt County, CA.

Study Year	Average stream temperature in Celsius (°F in parentheses) April	May	June	July	Avg.
2001	9.4 (48.9)	15.1 (59.2)	17.5 (63.5)	20.9 (69.6)	15.7 (60.3)
2002	10.7 (51.3)	13.1 (55.6)	18.0 (64.4)	21.3 (70.3)	15.8 (60.4)
2003	8.5 (47.3)	11.2 (52.2)	17.2 (63.0)	21.1 (70.0)	14.5 (58.1)
2004	10.6 (51.1)	13.8 (56.8)	17.7 (63.9)	21.6 (70.9)	15.9 (60.6)
2005	9.2 (48.6)	11.6 (52.9)	13.4 (56.1)	19.4 (66.9)	13.4 (56.1)
2006	8.7 (47.7)	12.4 (54.3)	17.7 (63.9)	21.1 (70.0)	15.0 (59.0)
2007	9.5 (49.1)	13.0 (55.4)	16.5 (61.7)	20.3 (68.5)	14.8 (58.6)

The MWAT during the trapping period in YR 2007 at the trap site was 21.5 °C (70.7 °F) and occurred on 7/25/07 (Table 32). MWMT in YR 2007 was 24.9 °C (76.8 °F) and also occurred on 7/25/07 (Table 32). The lowest values for MWAT and MWMT over seven years of temperature monitoring occurred in YR 2007 (Table 32). The highest MWAT occurred when stream temperatures were lethal to juvenile salmonids in YR 2006.

Table 32. Maximum weekly average temperature (MWAT) and maximum weekly maximum temperature (MWMT) for stream temperatures °C (°F in parentheses) at the trap site in upper Redwood Creek, Humboldt County, CA., study years 2001 – 2007.

	MWAT**		MWMT***	
Study Year	Date of occurrence	°C (°F)	Date of occurrence	°C (°F)
2000	-	-	-	-
2001	7/25/01	21.8 (71.2)	7/25/01	27.9 (82.2)
2002	7/29/02	21.9 (71.4)	7/27/02	26.4 (79.5)
2003*	7/29/03	23.1 (73.6)	7/29/03	27.4 (81.3)
2004	7/25/04	23.3 (73.9)	7/25/04	28.2 (82.8)
2005*	8/05/05	21.9 (71.4)	8/05/05	25.7 (78.3)
2006*	7/25/06	24.1 (75.4)	7/25/06	28.0 (82.4)
2007	7/25/07	21.5 (70.7)	7/25/07	24.9 (76.8)

* Data truncated to 8/05/05 for comparison with other years.
** MWAT is the maximum value of a 7-day moving average of daily average stream temperatures.
*** MWMT is the maximum value of a 7-day moving average of daily maximum stream temperatures.

The average stream temperature significantly increased over the study period in YR 2007 (Correlation, $p < 0.000001$, $r = 0.96$, slope is positive, power = 1.0) (Figure 24).

Similar to past study years, average daily stream temperature in YR 2007 was significantly related to the (transformed) average daily stream gage height at the trapping site (Regression, $p < 0.000001$, $R^2 = 0.90$, slope is negative, power = 1.0).

The minimum stream temperature in YR 2007 was 5.7 ^{o}C (42.3 ^{o}F) and occurred on 3/27/07; the maximum stream temperature was 25.5 ^{o}C (77.9 ^{o}F) and occurred on 7/10/07, 7/23/07, and 7/24/07 (Figure 24).

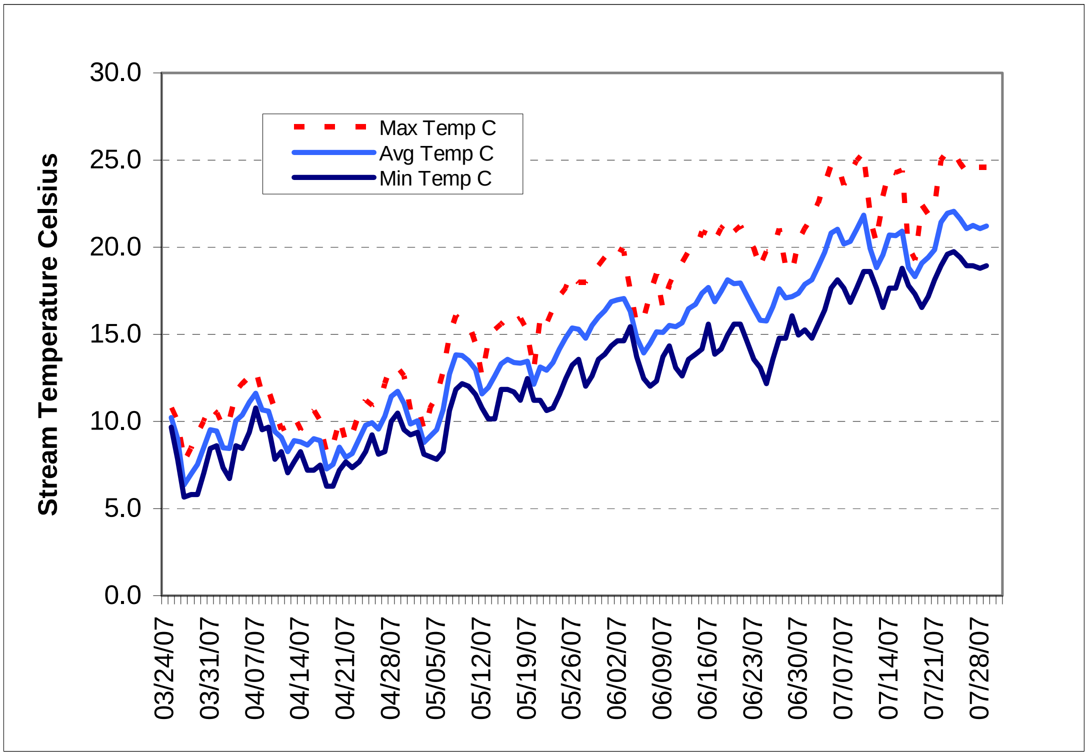

Figure 24. Average, minimum, and maximum stream temperature (Celsius) at the trap site, upper Redwood Creek, Humboldt County, CA., 2007.

The previous six year average daily stream temperature also increased over time (Correlation, $p < 0.000001$, $r = 0.98$, slope is positive, power = 1.0) (Figure 25). Median daily stream temperature in YR 2007 (14.8 ^{o}C) was not significantly different than the median (15.7 ^{o}C) for the previous six year average (Kruskal-Wallis One-Way ANOVA on Ranks, $p = 0.11$).

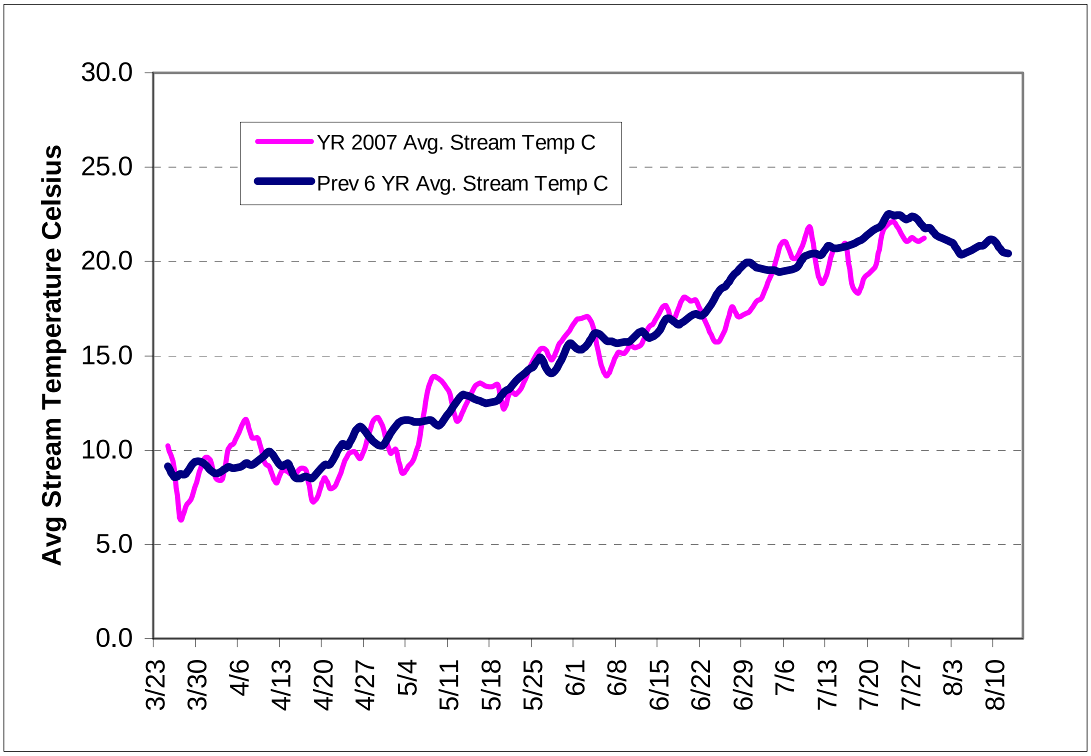

Figure 25. Average daily stream temperatures (Celsius) during the trapping period in YR 2007 and the average of previous six study years, upper Redwood Creek, Humboldt County, CA.

(Lethal) Stream Temperatures in late July

There were no lethal stream temperatures recorded in study YR 2007, and we did not observe any juvenile salmonid mortalities in the stream.

DISCUSSION

The main goal of our downstream migration study in upper Redwood Creek is to estimate and monitor the production of Chinook salmon, steelhead trout, and coho salmon (if present) in a reliable, long-term manner. Redwood Creek is a difficult, 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 run timing, precipitation, hydrology, water depth, 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 eighth consecutive year of trapping in upper Redwood Creek occurred during an average water year with respect to rainfall amounts in Redwood Valley and average stream discharge measured at the O'Kane gaging station. Rainfall in WY 2007 (199 cm) was near the middle of the 22 year record (ranged from 90 – 250 cm), and stream discharge in WY 2007 (203 cfs) also fell near the middle of the 36 year record. During the majority of the trapping period, rainfall in YR 2007 was slightly less (5%) than rainfall for the historic and previous seven year average. The month of April accounted for most of the rainfall during the trapping period (similar to past study years), and was also the month with the highest average streamflow. The lowest values in rainfall and stream discharge during the majority of the trapping period occurred in July.

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. Two days were not trapped during the course of the study due to a high flow event on 3/28/07, and when a log jammed the trap's cone on 4/22/07. The estimates for catch and subsequent expansions to the population level, based on the missed trapping days, were negligible for each species at age; the greatest impact on a population estimate was estimated at 1.00%, and the adjusted point value easily fell within the 95% confidence interval of the un-adjusted point estimate. The uncertainty or error in the population estimate for a given species at age ranged from 13 – 23%. Thus, this season's trapping resulted in very good estimates of wild Chinook salmon and steelhead trout smolt emigration (production) from areas upstream of the trapping site.

0+ Chinook Salmon

0+ Chinook salmon (ocean-type) emigrating from upper Redwood Creek were the most numerous migrant captured by the smolt trap for four out of eight years. Low catches occurred in YRS 2003, 2005, 2006, and 2007; and the total catch in YR 2007 was 84% less than the average catch of the previous seven years.

The population of 0+ Chinook salmon emigrating from upper Redwood Creek was variable over the eight consecutive years of study; production was greater than 350,000 individuals for the first three years, less than 1,000 in the fourth year, the fifth year experienced the greatest peak of 630,000 and for the past three years, production was less than 70,000. The eight year trend in population abundance over time showed a negative decline, however, statistical significance was not detected ($p = 0.13$). Population abundance in YR 2007 was higher than the past three years, yet much lower (by 76%) than the previous seven year average. The reduction in population emigration in YR 2007 could be due to: 1) change in adult spawner distribution in the watershed, 2) simple decrease in the total number of spawners upstream of the trap site, or 3) a combination of factors 1 and 2. Flood type flows were ruled out because none occurred during egg development.

If adult salmon returning to Redwood Creek changed their spawning distribution such that most spawned downstream of the trap site, we would naturally see a sharp decrease in the production of juvenile Chinook salmon emigrating from upper Redwood Creek. Since we currently do not count adults or have an index of adult escapement, it is not possible to state that a major change in spawning distribution occurred and was reflected by low juvenile emigration in YR 2007. The emigrant population passing the rotary screw trap in lower Redwood Creek in YR 2007 (N = 141,061) does not give much supportive evidence for a change in population distribution because it was only 55,912 individuals higher than the low emigration observed in YR 2006. Had there been a drastic change in the distribution of adult Chinook salmon in the watershed, holding additional factors constant, there should have been a much larger increase in the number of migrants passing the lower trap compared to the previous year. Data from the lower trap was able to show: 1) the severe decrease in 0+ Chinook salmon numbers was not limited to upper Redwood Creek, and included the entire Redwood Creek watershed upstream of where Prairie Creek enters Redwood Creek, and 2) production of 0+ Chinook salmon in YR 2007 was greater in areas downstream of the upper trap site. Unfortunately, peaks in stream flow (> 10,000 cfs) measured in lower Redwood Creek in January 2007 and February 2007 were high enough to potentially mobilize the bedload and redd gravels (Mary Ann Madej pers. comm. 2005). Thus, a drastic change in the adult spawner distribution in the watershed (favoring spawning in areas downstream of the upper trap) could have been masked by scouring of spawning redds.

A low number of adults returning to areas upstream of the trap site would also result in a noticeable reduction in juvenile production. Since there were no flows capable of mobilizing the streambed in WY 2007, the most plausible explanation for low juvenile production in YR 2007 is that fewer adults returned to spawn upstream of the trap site. Juvenile production in YR 2007 was higher than production in YR 2006, however, flood type flows did occur for the YR 2006 cohort. The flood type flows in upper Redwood Cr can drastically reduce juvenile production, as evidenced by the cohort crash in YR 2003 (N = 987) and low production in YRS 2005 and 2006 (N < 40,000).

Although no flood type flows occurred for the 2007 cohort, the relationship of flood flows on the production of juvenile Chinook salmon over eight years was significantly negative. The regression model was able to explain 60% of the variation in population abundance. Several investigators have shown that the scour of redds due to high stream flows 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. 2002, Don Chapman pers. comm. 2003, and 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 during Chinook salmon intragravel development was the second most important variable in their models used to predict the return rate of adult Chinook salmon. They further report that "large flow events may be a key factor in regulating Chinook salmon populations in the Skagit River basin, Washington" (Greene et al. 2005). Three of the eight current study years in upper Redwood Creek experienced flows capable of scouring spawning redds (or jostling the gravels/cobbles that make up the redds), a likely explanation for the poor production of each cohort the following spring. These high, potentially damaging stream flows in upper Redwood Creek are not uncommon; the recurrence interval is estimated to be around 3.1 years, a relatively small flood event for triggering widespread riffle and spawning gravel scour under normal circumstances (Randy Klein, pers. comm. 2008).

An alternative explanation to the observed decreases in abundance could be that the 0+ Chinook salmon simply remained upstream of the trap site in YRS 2003, 2005, 2006, and 2007. However, this is not likely because few juvenile Chinook salmon hold over for another year to out-migrate in Redwood Creek. This study shows that less than 0.004% of the total juvenile Chinook salmon production over-summer and over-winter to emigrate as 1+ Chinook salmon the following spring. Additionally, no 0+ Chinook salmon in upper Redwood Creek held over from YRS 2003, 2005 and 2006 to be captured as one-year-olds the following year; thus holding over is an unlikely explanation for the low production observed in YR 2007.

0+ Chinook salmon monthly population emigration in YR 2007 was severely reduced from the previous seven year average, with the biggest monthly reductions occurring in April (79% or 87,091 individuals) and May (82% or 78,760 individuals). The majority of juvenile Chinook salmon in YR 2007 migrated downstream during April - June (96% of total emigration), similar to the pattern for the previous seven year average (April – June, 96% of emigration). However, highest numbers emigrated during June in YR 2007 (similar to YR 2006), compared to April for the previous seven year average. Weekly population emigration (transformed) in YR 2007 was positively related, albeit weakly, to stream discharge ($R^2 = 0.29$); and negatively related to average stream temperature ($R^2 = 0.35$) and week number ($r = 0.70$). Thus, more 0+ Chinook salmon were emigrating earlier in the season when stream temperatures were lower and stream discharge was higher compared to later in the season. Very similar results were found in YRS 2005 and 2006 (Sparkman 2005).

The 0+ Chinook salmon (ocean-type) migrants in upper Redwood Creek exhibit two different juvenile migratory life histories (fry and fingerling) based on size (FL, WT) and time of downstream migration. The fry (Avg. FL = 39 mm in YR 2007) are migrating shortly after emergence from spawning redds, and therefore are much smaller than the fingerlings (Avg. FL = 61 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 some overlap in downstream migration, temporal differences in migration timing between the two life history forms are evident by the two peaks in migration. For example, the first weekly peak in population emigration in YR 2007 occurred during 4/09/07 – 4/15/07 (N = 10,086), and primarily consisted of fry with an average FL of 38 mm; the second peak occurred during 6/04/07 – 6/10/07 (N = 12,564) and primarily consisted of fingerlings with an average FL of 59 mm.

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

The emigration of 0+ Chinook salmon fry in YR 2007 began near the onset of trapping, peaked in mid April (same week as for the previous seven year average), and tapered off to very low values by the middle to end of May. Fingerling migration in upper Redwood Creek began in very low numbers in April, peaked in mid-June (same weeks as for the previous seven year average), and tapered to low values by early 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.

Large numbers of Chinook salmon fry emigrate soon after redd emergence in upper Redwood Creek, with percentages ranging from 1 – 69% of the total Chinook salmon emigrant population per study year (excluding YR 2003). The percentages of juvenile Chinook salmon migrating as fry (46% of total or 31,615 individuals) or fingerlings (54% of total or 36,668 individuals) in YR 2007 were statistically different than for the previous seven year average, such that a lesser proportion of fry and a higher proportion of fingerlings were present in YR 2007. As expected, the proportion of fry and fingerlings present in YR 2007 was statistically non-random (eg different than a 50/50 ratio).

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

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

I used linear regression to investigate any relationships between average stream flow (surrogate for habitat space), average stream temperature, and seasonal 0+ Chinook population estimate on the percentage of emigrating fry each year in upper Redwood Creek. 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 as they migrate downstream (Roelofs and Klatte 1996; Roelofs and Sparkman 1999, Walt Duffy pers. comm. 2005).

The average size (FL, Wt) of 0+ Chinook salmon emigrants in YR 2007 was less than the size in YR 2006. Linear regression detected a significant negative relationship of seasonal population emigration on average FL which may indicate a density-dependent relationship; with higher emigration we see a decrease in the average FL. The average size (FL, Wt) for a given population estimate over the seven study years was not related to the percentage of fry or fingerlings in the population estimate; thus ruling out that average size by study year was more related to the number of fry than to the total population at large. The density-dependent relationship of population numbers on average size suggests that rearing space or carrying capacity (and food availability) upstream of the trap site is limiting the average size of Chinook salmon juveniles at higher population abundances. However, the current carrying capacity is expected to be much less than the carrying capacity of the past because Redwood Creek has changed over time, and is currently considered sediment and temperature impaired by the USEPA. If habitat is limiting the size of smolts at higher abundances, successful watershed restoration in the upper basin should allow for the juvenile Chinook salmon to gain a larger size than currently observed, even if the number of emigrants in the population is relatively large.

Although a negative relationship of average size with population abundance was detected for 0+ Chinook salmon, the average weekly FL and Wt in any given year increased over the study period. Average weekly FL and Wt in YR 2007 followed a similar pattern over time; starting out low and relatively stable for the first seven weeks, then increasing throughout the end of the study period.

The emigrants were small in size during the first seven weeks because the vast majority of catches were emergent fry (fry that recently emerged from redds). The rather sharp increase in FL and Wt by week in YR 2007 was attributable to the increasing percentage of fingerlings in the catch over time compared to fry ($p < 0.001$ for each test). Unwin (1985) reported a similar finding in his trapping studies in New Zealand.

The relationships of weekly FL and Wt in YR 2007 with the previous six year average were numerically similar for the first seven weeks because emergent fry show little variation in size (FL, Wt) (Roelofs and Sparkman 1997; Sparkman 1997; Sparkman 2004). Thereafter, average weekly FL's and Wt's in YR 2007 were generally greater than the six year average. These increases in weekly FL's and Wt's indicate growth was taking place within the study periods. The rough or group estimate of growth rate from

4/02/07 to 7/08/07 equaled 0.34 mm/d and 0.03 g/d; these values were close to those determined in YR 2005 (0.41 mm/d; 0.05 g/d) and YR 2006 (0.36 mm/d; 0.04 g/d).

A growth rate of 0.34 mm/d falls 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 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 (Sparkman 2004c, study 2i3), 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 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 the change in 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 that the 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. Yearly catches ranged from 0 – 29 individuals, and in YRS 2000, 2004 - 2007 zero were captured. Stream-type Chinook salmon are easily differentiated from ocean-type by size at time of downstream migration. For example, the average FL in May 2003 was 124 mm for 1+ Chinook salmon and 58 mm for 0+ Chinook juveniles. The total number of 1+ Chinook salmon juveniles captured over eight study years equaled 68 individuals, or 0.001% of the total juvenile Chinook salmon catch.

When present, 1+ Chinook salmon from upper Redwood Creek are more likely to be progeny of fall/winter-run Chinook salmon adults than from spring-run adults (Stream-type) because few if any spring-run Chinook salmon are observed during spring and summer snorkel surveys in Redwood Creek (David Anderson, pers. comm. 2004). For example, in 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) (David Anderson, pers. comm. 2005). Additionally, stream flows during late spring/summer months can become so low that adult upstream passage into upper Redwood Creek can become problematic. High average stream temperatures (eg > 20 °C) and maximum stream temperatures (24+ °C or 75 °F) may also prevent any adult spring-run Chinook salmon migration into upper Redwood Creek, or inhibit their ability to over-summer in pools. Thus, a spring run of Chinook salmon adults is probably not responsible for the production of yearling Chinook salmon juveniles in Redwood Creek. Bendock (1995) also found both stream-type and ocean-type juvenile Chinook salmon in an Alaskan stream which only has one adult Chinook salmon race; and Connor et al. (2005) reported that fall Chinook salmon in the Snake River produced juveniles exhibiting an ocean-type or stream-type juvenile life history. Teel et al. (2000) found that for some populations of coastal Chinook salmon, ocean-type and stream-type juveniles were genetically undifferentiated, and probably arose from a common ancestor. They further report that the stream-type life history probably evolved after the ocean-type colonized (post glacial period) the rivers in study. An important question which may be unanswerable, 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 in upper Redwood Creek may be important for increased ocean survival of Chinook salmon juveniles, and general species diversity (Don Chapman pers. comm. 2003, Sparkman 2006).

0+ Steelhead Trout

Considerable numbers of young-of-year steelhead trout migrate downstream from upper Redwood Creek during spring and summer months; over eight consecutive study years we captured 672,802 individuals. 0+ steelhead trout were the most numerous juvenile salmonid captured in the trap for four out of eight years, and were the most numerous age class migrant for juvenile steelhead trout each study year. Clearly, stream habitat upstream of the trap site is important for adult steelhead trout reproduction.

The total catch of 0+ steelhead trout migrating downstream in YR 2007 (n = 68,573) was greater than catches in YRS 2000, 2005 and 2006, yet 21% lower than the previous seven year average catch. Unlike study years with less catches, we observed numerous 0+ steelhead rout in margin areas of the stream near the trap site in YR 2007.

Young-of-year steelhead trout were caught in low numbers (< 30 individuals) from 3/23 – 5/04/07. Thereafter, daily catches were generally greater than 40 per day until the end of the trapping period when less than 10 individuals per day were captured. The average daily catch over the entire trapping period equaled 532. Peak catches occurred on 5/26/07 (n = 2,355), 6/05/07 (n = 3,660), and 7/19/07 (n = 2,353), with the last peak occurring during times of low migration.

The monthly pattern in downstream migration in YR 2007 was similar to the previous seven year average in that catches (and migration) increased until June (peak month) and then decreased to the end of the study period. However, in YR 2007 the majority of catches occurred during May and June (88%) compared to June and July (70%) for the previous seven year average. The largest decrease in monthly catches in YR 2007 (compared to the average) occurred in July, similar to data in YR 2006. The total catch in July 2007 (n = 7,939) was 70% (or 18,620 individuals) less than the previous seven year average catch for July.

The average FL for 0+ steelhead trout in YR 2007 (Avg. = 37 mm) was the second lowest of the current seven study years, and was probably influenced by the high percentage (63%) of fry (FL < 40 mm) migrating downstream. Emergent fry (newly emerged from spawning redds, FL < 32 mm) comprised 46% of the total catch. Fry were present in every week when 0+ steelhead trout were captured (including catches during 7/23/07 – 7/29/07), and the mode in FL for all measured 0+ steelhead trout in YR 2007 was 29 mm (size of emergent fry). The average FL (mm) by study year was not related to the number of 0+ steelhead trout captured each year, thus no density-dependent relationship was detected.

Average weekly FL in YR 2007 followed the same pattern over time with the previous seven year average for 11 out of 16 comparable weeks. Unlike other study years, the first two weeks of FL measurements in YR 2007 were about 4 mm greater than the previous seven year average, which indicates that some adult steelhead trout probably spawned earlier than previous years. However, the following weekly FL's were generally the same as the previous seven year average until 7/02/07. As in previous study years, average weekly FL's in April and May represented emergent fry (FL < 32 mm). In June and July more 0+ steelhead trout were migrating downstream as parr, which was reflected in the increase in average weekly FL.

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 2006). Young-of-year steelhead trout downstream migration in upper Redwood Creek is considered to be stream re-distribution (both passive and active) because juvenile steelhead trout normally smolt and enter the ocean at age two, with lesser numbers out-migrating at ages 1 and 3.

The number of 0+ steelhead trout that can remain upstream of the trap site is 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. 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). However, a limitation with the view of habitat carrying capacity's affect on migration is that it fails to explain why juvenile fish emigrate when upstream fish densities or population levels are low.

The overall decrease we observed in YR 2007 could be due to a variety of factors: 1) changes in the number of adult steelhead spawning above the trap site, 2) change in redd gravel conditions, 3) change in carrying capacity of stream habitat upstream of trap site, 4) decrease in the percentage of the total population that passively or actively migrates downstream, or 5) some combination of factors 1 - 4. The potential variable of trapping efficiency among study years would not account for the general decrease we observed in YR 2007 because the trap was operated in the same manner as in other study years (time of placement, use of weir panels, etc).

Changes in adult spawner distribution in the watershed could have occurred but seem unlikely because winter and early spring stream flows were adequate for upstream passage. In addition, flows were very high near the time of spawning such that adult steelhead could have migrated to the end of anadromy. With respect to adults, the probability that fewer adults were present upstream of the trap site seems more plausible than a large scale change in spawner distribution in the watershed.

Adult steelhead in upper Redwood Creek generally spawn February - April, and in YR 2007 we observed adult steelhead on redds upstream of the trap site, with the latest observation occurring in May. In WY 2007, we had no peaks in streamflow that could have scoured steelhead trout redds, therefore, the decrease in catches compared to the seven year average was not due to flood type flows. Flows less than about 5,000 cfs are not expected to mobilize streambed gravels (or redds) (Randy Klein pers. comm. 2003);

and in YR 2003, we captured 102,954 0+ steelhead trout that had been in redds when flows reached 3,500 cfs.

A change in the percentage of total juvenile steelhead production in upper Redwood Creek that migrates downstream may account for some of the decrease in catches we observed in YR 2007. 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. If this were true, and over-summer and over-winter conditions were not harsh or cause high mortality, then we should see a large increase in the number of 1+ steelhead trout emigrating in YR 2008.

During periods of high stream temperatures (eg July and August) we frequently observed young-of-year steelhead trout in upper Redwood Creek utilizing stream areas influenced by groundwater seeps in very high numbers relative to those seen in non-influenced seep areas. However, in YR 2006 (and YR 2005) high stream flows deposited large amounts of sands and small gravels that completely covered the groundwater seeps such that very few juvenile steelhead trout were observed in these areas. In YR 2007, we observed some evidence of localized scour within the channel, but not where the seeps were located. In YR 2007 the seeps were not able to cool the stream, and 0+ steelhead trout were not seen in the previously seep influenced stream water. Thus, groundwater influenced refugia areas are not permanent, and can be affected by sedimentation of the streambed and margin areas of the stream.

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

1+ Steelhead Trout

Fairly large numbers of 1+ steelhead trout emigrate from upper Redwood Creek during the spring/summer emigration period. Population emigration from YRS 2000 – 2006 ranged from 26,176 – 68,030 and averaged 38,748 individuals. Population emigration in

YR 2007 (N = 34,431) was greater than emigration in YRS 2002, 2003, 2005, and 2006; yet 11% less than the previous seven year average. The population of 1+ steelhead trout declined over the eight study years; linear correlation detected a significant negative trend in 1+ steelhead trout population abundance over time ($p < 0.05$), which indicates that fewer 1+ steelhead trout were emigrating each year compared to previous years. Population emigration peaked during 5/07/07 – 5/13/07 (N = 6,777) and 6/04/07 – 6/10/07 (N = 4,866). The peak on 5/07 – 5/13 occurred during the same week as the peak for previous seven year average. The monthly peak in emigration occurred in May for YR 2007 and the previous seven year average; in contrast, emigration in June 2007 was much higher than the previous seven year average emigration in June.

The average size of 1+ steelhead trout in YR 2007 (FL = 85.4 mm, Wt = 7.41 g) was the second lowest of the current eight study years, and about 2.5 mm and 0.53 g less than the previous seven year average. The general trend in FL over study years was significantly negative, however, for Wt no significant difference was detected. The weekly FL and Wt in YR 2007 and for the previous seven year average significantly increased over time (weeks). Median FL and Wt in YR 2007 were not significantly different than the previous seven year average, thus the size of 1+ steelhead trout smolts in YR 2007 was very similar to the average. The FL of 1+ steelhead trout over the seven study years was positively related to the population size; with a higher population, we observed a greater FL. This is in contrast to the normal viewpoint of density-dependent relationships in which higher fish densities result in smaller fish sizes. The regression indicates that if stream conditions were favorable for survival, they were also favorable for growth.

Information in the literature indicates that steelhead smolting at age 1 is not uncommon, particularly in streams that are south of British Columbia (Busby et al. 1996, Quinn 2005). The percentage of 1+ steelhead trout migrants showing smolt characteristics in YR 2007 (90%) was significantly greater than the percentage (43%) for the previous seven year average. These differences are likely to be real because between-observer variation was minimized in three different ways: 1) each crew member used the same protocol, 2) each crew member was thoroughly trained and tested, and 3) some of the crew members had worked on this study for the previous four years. Regressions of 1+ steelhead trout population size or average FL or Wt on the percentage of 1+ steelhead trout showing smolt characteristics each year were non-significant (similar to data in YRS 2005 and 2006); thus for the data tested (n = 8), abundance and fish size did not have any influence on the seasonal percentage of smolt designations. However, average daily stream temperature by study year influenced the percentage of 1+ steelhead trout showing smolt characteristics; during trapping periods with cooler temperatures, more of the steelhead trout were in a smolt stage. Quinn (2005) reported that stream temperatures play an important role in smoltification.

1+ steelhead trout are actively emigrating from upper Redwood Creek because the lower trap in Redwood Creek (RM 4) has consistently captured efficiency trial fish, elastomer marked fish (study years 2001, 2004, and 2005), and pit tagged fish (YRS 2005, 2006, and 2007) released from the upper trap site. In addition, 1+ steelhead trout from upper Redwood Creek have been observed in the estuary of Redwood Creek every year since the beginning of this study (David Anderson, pers. comm. 2007). We have not observed re-migration of 1+ steelhead trout into 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 trap was 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 2 year-old 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 indicates 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.

Each study year the population of 1+ steelhead trout emigrating from upper Redwood Creek was far larger than 2+ steelhead trout population emigration. The ratio of 1+ to 2+ steelhead trout in YRS 2000 - 2006 ranged from 4:1 to 14:1 and averaged 9:1; in YR 2007 the ratio was 12:1. 1+ steelhead trout downstream migration is not unique to Redwood Creek, and other downstream migration studies have routinely documented 1+ steelhead trout emigration (USFWS 2001; Ward et al. 2002; Johnson 2004; Bill Chesney pers. comm. 2006, among many others). Based upon studies in other streams, the number of returning adult steelhead trout that went to the ocean as one-year-old smolts is relatively low, and usually less than 23% (Pautzke and Meigs 1941; Maher and Larkin 1955; Busby et al. 1996, McCubbing 2002). Based upon a limited number of scale samples (n = 10) from adult steelhead trout in Redwood Creek, 30% of the adults entered the ocean as one-year-old juveniles. CDFG AFRAMP is currently collecting scale samples from adult steelhead to increase sample size (author, in progress). The percentage of adult steelhead trout that smolt and enter the ocean at age-1, and the reason(s) for the relative large number of 1+ steelhead trout emigrating from upper Redwood Creek and from the basin of Redwood Creek (Sparkman, 2007b, study 2i3) warrants further investigation. I hypothesize that 1+ (and 0+) steelhead trout have changed their life history to limit the time spent in freshwater in order to avoid high, and at times, lethal stream temperatures. Over-summer conditions could be limiting the production of older age class production (2+ steelhead trout) in upper Redwood Creek.

2+ Steelhead Trout

In several studies investigating steelhead life histories, the majority of the returning adult steelhead spent two or more years as juveniles in freshwater prior to ocean entry (Pautzke and Meigs 1941; Maher and Larkin 1955; Busby et al. 1996, Smith and Ward 2000; McCubbing 2002). For example, Pautzke and Meigs (1941) reported that 84% of returning adult steelhead in the Green River had spent two or more years as juveniles in freshwater. Maher and Larkin (1955) found that 98% of the adult steelhead they examined had spent two or more years in freshwater prior to entering the ocean, and McCubbing (2002) reported 92% of steelhead adults in a British Columbia stream had spent two or more years as juveniles in freshwater. 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 is that it is the least numerous juvenile steelhead trout that emigrates from upper Redwood Creek. For example, in YR 2007 the ratio of 0+ steelhead trout to 2+ steelhead trout equaled 24:1, and the ratio of 1+ steelhead trout to 2+ steelhead trout equaled 12:1.

2+ steelhead trout population emigration during 2000 – 2006 ranged from 1,866 – 12,668, and averaged 5,366 individuals. Population emigration in YR 2007 (N = 2,861) was the fourth lowest in eight consecutive years, and 53% less than the average emigration over the previous seven years. Population emigration in YR 2007 was greater than YRS 2003, 2005, and 2006; however, the pattern or trend in population size over the eight study years was significantly negative. Thus, we were able to detect a statistically significant trend for 2+ steelhead trout with eight years of data.

Population emigration peaked during 6/04 – 6/10 (N = 384), with a smaller peak occurring 4/09 – 4/15 (N = 248); the smaller peak coincided with the peak for the previous seven year average. Emigration in YR 2007 was delayed compared to the previous seven year average; the most important month in YR 2007 was June compared to April for the previous seven year average. The majority of migration occurred during May and June in YR 2007 compared to April and May for the previous seven year average. Unlike other study years, weekly emigration was not significantly related to gage height of the stream (+), stream discharge (+), and stream temperatures (-). In past study years, greater numbers of 2+ steelhead trout emigrated earlier in the trapping season when stream discharge was higher and stream temperatures were cooler compared to later in the season. These relationships were fairly typical for 2+ steelhead trout population emigration from upper Redwood Creek, and suggested 2+ steelhead trout have adapted to lower stream flows and higher water temperatures by emigrating at a higher percentage of the total prior to these conditions. However, in YR 2007 the reduction in emigration in April and May contrasted these relationships.

The average size of 2+ steelhead trout in YR 2007 (FL = 147 mm, Wt = 35 g) was the third lowest of eight study years; however, the average size over study years did not significantly change. Unlike 1+ steelhead trout, the FL (and Wt) of 2+ steelhead trout over the seven study years was not related to emigrant population size. The pattern in weekly FL and Wt in YR 2007 was similar to the pattern for the previous seven year average; highest values occurred during the first eight weeks of trapping, and the lowest valued occurred near the mid point of the trapping period. For the remaining weeks, the size of 2+ steelhead trout emigrants gradually increased to the end of the study period. Both weekly FL and Wt in YR 2007 (and for the previous seven year average) significantly decreased over time (weeks). The decrease in average FL and Wt by week during study year 2007 is typical of 2+ smolts in 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 emigrants showing smolt characteristics in YR 2007 (99%) was the same as YRS 2005 and 2006 (90%), and about 17 percentage points greater than the previous seven year average. Smolt percentages over all study years were negatively related to 2+ steelhead trout population abundance (transformed) and average daily stream temperature. Thus, there were less smolt designations for higher population abundances and during study periods with higher stream temperatures. In previous study years, the percentage of smolt designations was also positively related to stream discharge. Quinn (2005) reported that stream temperatures play an important role in smoltification, and our data shows that 62% of the variation in smolt percentages over eight study years can be attributed to the variation in stream temperature. Average fish size (FL, Wt) by year had no influence on the percentage of 2+ steelhead trout showing smolt characteristics.

2+ steelhead trout are actively emigrating from upper Redwood Creek because the lower trap in Redwood Creek (RM 4) has consistently captured efficiency trial fish and elastomer marked fish released from the upper trap. In addition, 2+ steelhead trout from upper Redwood Creek have been observed in the estuary of Redwood Creek every year since the beginning of this study (David Anderson, pers. comm. 2007). We have not observed re-migration of 2+ steelhead trout into upper Redwood Creek based upon elastomer marked releases of 2+ steelhead trout in YRS 2001, 2004, and 2005; and pit tagged releases in YRS 2004, 2005, and 2006. These tests confirmed that the elastomer marked fish or pit tagged 2+ steelhead trout did not migrate back upstream to rear for another year and emigrate as 3 year-old steelhead trout smolts. The very low number of 3+ steelhead trout smolts (expanded) observed in the previous seven years of study (0.50% of 2+ steelhead trout population) and in YR 2007 (0.8% of total population) provides more evidence that the 2+ steelhead trout are migrating to the ocean, and not just re-distributing in the stream to eventually over-winter a third season.

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 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 upper 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 relates to future adults (and watershed conditions) is hard to dismiss or invalidate. With respect to younger juvenile stages (0+ and 1+), the 2+ steelhead smolt is the best candidate for assessing steelhead status, trends, and abundance when information on adult steelhead trout is unavailable 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. Along these same lines, Ward et al. (2003) reported that the 2+ steelhead smolt was a more reliable response variable with respect to stream restoration than late summer juvenile densities because of being less variable.

0+ Pink Salmon

Pink salmon in California are recognized as a "Species of Special Concern", 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 Redwood Creek prior to our downstream migration trapping efforts. The pink salmon in Redwood Creek are in very low numbers, and prior to study year 2005, were only caught in even numbered years (e.g. YR 2000, YR 2002, and YR 2004). The two individuals caught in YR 2005 may indicate that pink salmon are now spawning upstream of the trap site in even and odd numbered years; however, no pink salmon were captured in YRS 2006 and 2007.

It is hard to say if the parents of the juvenile 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 from upper Redwood Creek, it appears that pink salmon are occasionally present and reproducing, albeit in low numbers.

Coho Salmon

One of the greatest discoveries in YR 2007 was the capture of six young-of-year coho salmon for the first time in eight consecutive years of study. Prior to YR 2007, we captured, observed, and counted 1.37 million juveniles without a single juvenile coho salmon observation. In previous reports I mentioned that we should occasionally see at least a small number of juvenile coho salmon from adults that strayed upstream from downstream tributaries or mainstem reaches.

Coho salmon were historically present in areas upstream of the trap site based upon observations by Marlin Stover and Bill Chezum (long time residents in Redwood Valley, pers. comm. 2000 and 2001). I talked with both Marlin and Bill about coho salmon distribution in upper Redwood Creek. Bill Chezum (pers. comm. 2001) observed schools of adult coho salmon in areas upstream of the current trap site while growing up in Redwood Valley. He particularly mentioned seeing coho in the 1940's and early 1950's.

Every year he watched the fish swim past him in schools during their spawning run, and around the time of the 1955 flood event, the coho seemingly disappeared. Marlin Stover (pers. comm. 2000), who is also a long time resident in Redwood Valley, corroborates Bill Chezum's observations of adult coho in upper Redwood Creek. Minor Creek, a tributary to Redwood Creek upstream of the trap site, supposedly supported runs of coho salmon. Lacks Creek, a tributary to Redwood Creek downstream of the trap site by about 9 miles, currently supports coho salmon (Bill Jong, pers. comm. 2003; CDFG 1953); and Prairie Creek (tributary to Redwood Creek at about RM 3.7) supports a fairly stable population of coho salmon. Prior to our catches in juvenile coho salmon in YR 2007, the most recent citing of juvenile coho salmon upstream of the trap site occurred in 1997 (Tom Weseloh, pers. comm. 2003).

The next important observation for juvenile coho salmon in upper Redwood Creek will be the capture of 1+ coho salmon smolts in YR 2008. The presence of 1+ coho salmon will indicate whether the young of year coho salmon were able to survive stream habitat conditions (particularly during summer months which typically have the highest stream temperatures during a given water year). Optimistically, we may be documenting the return of coho salmon populations in upper Redwood Creek. We plan on taking genetic samples from juveniles, if present, in YR 2008 to determine how many adults were responsible for the juveniles we captured using mitochondrial DNA analysis techniques.

Cutthroat Trout

A low number of cutthroat trout were captured in all eight study years (< 9 individuals each year, total = 29), and only two individuals were captured in YR 2007. All cutthroat trout that were captured were in a smolt stage. An unknown number or percentage of cutthroat trout will residualize in the stream for varying years, and not out-migrate to the estuary and ocean; thus the low trap catches may not necessarily reflect a low population size in upper Redwood Creek. However, if there were large numbers present, we would probably catch much more than we do, as they re-distribute or migrate downstream. For example, juvenile salmonid trapping efforts in Prairie Creek consistently capture cutthroat trout during spring/early summer as they migrate downstream (Roelofs and Klatte 1996; Roelofs and Sparkman 1999, Walt Duffy, pers. comm. 2006).

We did not consider any of the young-of-year steelhead trout to be progeny of cutthroat trout because few aged 1 and older cutthroat trout were captured in any given year (average 4 per year). Upper Redwood Creek has far more older juvenile steelhead trout (1+ and 2+) than cutthroat trout as evidenced by trap catches. In the eight study years, the ratio of 1+ and 2+ steelhead trout combined catches to cutthroat trout catches each year ranged from 1,534:1 to 7,881:1, and using data from all years (pooled) equaled 2,870:1. The ratio in YR 2007 was 2,781:1. Ratios would be even higher if juvenile steelhead trout population data were used instead of catch data. It seems very unlikely that low numbers of cutthroat trout could produce a significant portion of the juvenile trout captures. Therefore, we considered the percentage of 0+ cutthroat trout included in the 0+ steelhead trout catch to be low and negligible.

We used three characteristics to identify coastal cutthroat trout: upper maxillary that extends past the posterior portion of the eye, slash marks on the lower jaws, and hyoid teeth; spotting is also usually more abundant on coastal cutthroat trout. Hybrid juveniles, the product of mating between steelhead trout and cutthroat trout, are commonly noted to be missing one or two of these characters. We have observed less than four individuals in the seven years that could have been hybrid juveniles. Thus, out of 83,225 1+ and 2+ steelhead trout catches, only 0.005% appeared to show hybrid characteristics. Based upon visual identification, the number of potential hybrids (age 1 and greater) is extremely rare in upper Redwood Creek.

Stream Temperatures

Similar to past study years, average daily stream temperature in YR 2007: 1) significantly increased over the study period, 2) was negatively related to stream discharge, and 3) was negatively related to stream gage height. The large influence of stream gage height (or stream discharge) on stream temperatures in Redwood Valley was evidenced by an R^2 of 0.90, which indicates that 90% of variation in temperature can be explained by the variation in gage height over time. Average daily stream temperature over study years 2001 – 2007 significantly declined over years, with a correlation coefficient of 0.70; this negative trend may indicate the riparian zone is maturing, and providing more shade compared to previous study years.

The average stream temperature (14.4 ^oC) during the trapping period in YR 2007 was the second lowest of the seven consecutive years of temperature data, and slightly below the previous six year average by 0.7 ^oC. Average monthly stream temperatures in YR 2007 ranged from 9.5 – 20.3 ^oC (49.1 – 68.5 ^oF) and median monthly temperatures did not show significant variation among study years. Stream temperatures in YR 2007 were not high enough, nor of sufficient duration to cause mortality of juvenile salmonids (as in YR 2006). The maximum stream temperature recorded in YR 2007 (25.5 ^oC, or 77.9 ^oF) was the lowest on record, and occurred on 7/24/07. MWAT (21.5 ^oC or 70.7 ^oF) and MWMT (24.9 ^oC or 76.8 ^oF) in YR 2007 were also the lowest on record. Similar to past study years, MWAT and MWMT occurred in late July. MWAT associated with the fish kill in YR 2006 equaled 24.1 ^oC.

Stream temperatures measured at the trap site appear to influence the degree of smolting for 1+ steelhead trout and 2+ steelhead trout; with colder temperatures, more of the juvenile steelhead emigrants were classified as smolts. Quinn (2005) reports that both photo period and steam temperature play important roles in smoltification by providing an external stimulus for the endocrine system, which drives the internal physiological changes necessary for smoltification.
Stream temperatures also appear to influence the migration of juvenile salmonids from upper Redwood Cr in YR 2007. The weekly migration of 0+ Chinook salmon populations was inversely related to stream temperatures; however, catches of 0+ steelhead trout were positively related to stream temperatures. Migration prior to times of increasingly higher stream temperatures could be a favorable life history strategy

because high stream temperatures can cause stress and mortality, among other negative outcomes. The increase in migration of 0+ steelhead trout with increasing stream temperatures may, in part, indicate rearing space or habitat conditions were not very favorable, and 0+ steelhead trout responded by increasing migration.

In general, emigration prior to times when streams or sections of streams reach high or maximum temperatures (July/August) can be viewed as an advantageous life history strategy, and one that juvenile salmonids in upper Redwood Creek appear to employ.

Inferences on Fishery Management, Watershed, and Stream Habitat Conditions

The number of returning adults to a given stream can be influenced by freshwater, estuarine, and marine habitats, harvest by humans and animals, and localized and global climates, among other factors. Fishery management is related to the status and trends of a given fish, which in turn can be related to stream habitat conditions, which in turn are related to watershed conditions.

Fishery Management

Data collected over the past eight years show significant, negative trends in abundance for 1+ and 2+ steelhead trout smolts, and a non-significant negative trend in 0+ Chinook salmon abundance. Downstream migrating smolts are the adults of the future, and if the smolts are declining, it is quite possible there will be fewer adults in the future. This is particularly true if the number of smolts is below carrying capacity of the freshwater habitat, which in upper Redwood Creek appears to be the case since population abundance graphs do not demonstrate a typical carrying capacity pattern (ie smolts are not leveling out at a given number). Our data support the current listing of steelhead trout and Chinook salmon populations in Redwood Creek as threatened under the Federal ESA; steelhead smolts are in steady decline, and 0+ Chinook salmon numbers are highly variable (relative boom or bust), and in a general decline. Although listing or de-listing anadromous salmonids in California under the Federal ESA is primarily limited to a given ESU (and not a specific river), steelhead trout and Chinook salmon in Redwood Creek should be protected under Federal and State ESA's. Thus, any human activity that may jeopardize the populations and habitat upon which they depend should be regulated in order to protect, conserve, and eventually improve the fisheries and habitat conditions in Redwood Creek.

Watershed Condition/Management

The condition and management of a given watershed impact stream habitat, which in turn can impact juvenile salmonid presence, life history (s), and population abundances. Several studies indicate that juvenile age composition in out-migrants can change to younger ages after watersheds are logged (Bisson and Sedell 1984; Hicks et al. 1991) or that smolt production decreases after logging (Hartman and Scrivener 1990). Our data corroborate these studies because we find each year that young-of-year steelhead trout migrants are much more numerous than older age class migrants, and 1+ steelhead trout smolts are much more numerous than 2+ steelhead trout smolts. Additionally, we are seeing significant declines in smolt numbers over years.

The current condition of the Redwood Creek watershed reflects a past legacy of extensive clear cut logging, removal of downed trees via tractors, associated road building to travel to and from logging sites, and natural processes. Roads are likely to be the major source of sediment input into Redwood Creek (Greg Bundros, pers. comm. 2008); however, fresh clear cut patches (un-vegetated) can also provide sediment yields to the stream. The road system in Redwood Creek includes a network of maintained and abandoned (unmaintained) roads that were built both before and after state forest practice regulations were implemented (Greg Bundros, pers. comm. 2008). Bundros and others (2004) estimate that nearly 60 percent of logging roads in Redwood Creek are unmaintained.

The watershed of Redwood Creek should be managed to improve conditions for fish and wildlife, and also allow for sustainable forest practices that do not compromise fish and wildlife habitat. The use of feller bunchers by some landowners to remove felled trees causes much less soil disturbance than log removal via tractors, and is encouraged. Other recommendations for minimizing damage to the watershed include: 1) sustainable harvest rates, 2) small clear cuts, or a change to selective cutting, 3) reducing the number of miles of roads in Redwood Creek, 4) decommissioning or upgrading abandoned roads, 5) maintaining roads that are currently in use, and decommissioning roads when no longer needed, 6) deferral of logging in riparian zones, especially in inner gorges, until riparian areas are fully stocked with mature conifers, and 7) greater oversight by Humboldt County of rural subdivision and associated road building (Greg Bundros, pers. comm. 2008). By following these guidelines the input of sediment to the stream would be greatly reduced. Additionally, the cessation of logging in riparian zones would allow for continued maturation and increased shade cover over the stream, and also allow for the recruitment of large woody debris into the stream channel, among other positive outcomes.

The Redwood Creek watershed may be entering a recovering state because current clear cut patches are much smaller in size than in past years and forest practices have improved over the past decade, with greater protection of riparian zones (Greg Bundros, pers. comm. 2008). The increased protection and maturation of the riparian zone may be reflected by the significant decrease in average stream temperatures at the trapping site. However, future logging in riparian zones could reverse the trend we are seeing.

<u>Stream Habitat Conditions/Management</u>

Watershed conditions upslope of the stream channel impact the condition of the stream, particularly in watersheds that have steep slopes, unstable geology, and receive considerable amounts of rain, such as the Redwood Creek watershed. The loss of stream habitat is considered by some to be the biggest single reason for the general decline in Pacific salmon, and specifically for coho salmon (Brown et al. 1994). Brown et al. (1994), in a summary of coho salmon populations in California, comment that most of the stream habitat loss or impairment is attributable to watershed disturbances associated with logging and other human activities. They further cite Redwood Creek as a coastal stream that was severely impacted from logging practices (Brown et al. 1994). The damage from large-scale clear cut logging was exacerbated by rain and flood events; Marlin Stover (pers. comm. 2000) commented that the 1964 flood event would not have caused as much damage to the watershed and stream channel had large scale clear cut logging not taken place. Similar to most streams in Humboldt County, California, Redwood Creek was listed as sediment and temperature impaired under section 303(d) of the Clean Water Act (CWA 2002; SWRCB 2003; USEPA 2003), primarily due to timber harvest, removal of riparian vegetation, widespread landslides into the stream, and channel aggredation (Madej et al. 2006).

Currently, the large proportion of young-of-year steelhead trout emigration compared to 1+ and 2+ steelhead trout population emigration suggests that rearing conditions, in combination with young-of-year passive out-migration and an innate/genetic tendency to out-migrate, may be limiting the abundance of older, juvenile steelhead trout age-class production from upper Redwood Creek. The decrease in older steelhead smolts can reduce the number of returning adults if estuary and ocean conditions do not compensate for the smolt decrease (likely scenario).

Decades of clear cut logging in Redwood Creek have minimized the amount and size of woody debris in Redwood Creek, such that large woody debris in upper Redwood Creek is nearly absent. Currently there are two large trees (*Pseudotsuga menziesii* - Douglas Fir) in the channel at the trapping site, however, this is an exception and not the norm based upon aerial observations (Author, 2007). Most of the few pieces of wood in the stream are alder, which have a much shorter retention time than Pseudotsuga menziesii or *Sequoia sempervirens* (Coast Redwood). The lack of large woody debris in the stream channel reduces stream habitat complexity, which in turn can negatively impact juvenile salmonids, particularly during winter conditions. Decreases in coho salmon abundance in California have been correlated with land use activities (logging) that reduced the amount of large woody debris in streams (Brown et al. 1994). Logging in riparian zones also reduces canopy cover over the stream, with the result of increased stream temperatures due to increased solar radiation. Aerial photographs of Redwood Creek in the 1940’s (pre-industrialized logging) showed a stream not visible due to canopy cover, which greatly contrasts the current, high visibility due to reduced canopy cover.

Redd gravels: The condition of redd gravels in upper Redwood Creek appears to be sufficient based upon relatively high emigration and trap catches of young of year Chinook salmon and steelhead trout. For example, the large number of 0+ steelhead trout catches (often exceeding 90,000 individuals each year) indicates that the adults successfully spawned. We can’t say how successful the adults were because: 1) we did not count adults, 2) we do not know average fecundity for Chinook salmon or steelhead trout, 3) we did not trap individual redds for survival to emergence information, and 4) we did not conduct any studies to document the percentage of fine sediments or average particle size in spawning redds. However, if the spawning redds contained large amounts of fine sediments (> 20-30%), we would probably not catch as many young of year steelhead trout and Chinook salmon as we did during the eight study years.

A main caveat with the spawning gravels is that they seem overly susceptible to scour during high winter flows. These high, potentially damaging stream flows in upper Redwood Creek are not uncommon; the recurrence interval is estimated to be around 3.1 years, which means a relatively small flood event triggers widespread riffle and spawning gravel scour under normal circumstances (Randy Klein, pers. comm. 2008). However, given that Redwood Creek drastically changed (widening of the stream channel and decrease in water depth) due to a combination of past land management practices (clear cut logging, tractor logging, and associated road building), and large flood events in 1955, 1964, and the 1970's, I hypothesize that particle size (Dg) of the surface gravel layer (armor) and underlying gravel matrix in the stream has been reduced and thus redds are more susceptible to scour than before anthropogenic influences. Successful watershed restoration, more benign logging practices (selective cutting and sustainable harvest rates), and natural recovery processes should allow coarsening of riffles and spawning gravels through time and thus reduce their susceptibility to scour, but this will be a slow process. Additionally, these same factors (watershed restoration, etc.) may speed up hydrologic recovery, possibly reducing flood peak magnitudes (Dunne and Leopold 1998) and their attendant role in redd scour (Randy Klein, pers. comm. 2008).

Over-summer habitat: The quantity and condition of the stream habitat during summer low flow conditions can impact juvenile steelhead trout populations. Young of year Chinook salmon are probably not affected by over-summer conditions because most emigrate from upper Redwood Creek before July. The two most important physical variables during summer conditions are stream temperatures and stream flow. Our data show that stream temperatures during summer often exceed optimal temperatures for survival and growth for juvenile steelhead trout; and in YR 2006 stream temperatures reached lethal levels. As stream flows drop considerably in the summer, less space is available for juvenile rearing and stream temperatures increase. The two factors, when combined, could be limiting the production of juvenile steelhead trout by serving as a bottleneck to production and survival. The best fish indicators we have for indirectly assessing summer habitat conditions are 1+ and 2+ steelhead trout smolts because they have successfully overcome summer (and first winter) conditions. If electro-fishing upper Redwood Creek was feasible and efficient, we could study the change in the population abundance of young-of-year steelhead trout at the beginning and end of the summer period. However, electro-fishing is not feasible in upper Redwood Creek due to the depth and size of most pools. Such a study would also have to operate downstream migrant traps in the mainstem and tributaries to account for emigration and immigration.

We have observed young of year steelhead trout utilizing groundwater seeps which are much cooler than the temperatures in the mainstem of upper Redwood Creek. However, we cannot assume that these seeps will fully compensate for the rather harsh conditions that exist in the mainstem of upper Redwood Creek during mid to late summer. In recent years various groundwater seeps located at the trap site were buried by sand deposits, and became unusable for juvenile salmonids. In order to more fully understand over-summer habitat conditions, studies should be undertaken which specifically quantify and qualify habitat conditions. When conducted over many years, these data could offer insights into the smolt numbers we observe. Positive changes to over-summer conditions could occur when the riparian community matures (which would help minimize solar heating of the stream) and if pools scour (and remain scoured) to achieve suitable depths for over-summering.

Over-winter habitat: The quantity and condition of over-winter habitat can also impact juvenile steelhead populations. Unfortunately, very little is known about the quantity and quality of over-winter habitat in upper Redwood Creek. Redwood Creek follows a fault (Grogan) for many miles, and this fault forces the stream to follow a straight line. By traveling in a straight line, the stream cannot meander as easily, thus the formation and maintenance of backwater pools and alcoves are minimized. Additionally, the lack of large woody debris also limits over-winter habitat. The amount of suitable habitat in upper Redwood Creek during winter is probably a limiting factor because there do not appear to be many backwaters, alcoves, and side channels in upper Redwood Creek based upon aerial observations (Author, 2007). These habitat types (backwaters etc.) are important areas because they offer refuge from swift currents. Similar to over-summer conditions, 1+ and 2+ steelhead populations are the best indicators of over-winter conditions because they have successfully lived through winter conditions. In order to more fully understand over-winter habitat conditions, studies should be undertaken which specifically quantify and qualify habitat conditions. When conducted over many years, these data could offer insights into the smolt numbers we observe. The 'trick' will be to have a study designed which can separate impacts of over-summer conditions and over-winter conditions on juvenile steelhead smolt populations. If studies found that the amount of suitable winter habitat was low and potentially limiting, restoration work which involved the formation and maintenance of key habitat types (backwaters, alcoves, side channels, deep pools, large woody debris, etc) would be beneficial to steelhead trout smolt populations.

The stream habitat in Redwood Creek should be managed to protect, conserve, and improve salmonid habitat, similar to protecting the watershed at large. Sediment inputs need to be curtailed, large woody debris needs to be recruited, and riparian zones should be conserved to allow for adequate shading of the stream, which in turn should decrease summer stream temperatures. Although Redwood Creek will most likely never return to a pre-logging condition, if we decrease sediment yields and cease logging in riparian zones the stream might become more functional and hospitable to salmonids by having cleaner gravels, deeper pools, cooler stream temperatures, and increased habitat complexity.

CONCLUSIONS

For the first time in eight consecutive years, 0+ coho salmon were captured moving downstream from upper Redwood Creek, thus indicating some number of adult coho salmon were able to reproduce in areas upstream of the trapping site.

The total number of juvenile salmonids emigrating from upper Redwood Creek in YR 2007 (N = 174,156) was greater than YRS 2003, 2005, and 2006; and was the fourth lowest of eight study years. Population abundances for 0+ Chinook salmon, 1+ steelhead trout, and 2+ steelhead trout in YR 2007 were greater than YRS 2005 and 2006. 0+ Chinook salmon population emigration in YR 2007 showed the greatest reduction (76%) compared to the previous seven year average. The decrease in YR 2007 was most likely due to a low number of returning adults because stream discharge was not high enough to mobilize redd gravels after reproduction, and stream flows were adequate for adult passage into upper Redwood Creek.

1+ steelhead trout population emigration in YR 2007 was 11% less than the previous seven year average, and 2+ steelhead trout in YR 2007 was 47% less than the seven year average. All juvenile salmonids showed a negative trend in population abundance over the eight study years; yet statistical significance was only found for 1+ steelhead trout and 2+ steelhead trout. However, due to the steepness of the decline (slope of regression line) for 0+ Chinook salmon, population data collected thus far over the eight consecutive years does not currently support de-listing Chinook salmon or steelhead trout in Redwood Creek from the Federal ESA.

Similar to past study years, there were far more 0+ steelhead trout emigrating from upper Redwood Creek than older, juvenile age classes; the ratio of 0+ SH to older juvenile age classes equaled 2:1. Marked 0+ steelhead trout released at the upper trap were captured at the lower trap for the second consecutive year, which indicates that 0+ steelhead trout can migrate considerable distances in search of rearing areas. These experiment could be the first to document long range dispersal of young-of- year steelhead trout from spawning areas.

Most of the Chinook salmon in upper Redwood Creek migrated downstream during April and June (similar to YR 2006) in YR 2007, with the biggest reductions in emigration occurring in April and May. Most of the 1+ steelhead trout migrated downstream during May and June (similar to YR 2006); and most of the 2+ steelhead trout migrated downstream during May and June. The biggest reduction in emigration for both 1+ and 2+ steelhead trout occurred in April.

The population of 0+ Chinook salmon emigrants in YR 2007 consisted of both fry and fingerlings(as in previous study years), with slightly more fingerlings emigrating than fry. The two noticeable peaks in 0+ Chinook salmon migration (separated by about seven weeks) do not indicate two distinct runs of adult Chinook salmon spawned in upper Redwood Creek because of vast differences in the average size of migrants in each peak. The larger migrants associated with the second peak could 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. No relationships between the percentage of fry and population size, stream temperature, or stream discharge were detected, thus the mechanism for fry dispersal could be genetic. We are currently collecting genetic samples from both fry and fingerlings to later test for any significant differences.
The average size of emigrating juvenile Chinook salmon in YR 2007 was the lowest of record, and about five percentage points lower than the previous six year average. A density-dependent relationship of emigrant numbers and size was detected for 0+

Chinook salmon over eight years; with higher numbers emigrating, the average size of the emigrants decreased.

Similar to Chinook salmon, the average size of 0+ steelhead trout in YR 2007 was the smallest of record. The average size of 1+ steelhead trout was the second lowest of record, and the average size of 2+ steelhead trout was the third lowest; however, differences were slight and may not be biologically meaningful. The average size of 1+ steelhead trout was positively related to 1+ steelhead trout population abundance. This may indicate that stream conditions favorable for survival were also favorable for growth. No such relationships were detected for 0+ or 2+ steelhead trout.

Pit tagged 0+ Chinook salmon (n = 245) and 1+ steelhead trout (n = 18) released from upper Redwood Creek were recaptured 29 miles downstream at the second trap in lower Redwood Creek. Travel time for 0+ Chinook salmon in YR 2007 ranged from 2.5 – 29.5 d, and averaged 10.7 d; in YR 2005 travel time averaged 7.5 d and in YR 2006 averaged 8.0 d. Travel time in YR 2007 was positively related to size (FL, Wt) at time of recapture. 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 YR 2005 (Avg. = 8.2 mi/d) and YR 2006 (Avg. = 5.5 mi/d).

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 in YR 2007 ranged from 3.5 – 55.5 d, and averaged 29.5 d; travel rate ranged from 0.5 – 8.3 mi/d, and averaged 1.6 mi/d. Travel time in YR 2007 was greater than YRS 2005 and 2006, and 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 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 temperatures (-). 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 shows that stream temperatures are negatively affecting growth, which in turn may prevent 1+ steelhead trout from attaining a size that is 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 smolts showed reduced growth rates with increasing water temperatures in the river, 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. 2007) 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 lower 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).

The average daily stream temperature per study year significantly decreased over time, and may reflect a maturing riparian zone along Redwood Creek. Average stream temperature in YR 2007 was the second lowest of the seven consecutive years of data, with a maximum temperature of 77.9 ^{o}C being the lowest on record. Both MWAT and MWMT in YR 2007 were also lower than MWAT and MWMT in previous study years. Stream temperatures in YR 2007 were not high enough, nor of a long enough duration to cause any observable mortality to juvenile salmonids. During the fish kill in YR 2006, both MWAT and the daily maximum stream temperature (29.5 ^{o}C or 85.1 ^{o}F) were the highest of record, and may prove as a useful indicator of lethal stream temperatures in upper Redwood Creek.

RECOMMENDATIONS

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

The most important recommendation to make is to continue this study over multiple consecutive years (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 upper Redwood Creek, which will increase our understanding of juvenile salmonids (smolts).

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

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

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

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

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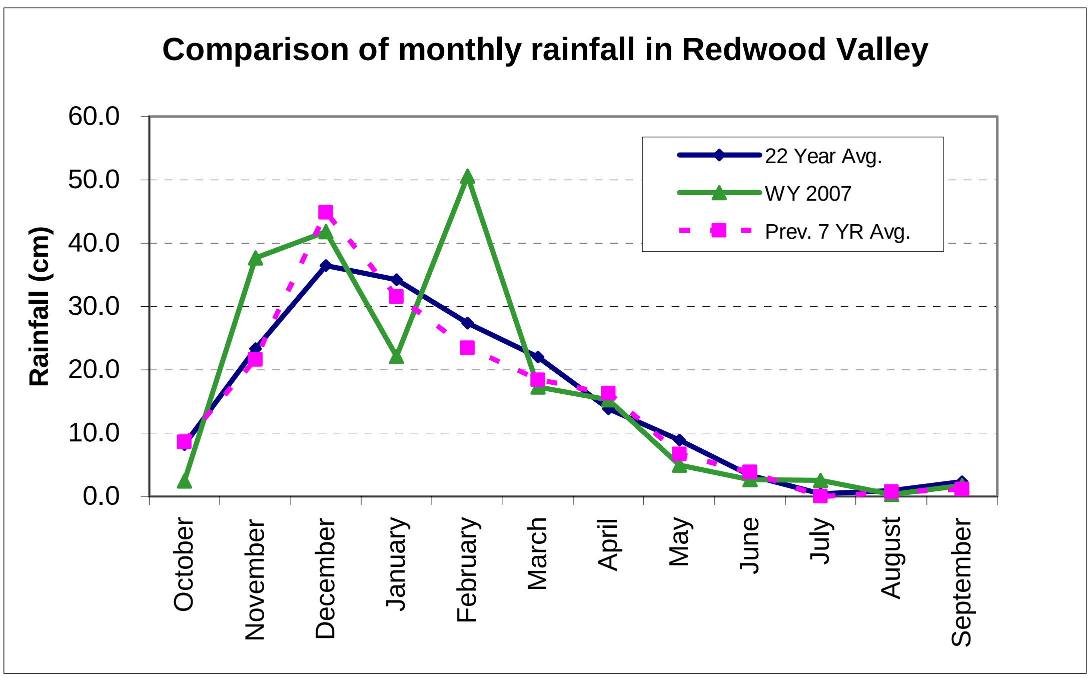
APPENDICES

Appendix 1. Comparison of 22 year average annual rainfall with average of previous seven water years (2000 - 2006) and water year 2007 at Hinz family residence, Redwood Valley, Redwood Creek, Humboldt County, California.

	Annual Rainfall* (centimeters)		
Month	Historic Average	Average of previous 7 water years (2000-06)	Water Year 2007
Oct.	8.2	8.6	2.4
Nov.	23.3	21.6	37.6
Dec.	36.5	44.8	41.8
Jan.	34.2	31.5	22.1
Feb.	27.4	23.5	50.6
Mar.	22.0	18.3	17.3
Apr.	13.8	16.2	15.2
May	8.9	6.6	5.0
June	3.3	3.9	2.6
July	0.4	0.0	2.5
Aug.	0.9	0.7	0.3
Sept.	2.3	1.1	1.7
Total:	181.2	176.9	199.2

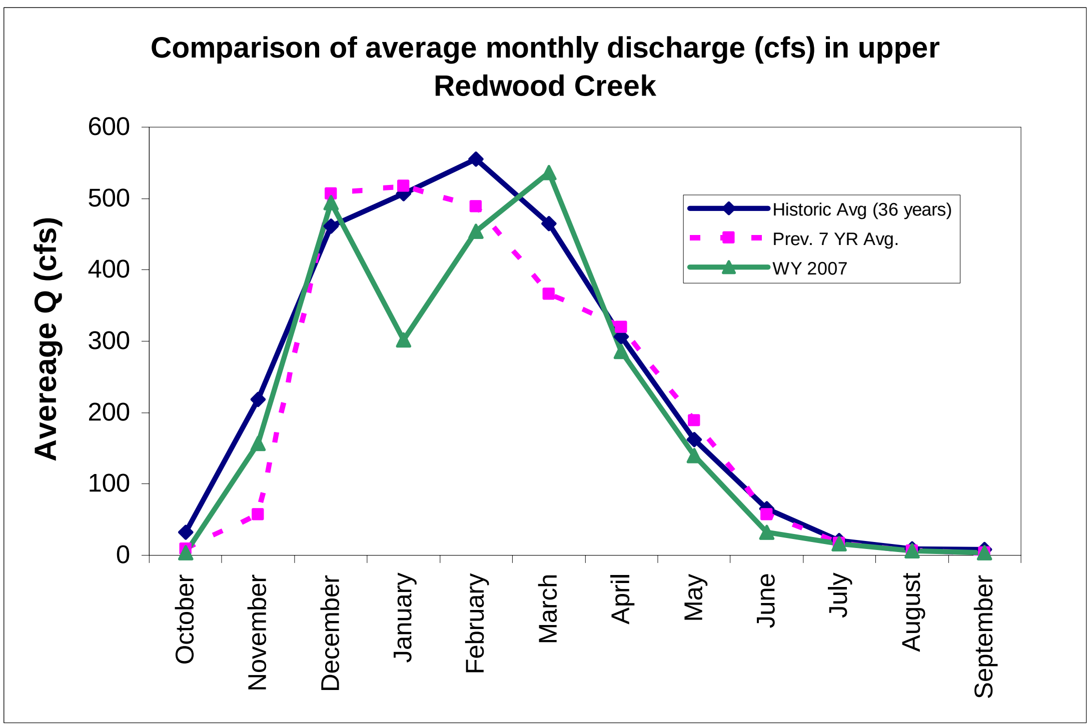
* Data courtesy of Redwood National Park, Vicki Ozaki pers. comm. 2007.



Appendix 2. Comparison of 36 year average monthly discharge (cfs) with average of previous seven water years and water year 2007, O'Kane gaging station, upper Redwood Creek, Humboldt County, CA. (USGS 2007).

	Annual Discharge* (cfs)		
Month	Historic Average	Average of previous 7 water years (2000-06)	Water Year 2007
Oct.	32	9	4
Nov.	218	58	157
Dec.	462	507	494
Jan.	507	517	302
Feb.	555	489	454
Mar.	465	366	536
Apr.	306	320	286
May	162	189	140
June	66	57	32
July	21	17	16
Aug.	9	6	6
Sept.	8	4	4
Avg:	234	212	203

* Data courtesy of Chris O'Neil, pers. comm. 2007.



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.

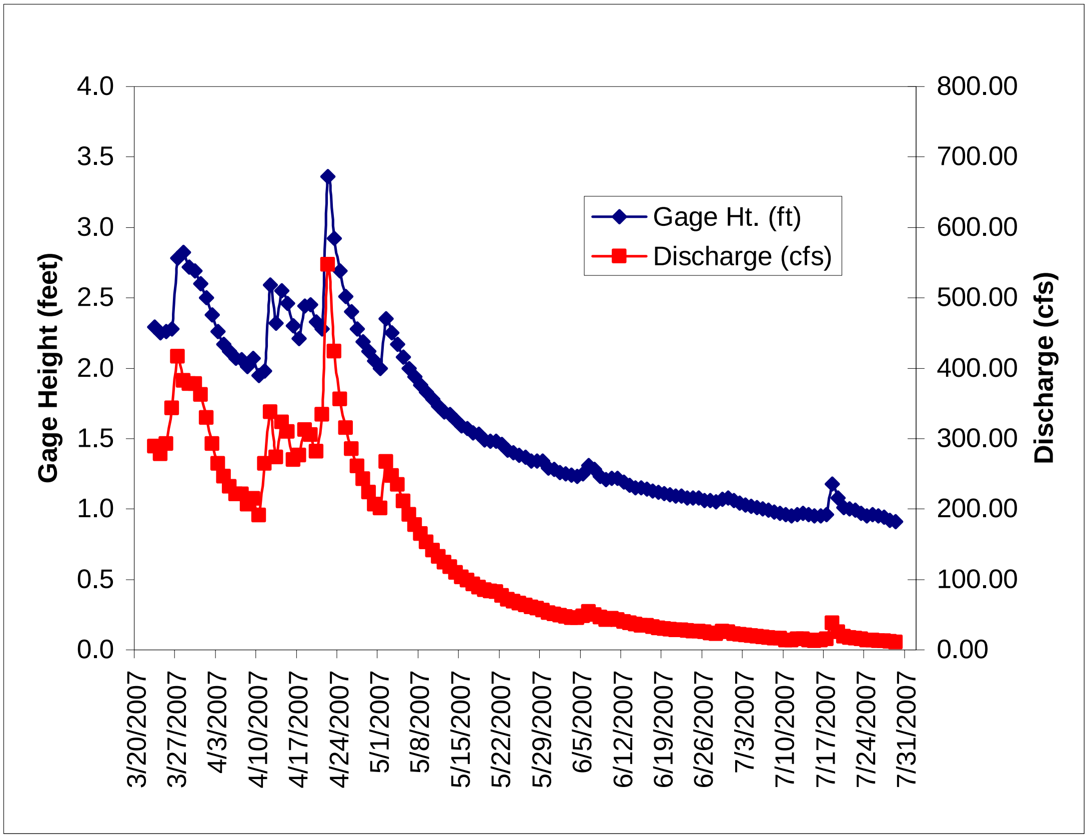
Coho Salmon

1. To determine the number of parents responsible for the juveniles captured in the fish trap.
2. To test for possible genetic differences between fish captured in the lower basin and upper basin.
3. To construct a genetic data base for future comparisons and analyses.

Both Species:

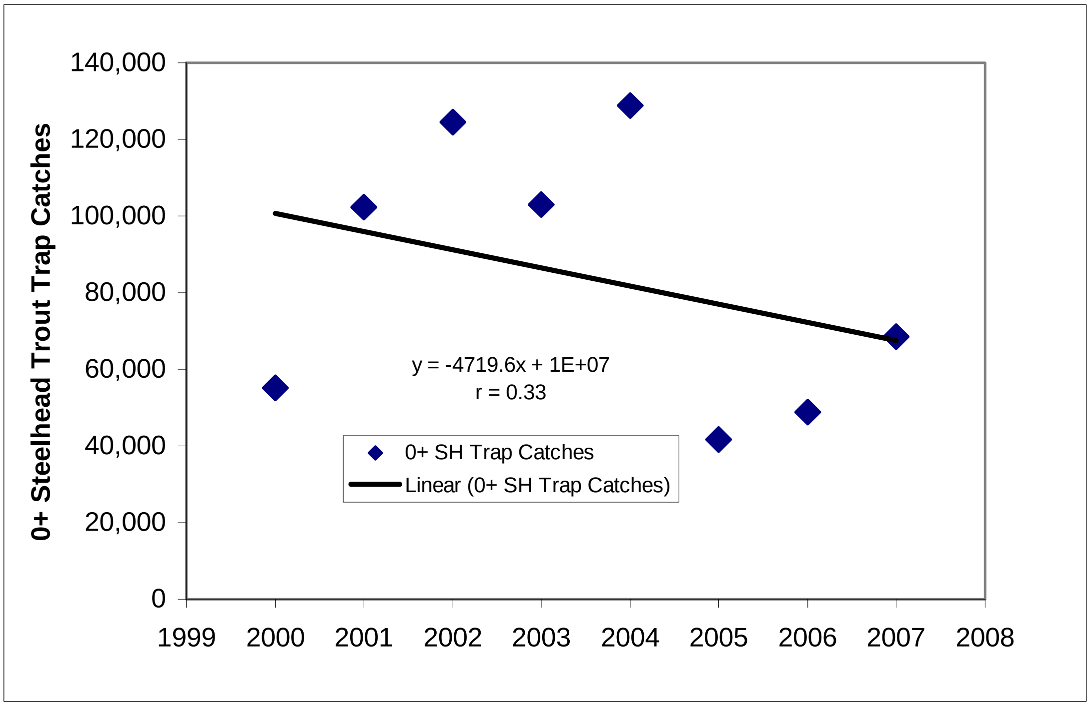
1. To test for possible genetic differences between fish captured in the lower basin and upper basin.
2. To construct a genetic data base for future comparisons and analyses.

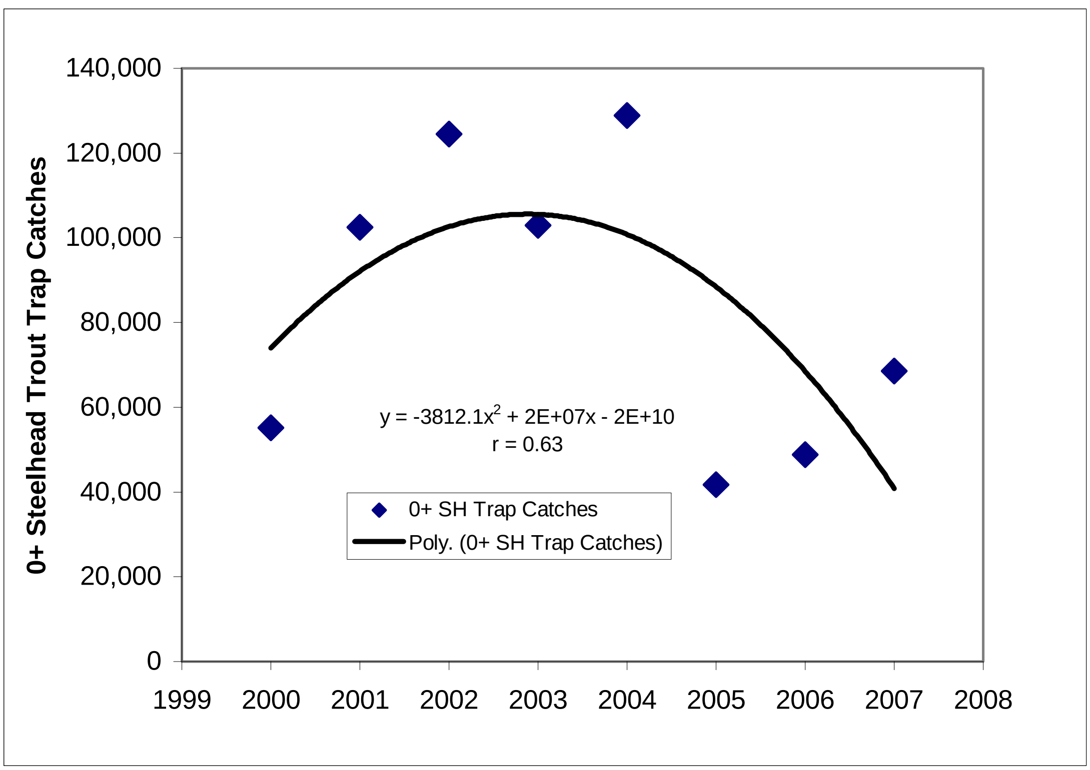
Appendix 4. Graphical representation of daily stream gage height (ft.) at trap site and average daily stream flow (cfs) measured at O'Kane gaging station (USGS 2007), upper Redwood Creek, Humboldt County, CA., YR 2007.



Appendix 5. Photographs of 0+ coho salmon captured for the first time in eight consecutive years, upper Redwood Cr, Humboldt County, CA., 2007.

Appendix 6. Linear (top graph) and polynomial (bottom graph) trend lines for 0+ steelhead trout trap catches over eight study years, upper Redwood Creek, Humboldt County, CA.





Appendix 7. Regression and correlation results for tests of average weekly gage height (ft), stream discharge (cfs), stream temperature (^{o}C), and time (week number) on weekly catches for each species at age, and regression results of trapping efficiencies on 0+ Chinook salmon, 1+ steelhead trout, and 2+ steelhead trout weekly catches, upper Redwood Creek, Humboldt County, CA., 2007.

Weekly Values		Regression Results			
Y variable (Catches)	X variable	p value	R^2 or r*	Slope Sign	Power of test
0+ KS**	Gage height	*0.03*	0.32	Negative	0.62
0+ KS**	Discharge	*0.02*	0.36	Negative	0.71
0+ KS**	Temperature	0.14	0.16	Positive	0.31
0+ KS**	Week number	0.14	0.27*	Positive	0.31
0+ KS**	Trap efficiency	*0.03*	0.31	Positive	0.61
0+ SH**	Gage height	*0.00004*	0.66	Negative	0.99
0+ SH**	Discharge	*0.000004*	0.74	Negative	1.00
0+ SH**	Temperature	*0.002*	0.46	Positive	0.93
0+ SH**	Week number	*0.001*	0.70*	Positive	0.96
1+ SH	Gage height	0.42	0.05	Negative	0.12
1+ SH	Discharge	0.24	0.10	Negative	0.21
1+ SH	Temperature	0.68	0.01	Positive	0.07
1+ SH	Week number	0.66	0.12*	Positive	0.07
1+ SH	Trap efficiency	0.51	0.03	Negative	0.10
2+ SH	Gage height	0.39	0.06	Negative	0.13
2+ SH	Discharge	0.39	0.06	Negative	0.13
2+ SH	Temperature	0.33	0.08	Positive	0.15
2+ SH	Week number	0.16	0.24*	Positive	0.12
2+ SH	Trap efficiency	0.16	0.15	Negative	0.27

* R^2 is for physical variables (temperature, etc.), "r" is for trapping week number.
** Log (x+1) transformation.
P values in italics indicates statistical significance for that test.

Appendix 8. Regression and correlation results for tests of average weekly gage height (ft), stream discharge (cfs), and stream temperature (^{o}C) on weekly population emigration of 0+ Chinook salmon, 1+ steelhead trout, and 2+ steelhead trout in YR 2007, upper Redwood Creek, Humboldt County, CA.

Weekly Values		Regression Results			
Y variable (Population)	X variable	p value	R^2 or r*	Slope Sign	Power of test
0+ KS**	Gage height	0.10	0.17	Positive	0.37
0+ KS**	Discharge**	*0.03*	0.29	Positive	0.63
0+ KS**	Temperature	*0.01*	0.35	Negative	0.75
0+ KS**	Week number*	*0.007*	0.63	Negative	0.83
1+ SH	Gage height	0.81	0.004	Negative	0.06
1+ SH	Discharge	0.54	0.02	Negative	0.09
1+ SH	Temperature	0.77	0.006	Negative	0.06
1+ SH	Week number*	0.73	0.09	Negative	0.06
2+ SH	Gage height	0.85	0.002	Positive	0.05
2+ SH	Discharge	0.98	0.000	Positive	0.05
2+ SH	Temperature	0.45	0.04	Negative	0.11
2+ SH	Week number*	0.48	0.17	Negative	0.10

* R^2 is for physical variables (temperature, etc.), "r" is for trapping week number.
** Log (x+1) transformation.
P values in italics indicates statistical significance for that test.

Appendix 9. 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 24.
** SEM = standard error of mean.

Appendix 10. Release groups, sample size, 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 11. 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 24.
** SEM = standard error of the mean.

Appendix 12. 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 12 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 24. *P values* in italics indicates statistical significance for that test.
** Transformed with log(x+1)

Appendix 13. 0+ Chinook salmon delayed mortality test results (n = 36), upper Redwood Creek, Humboldt County, CA., 2007.

Age / spp.*	Date	(n)	Duration (Hrs)	Average Water Temp (C)	Delayed Mortality Tests: Fin Clipping Morts./ Total	Fin Clipping % Mort.	Handling Morts./ Total	Handling % Mort.	Pit Tagging Morts./ Total	Pit Tagging % Mort.
0+KS	3/30 – 3/31	3	36	9.2	0/3	0.00				
0+KS	4/01 - 4/02	7	24	9.0	0/7	0.00				
0+KS	4/08 – 4/09	64	36	10.7	0/64	0.00				
0+KS	4/18 – 4/19	26	36	7.5			0/26	0.00		
0+KS	4/23 – 4/24	7	24	9.4	0/7	0.00				
0+KS	4/25 – 4/26	23	36	9.7	0/23	0.00				
0+KS	4/28 – 4/29	42	36	11.8	0/42	0.00				
0+KS	4/30 – 5/01	44	36	10.5	0/44	0.00				
0+KS	5/07 – 5/08	80	36	13.7	0/80	0.00				
0+KS	5/22 – 5/22	3	10	13.9					0/3	0.00
0+KS	5/26 – 5/27	2	36	15.7					0/2	0.00
0+KS	5/28 – 5/29	21	36	15.6					0/21	0.00
0+KS	5/30 – 5/31	39	36	16.6					0/39	0.00
0+KS	5/31 – 6/01	26	24	16.5			0/26	0.00		
0+KS	6/01 – 6/02	25	24	17.0					0/25	0.00
0+KS	6/03 – 6/04	20	36	17.1			0/20	0.00		
0+KS	6/04 – 6/04	38	10	16.8					0/38	0.00
0+KS	6/05 – 6/05	45	10	15.2					0/45	0.00
0+KS	6/06 – 6/07	61	36	14.6					0/61	0.00
0+KS	6/09 – 6/10	35	36	15.8					0/35	0.00
0+KS	6/11 – 6/12	74	36	16.2					0/74	0.00
0+KS	6/13 – 6/14	47	24	16.6					2/47	4.26
0+KS	6/18 – 6/19	47	36	18.5					0/47	0.00
0+KS	6/20 – 6/21	78	36	18.4					0/78	0.00
0+KS	6/23 – 6/24	58	36	16.7					0/58	0.00
0+KS	6/25 – 6/26	53	36	16.8					1/53	1.89
0+KS	6/27 – 6/28	42	36	17.8	0/42	0.00				
0+KS	6/30 – 7/01	36	36	18.2	0/36	0.00				
0+KS	7/02 – 7/03	38	36	19.1					2/38	5.26
0+KS	7/04 – 7/05	14	36	20.9	0/14	0.00				
0+KS	7/06 – 7/07	22	24	20.8			0/22	0.00		
0+KS	7/07 – 7/08	24	36	20.7					0/24	0.00
0+KS	7/09 – 7/10	4	36	22.0			0/4	0.00		
0+KS	7/10 – 7/10	4	10	23.3					0/4	0.00
0+KS	7/19 – 7/20	2	24	19.4					0/2	0.00
0+KS	7/22 – 7/23	1	24	21.8					0/1	0.00

* Age/species abbreviation is the same as in Figure 1.

Appendix 14. 0+ steelhead trout delayed mortality test results (n = 11), upper Redwood Cr, Humboldt County, CA., 2007.

					Delayed Mortality Tests			
					Fin Clipping		Handling	
Age / spp.*	Date	(n)	Duration (Hrs)	Average Water Temp (C)	Morts./ Total	% Mort.	Morts./ Total	% Mort.
0+SH	5/28 – 5/29	30	24	14.9			0/30	0.00
0+SH	6/02 – 6/03	30	24	17.0			0/30	0.00
0+SH	6/08 – 6/09	30	24	15.5			0/30	0.00
0+SH	6/15 – 6/16	30	24	17.8			0/30	0.00
0+SH	6/22 – 6/23	30	24	16.8			0/30	0.00
0+SH	6/26 – 6/28	30	48	17.3			0/30	0.00
0+SH	6/27 – 6/28	100	36	17.9	0/100	0.00		
0+SH	6/29 – 6/30	30	24	16.8			0/30	0.00
0+SH	7/06 – 7/07	30	24	20.7			0/30	0.00
0+SH	7/13 – 7/14	30	24	19.9			0/30	0.00
0+SH	7/19 – 7/20	100	24	19.3	0/100	0.00		

* Age/species abbreviation is the same as in Figure 1.

Appendix 15. 1+ steelhead trout delayed mortality test results (n = 45), upper Redwood Creek, Humboldt County, CA., 2007.

					Delayed Mortality Tests					
					Fin Clipping		Handling		Pit Tagging	
Age / spp.*	Date	(n)	Duration (Hrs)	Average Water Temp (C)	Morts./ Total	% Mort.	Morts./ Total	% Mort.	Morts./ Total	% Mort.
1+SH	3/30 – 3/31	5	36	9.2	0/5	0.00				
1+SH	4/01 – 4/02	3	36	9.0	0/3	0.00				
1+SH	4/03 – 4/04	9	36	9.6	0/9	0.00				
1+SH	4/05 – 4/06	9	36	11.0	0/9	0.00				
1+SH	4/05 – 4/06	12	36	11.0					0/12	0.00
1+SH	4/08 – 4/09	27	36	10.7	0/27	0.00				
1+SH	4/10 – 4/11	19	36	9.4					0/19	0.00
1+SH	4/12 – 4/13	20	36	8.8					0/20	0.00
1+SH	4/16 – 4/17	9	36	9.3	0/9	0.00				
1+SH	4/18 – 4/19	15	36	7.5	0/15	0.00				
1+SH	4/19 – 4/19	6	10	8.0					0/6	0.00
1+SH	4/23 – 4/24	41	36	9.7	0/41	0.00				
1+SH	4/25 – 4/26	19	36	9.7	0/19	0.00				
1+SH	4/25 – 4/26	25	36	9.7					0/25	0.00
1+SH	4/30 – 5/01	50	36	10.5	0/50	0.00				
1+SH	5/01 – 5/01	30	10	9.9					0/30	0.00
1+SH	5/07 – 5/08	30	36	13.7	0/30	0.00				
1+SH	5/08 – 5/08	30	10	14.6					0/30	0.00
1+SH	5/10 – 5/11	30	36	13.4					0/30	0.00
1+SH	5/14 – 5/15	50	36	13.4	0/50	0.00				
1+SH	5/15 – 5/15	30	10	14.0					0/30	0.00
1+SH	5/21 – 5/22	50	36	13.4	0/50	0.00				
1+SH	5/22 – 5/22	30	10	13.9					0/30	0.00
1+SH	5/26 – 5/27	13	36	15.7					0/13	0.00
1+SH	5/28 – 5/29	30	36	15.6					0/30	0.00
1+SH	5/30 – 5/31	30	36	16.6					0/30	0.00
1+SH	6/04 – 6/04	30	10	16.8					0/30	0.00
1+SH	6/09 – 6/10	30	36	15.8					0/30	0.00
1+SH	6/13 – 6/14	30	24	16.6					0/30	0.00
1+SH	6/18 – 6/19	30	36	18.5					0/30	0.00
1+SH	6/23 – 6/24	26	36	16.7					0/26	0.00
1+SH	6/25 – 6/26	20	36	16.8					0/20	0.00
1+SH	6/27 – 6/28	9	36	17.8	0/9	0.00				
1+SH	6/30 – 7/01	4	36	18.2	0/4	0.00				
1+SH	7/04 – 7/05	1	36	20.9	0/1	0.00				
1+SH	7/06 – 7/07	2	24	20.8			0/2	0.00		
1+SH	7/07 – 7/08	4	36	20.7					0/4	0.00
1+SH	7/09 – 7/10	1	36	22.0			0/1	0.00		
1+SH	7/10 – 7/10	1	10	23.3					0/1	0.00
1+SH	7/11 – 7/12	2	36	19.3			0/2	0.00		
1+SH	7/12 – 7/13	3	24	18.6					0/3	0.00
1+SH	7/16 – 7/17	1	24	20.7					0/1	0.00
1+SH	7/19 – 7/20	4	24	19.4					0/4	0.00
1+SH	7/22 – 7/23	1	24	21.8					0/1	0.00
1+SH	7/26 – 7/27	1	24	21.1					0/1	0.00

* Age/species abbreviation is the same as in Figure 1.

Appendix 16. 2+ steelhead trout delayed mortality test results (n = 45), upper Redwood Creek, Humboldt County, CA., 2007.

					Delayed Mortality Tests					
				Average	Fin Clipping		Handling		Pit Tagging	
Age / spp.*	Date	(n)	Duration (Hrs)	Water Temp (C)	Morts./ Total	% Mort.	Morts./ Total	% Mort.	Morts./ Total	% Mort.
2+SH	3/30 – 3/31	3	36	9.2	0/3	0.00				
2+SH	4/01 - 4/02	1	36	9.0	0/1	0.00				
2+SH	4/03 – 4/04	2	36	9.6	0/2	0.00				
2+SH	4/05 – 4/06	4	36	11.0					0/4	0.00
2+SH	4/08 – 4/09	4	36	10.7	0/4	0.00				
2+SH	4/10 – 4/11	1	36	9.4	0/1	0.00				
2+SH	4/12 – 4/13	14	36	8.8	0/14	0.00				
2+SH	4/16 – 4/17	5	36	9.3	0/5	0.00				
2+SH	4/18 – 4/19	5	36	7.5	1/5	20.00				
2+SH	4/23 – 4/24	10	36	9.7	0/10	0.00				
2+SH	4/25 – 4/26	6	36	9.7					0/6	0.00
2+SH	4/30 – 5/01	2	36	10.5	0/2	0.00				
2+SH	5/02 – 5/03	6	36	9.4					0/6	0.00
2+SH	5/05 – 5/06	2	36	10.4	0/2	0.00				
2+SH	5/07 – 5/08	3	36	13.7	0/3	0.00				
2+SH	5/09 – 5/10	3	36	13.8	0/3	0.00				
2+SH	5/14 – 5/15	3	36	13.4	0/3	0.00				
2+SH	5/16 – 5/17	4	36	13.8	0/4	0.00				
2+SH	5/21 – 5/22	2	36	13.4	0/2	0.00				
2+SH	5/26 – 5/27	2	36	15.7	0/2	0.00				
2+SH	5/28 – 5/29	9	36	15.6	0/9	0.00				
2+SH	5/30 – 5/31	8	36	16.6					0/8	0.00
2+SH	6/02 – 6/03	5	36	17.4	0/5	0.00				
2+SH	6/04 – 6/05	5	36	15.6	0/5	0.00				
2+SH	6/06 – 6/07	10	36	14.5	0/10	0.00				
2+SH	6/08 – 6/09	4	36	15.6	0/4	0.00				
2+SH	6/09 – 6/10	7	36	15.8					0/7	0.00
2+SH	6/11 – 6/12	1	36	16.0	0/1	0.00				
2+SH	6/13 – 6/14	2	24	16.6	0/2	0.00				
2+SH	6/13 – 6/14	1	24	16.6					0/1	0.00
2+SH	6/16 – 6/17	13	36	17.5	0/13	0.00				
2+SH	6/18 – 6/19	3	36	18.4	0/3	0.00				
2+SH	6/18 – 6/19	1	36	18.5					0/1	0.00
2+SH	6/20 – 6/21	9	36	18.3	1/9	11.11				
2+SH	6/23 – 6/24	3	36	16.7					0/3	0.00
2+SH	6/25 – 6/26	3	36	16.8	0/3	0.00				
2+SH	6/27 – 6/28	3	36	17.8	0/3	0.00				
2+SH	7/09 – 7/10	1	36	22.0			0/1	0.00		
2+SH	7/10 – 7/10	1	10	23.3					0/1	0.00
2+SH	7/11 – 7/12	3	36	19.3			0/3	0.00		
2+SH	7/12 – 7/13	3	24	18.6					0/3	0.00
2+SH	7/14 – 7/16	3	60	21.1			0/3	0.00		
2+SH	7/16 – 7/17	5	24	20.7					0/5	0.00
2+SH	7/19 – 7/20	2	24	19.4					0/2	0.00
2+SH	7/25 – 7/26	1	24	21.4					0/1	0.00

* Age/species abbreviation is the same as in Figure 1.