State of California
The Resources Agency
DEPARTMENT OF FISH AND GAME

2008 ANNUAL REPORT

UPPER REDWOOD CREEK
JUVENILE SALMONID (SMOLT) DOWNSTREAM MIGRATION STUDY
2000 - 2008 Seasons
PROJECT 2a5

Fisheries Restoration Grant Program (Project No. P0710541)

Prepared by

Michael D. Sparkman
Northern Region

Anadromous Fisheries Resource Assessment and Monitoring Program

January 2010

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ABSTRACT

Juvenile anadromous salmonid trapping was conducted for the ninth consecutive year in upper Redwood Creek, Humboldt County, California during the spring/summer emigration period (March – August) in YR 2008. 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. These data are also utilized for Viable Salmonid Population (VSP) Analysis.

A rotary screw trap and fyke net trap collectively operated 114 day/nights out of 114 possible, and captured 35,567 0+ Chinook salmon, 9 1+ Chinook salmon, 57,805 0+ steelhead trout, 6,843 1+ steelhead trout, 634 2+ steelhead trout, 4 cutthroat trout, 4 0+ pink salmon, 32 0+ coho salmon, and 7 1+ coho salmon to total 100,905 individuals. 1+ coho salmon were captured for the first time in nine consecutive years in YR 2008. Catches in YR 2008 were 1.12 times greater than catches in YR 2007, and 45% less than the previous eight year average catch. Average weekly trapping efficiency was 27% for 0+ Chinook salmon, 20% for 1+ steelhead trout, and 19% 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 2008 equaled 115,427 (107,558 – 123,297), and was 1.7 times greater than emigration in YR 2007 and 56% less than emigration for the previous eight year average. The large decrease in YR 2008 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 32,849 (29,177 – 36,522), and was 5% less than emigration in YR 2007 and 14% less than emigration for the previous eight year average. 2+ steelhead trout population emigration equaled 3,568 (2,749 – 4,366) and was 1.3 times greater than emigration in YR 2007 and 29% less than emigration for the previous eight year average. 0+ Chinook salmon, 1+ steelhead trout, and 2+ steelhead trout showed a significant, negative trend over the nine current study years.

With respect to successful watershed restoration, we expect: 1) stream temperatures to decrease in the summer, 2) a change in the age class structure of steelhead migrants to favor older, larger smolts, and 3) a general increase in smolt population abundances.

[1/] This paper should be referenced as: Sparkman MD. 2010. Upper Redwood Creek juvenile salmonid (smolt) downstream migration study, study year 2008. CDFG AFRAMP, 2008 Annual Report 2a5: 131 p.

INTRODUCTION

This report presents results of the ninth consecutive year of juvenile salmonid downstream migrant trapping in upper Redwood Creek, Redwood Valley, Humboldt County, California during the spring/summer emigration period. The study began in YR 2000, and was funded by the Redwood Creek Landowners Association (RCLA). Study years 2001 – 2008 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. The Fisheries Restoration Grant Program (FRGP) has assisted in funding this study from YR 2005 to the present (YR 2008, FRGP Project No. P0710541), and in YR 2008 the CDFG's Steelhead Trout Report-Restoration Card Program also provided financial assistance.

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 and cutthroat trout 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. 2006), 2) redd gravel conditions (Cederholm et al. 1981, Holtby and Healey 1986, Hartman and

Scrivener 1990), 3) in-stream habitat quality and watershed health (Tripp and Poulan 1986, Hartman and Scrivener 1990, Hicks et al. 1991, Bradford et al. 2000, Sharma and Hilborn 2001, Ward et al. 2002), 4) restoration activities (Everest et al. 1987 *in* Hicks et al. 1991, Slaney et al. 1986, Tripp 1986, McCubbing and Ward 1997, Solazzi et al. 2000, Cleary 2001, Ward et al 2002, McCubbing 2002, Ward et al. 2003, Roni et al. 2006), 5) over-winter survival (Scrivener and Brown 1993 *in* McCubbing and Ward 1997, Quinn and Peterson 1996, Solazzi et al. 2000, McCubbing 2002, Ward et al. 2002, Giannico and Hinch 2003), 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 2008 with comparisons to the average of the previous eight study years (YRS 2000 - 2007) and YR 2007.

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).

<u>Geology</u>

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

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

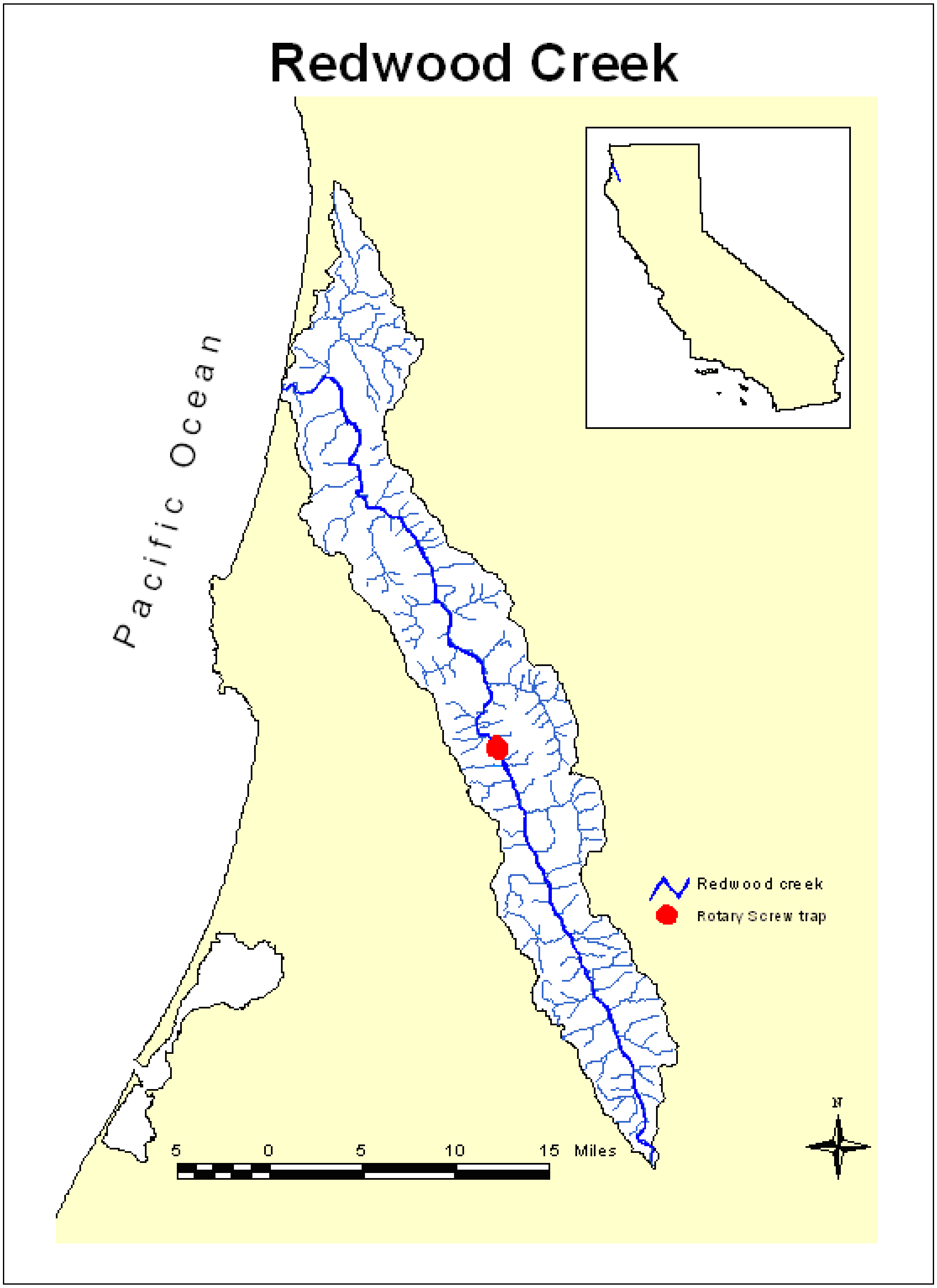

Figure 1. Redwood Creek watershed with rotary screw trap location (RM 33) in Redwood Valley, Humboldt County, CA., (scale is slightly inaccurate due to reproduction process; Charlotte Peters pers. comm. 2001).

Climate and Annual Precipitation

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

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 23 years (Vicki Ozaki pers. comm. 2008). Annual precipitation ranged from 90 cm (35.4 in.) to 250 cm (98.4 in.), and averaged 180.7 cm (71.1 in.). Most (96%) of the rainfall in Redwood Valley 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 2008 (169.6 cm or 66.8 in.) was 6.2% less than the historic average, 5.6% less than the previous eight year average (132 cm or 52 in.), and 14.8% less than WY 2007. Thus, rainfall in WY 2008 was slightly below average (Appendix 1).

The 23 year average monthly rainfall during the majority of the trapping season (April – July) totaled 26.0 cm (10.2 in.) (Table 1). Total monthly rainfall during this period of trapping in YR 2008 (16.4 cm or 6.5 in.) was about 37% less than the historic average and 39% less than the average of the previous eight study years. Rainfall in April 2008 accounted for 89% of the total rainfall during the majority of the trapping period (Table 1). Rainfall in May 2008 was the second lowest on record.

Table 1. Comparison of 23 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 8 study years (2000-07)	YR2008
Apr.	13.9	16.1	14.5
May	8.5	6.4	0.3
June	3.2	3.7	1.6
July	0.4	0.4	0.0
Total:	26.0	26.6	16.4

* Data courtesy of Redwood National Park, Vicki Ozaki pers. comm. (2008).

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 37 years (USGS 2008; Vicki Ozaki, pers. comm.. 2008). 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 2008). However, in WY 2008 average monthly flow peaked in January. Low flows in WY 2008 occurred in October - November and July - September. Using all years' data, mean monthly discharge in upper Redwood Creek was 233 cfs (6.6 m^3/sec), and ranged from 8 - 556 cfs (Appendix 2, USGS 2008). Average monthly discharge in WY 2008 equaled 194 cfs (5.5 m^3/sec) and was 17% less than the historic discharge, and 8% less than the previous eight year average (Appendix 2, USGS 2008).

The 37 year average monthly discharge during the majority of the trapping season (April - July) equaled 138 cfs (3.9 m^3/sec) (Table 2). Average monthly discharge from April – July, 2008 (98 cfs) was 29% less than the historic average, and 31% less than the previous eight year average (Table 2, data from USGS 2008).

Table 2. Comparison of 37 year average monthly discharge (Historic), average monthly discharge for the previous eight years, and monthly discharge in YRS 2007 and 2008 in upper Redwood Creek (O'Kane station) during the majority of the trapping period (USGS 2008).

	Monthly Discharge (cfs)			
Month	Historic	Previous 8 study years (2000-07)	YR 2007	YR 2008
Apr.	306	320	286	208
May	162	189	140	136
June	66	57	32	36
July	21	17	16	12
Ave:	139	146	119	98

Overstory

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

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

Understory

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

Redwood Creek History (Brief)

Redwood Creek watershed has experienced extensive logging of Redwood and other commercial tree species. By 1978, 81% of the original forest was logged, totaling 66% of the basin area (Kelsey et al. 1995). Most, if not all, remaining old growth Redwood is contained within Redwood National Park, which is downstream of the trap site. In conjunction with clear-cut logging, log removal via tractors, associated road building, geology types and geomorphic processes (eg debris slides and earthflows), and flood events in 1955 and 1964, large amounts of sediments were delivered into the stream channel (Madej and Ozaki 1996) with a resultant loss of stream habitat complexity (filling in of pools and flattening out of the stream channel, Marlin Stover pers. comm. 2000). Additional high flows occurred in 1972, 1975, and 1995 as well, and have helped influence the current channel morphology of Redwood Creek. Redwood Creek within the study area 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 increased stream complexity. However, in YR 2005 and to a much larger degree in YR 2006, large amounts of small gravels/sands were deposited at the trap site and areas downstream of the trap site; these deposits at the trap site were up to 2.5 ft deep. In YRS 2007 and 2008 we noticed that some scouring of the deposits had occurred, however, most of the rocks and cobbles were still covered by the deposits, with the finer sediments present along the stream margin as well.

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

Federal ESA Species Status

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

Coastal Chinook Salmon Evolutionarily Significant Unit (ESU), and are listed as "threatened" under the Federal Endangered Species Act (Federal Register 1999a). The definition of threatened as used by National Oceanic and Atmospheric Administration (NOAA) and the National Marine Fisheries Service (NMFS) is "likely to become endangered in the foreseeable future throughout all or a significant portion of their 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 23, 2008 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. In YR 2008, the habitat unit was still classified as 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 3, and for the first time in nine years, did not miss a single day of trapping.

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 3, stream flows were too low to operate the rotary screw trap, and a fyke net was deployed on July 3 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 2008 was discontinued on July 15 when the catch distribution for each species at age reached zero, or when relatively few individuals were caught in consecutive days.

The YR 2008 trapping season can be characterized with relatively few high flow events (Appendix 4), and frequent adjustments to the trap configuration to increase trapping efficiencies. The trap operated in the thalweg of the channel throughout the study. The largest daily increase in discharge occurred on 4/23/08 when the stream rose 0.81 ft (or 92 cfs). Trapping in YR 2008 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+ coho salmon (1+ CO), 1+ and greater cutthroat trout (CT), 1+ steelhead trout (1+ SH), and 2+ and greater steelhead trout (2+ SH). 0+ steelhead trout were only measured for fork length. 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+ 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+ Chinook salmon, 1+ steelhead trout, 2+ steelhead trout, 1+ coho salmon, and 1+ (and greater) cutthroat trout captured using the following criteria:

- Parr designated fish that had obvious parr marks present and no silvering of scales.

- Pre-smolt designated individuals with less obvious parr marks, showed some blackening of the caudal fin, and were in the process of becoming silver colored smolts. Pre-smolt was considered in-between parr and smolt.

- Smolt designated fish that were very silver in coloration (i.e. smoltification), had little to no parr marks present, and had blackish colored caudal fins**.** 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 well with gill ATPase activity and skin guanine concentration.

Population Estimates

The number of fish captured by the trap represented only a portion of the total fish moving downstream in that time period. Total salmonid out-migration estimates (by age and species) were determined on a weekly basis for 0+ Chinook salmon, 1+ steelhead trout, and 2+ steelhead trout using stratified and non-stratified mark-recapture methods described by Carlson et al. (1998). Sample sizes for marking 1+ Chinook salmon, 1+ 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 one to four times a week for 0+ Chinook salmon, 1+ steelhead trout, and 2+ steelhead trout. 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 (and data) 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, 2007, and 2008). 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 manually released upstream of the trap site at night. Night releases generally occurred from 2000 – 2300.

Additional Experiments

<u>Re-migration</u>

In YR 2007 we pit tagged and released 48 2+ steelhead trout, 484 1+ steelhead trout, and 691 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 2007 re-migrated back upstream of the upper trap to be later caught in YR 2008 as one, two or three year old fish. We have investigated re-migration in previous study years as well (YRS 2001 - 02, and 2004 - 2006). Every 2+ steelhead trout captured by the trap in upper Redwood Creek during YR 2008 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 2008 to investigate travel time from the upper to the lower trap (this study) because individual fish cannot be uniquely identified when elastomer marks are used for batches of fish, and the mark is rather difficult to apply for fish under 85 mm (FL). Pit tags (passive integrated transponder tags) offer the ability of individual recognition by using numbers unique to each tag (and marked fish). In YR 2008 (and YRS 2005 - 2007) we used Pit Tags to investigate both travel time and growth of tagged fish as they migrated downstream from Redwood Valley to be later caught at the smolt trap in lower Redwood Creek, or estuary (David Anderson, pers. comm. 2008). We found pit tagging to be easier and faster than applying elastomer. Pit tags used in the study were 11.5 mm long x 2 mm wide, and weighed 0.09 g (ALLFLEX USA, Inc., PO BOX 612266, Dallas/Ft Worth Airport, Texas). Pit tags were applied to randomly selected 1+ steelhead trout (n = 203), 2+ steelhead trout (n = 28) and 0+ Chinook salmon smolts (FL $\geq$ 66 mm**,** n = 133) using the same techniques as in previous study years. Fish were anesthetized with MS-222, and measured for FL (mm) and Wt (g) prior to tagging. A scalpel (sterilized with a 10:1 solution of water to Argentyne; Argent Chemical Laboratories, 8702 152nd Ave. N.E., Redmond, WA, 98052) was used to make a small incision (2 - 3 mm long) into the body cavity just posterior (about 3 - 5 mm) to a pectoral fin. The incision was dorsal to the ventral most region of the fish to help prevent the tag from exiting the incision. Tags were also sterilized with Argentyne, and then inserted by hand into the body cavity via the incision. Glue was not used to close the incision after tag placement because previous experience with tagging showed it was unnecessary, and in YR 2007 we found tag retention from 24 – 48 hrs post tagging to be 100%. In addition, Dare (2003) found pit tag retention to equal 99.9% for juvenile Chinook salmon held in raceways for a period of 28 d. 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.

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 either released at night or during the day 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 nearly 50% of the recaptured pit tagged salmon and 75% of recaptured steelhead trout showed growth; if the tag had a negative impact upon juveniles we would expect more fish to not grow, or lose weight when compared to those that did grow.

Delayed Mortality

We conducted several delayed mortality tests for captured 0+ Chinook salmon (n = 22 tests), 0+ steelhead trout (n = 1 test), 1+ steelhead trout (n = 24 tests), and 2+ steelhead trout (n = 31 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 223 for 0+ Chinook salmon, 208 for 1+ steelhead trout, and 148 for 2+ steelhead trout. Test durations ranged from 24 - 36 hrs.

Handling tests were for fish that were anesthetized and measured for FL, or FL and WT. Total sample size was 168 for 0+ Chinook salmon, 30 for 0+ steelhead trout, 5 for 1+ steelhead trout, and 1 for 2+ steelhead trout. The duration of tests was 24 – 36 hrs for each species at age.

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 133 for 0+ Chinook salmon, 186 for 1+ steelhead trout, and 21 for 2+ steelhead trout. The duration of each test ranged from 12 – 36 hrs, with 36 hrs being most common.

Pit Tag Retention

We did not perform any pit tag retention tests in YR 2008 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) at the trap in lower Redwood Creek 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 15, 2008. 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 2008), 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. = 13.78 and 13.84 ^{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 3/8" diameter rope. Probes were set to record stream temperatures (^{o}C) every 30 minutes and recorded about 6,240 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 - 2008 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, stream gage height and lunar phase 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, average weekly stream discharge, and lunar phase) 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 nine 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, 2007, and 2008) (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). Regression was also used to develop a model to predict the abundance of 0+ Chinook salmon in YR 2008 using abundance data from YRS 2000 – 07 and coded peak streamflow data (0 or 1).

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 eight years of downstream migrant trapping in upper Redwood Creek (FL nadir ranged from 42 – 45 mm, mean = 44 mm; nadir in YR 2008 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 nine years of data collection (eight 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. 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 (7/09 - 7/15) 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 105. 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 2008 and for the previous seven year average for Chinook salmon, and previous eight 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 2008 with the seven year average for 0+ Chinook salmon (excludes YR 2003), and eight 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 2008 differed from the previous eight year average. The percentage of fry and fingerlings in YR 2008 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 2008 with the previous eight year average. Parr stage was not included in the test for 2+ steelhead trout because in YR 2008 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 ($n = 36$) and 1+ steelhead trout ($n = 8$) smolts in YR 2008 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 (4/03 – 7/15), average daily stream temperatures at the upper trap site ranged from 6.4 – 21.9 ^{o}C (43.5– 71.4 ^{o}F) and average daily stream discharge ranged from 9.2 - 329 cfs (O'Kane gage, USGS 2008). Average daily stream temperatures at the lower trap site ranged from 8.3 – 18.6 ^{o}C (46.9 - 65.5 ^{o}F) and average daily stream discharge ranged from 39 - 1560 cfs (Orick gage, USGS 2008). 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 2008 compared to the previous seven year average (YRS 2001-2007). 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 – 2008. 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 2008; the same test was applied to the previous seven 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 2008; and the relationship of average discharge during each trapping season on average stream temperature each season (n = 8) (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 - 9 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 nine 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 3/23/08 - 7/03/08 and trapped 102 day/nights out of a possible 102. The fyke net operated from 7/03/08 - 7/15/08 and trapped 12 day/nights out of a possible 12. The trapping rate in YR 2008 was 100% compared to 97% for the previous eight year average (ranged from 92 - 99%).

Species Captured

<u>Juvenile Salmonids</u>

Species captured in YR 2008 included: juvenile Chinook salmon (*Oncorhynchus tshawytscha*), juvenile steelhead trout (*O. mykiss*), coastal cutthroat trout (*O. clarki clarki*), juvenile coho salmon (*O. kisutch*), and juvenile pink salmon (*O. gorbuscha*). A total of 100,905 juvenile salmonids were captured in YR 2008 (Figure 2).

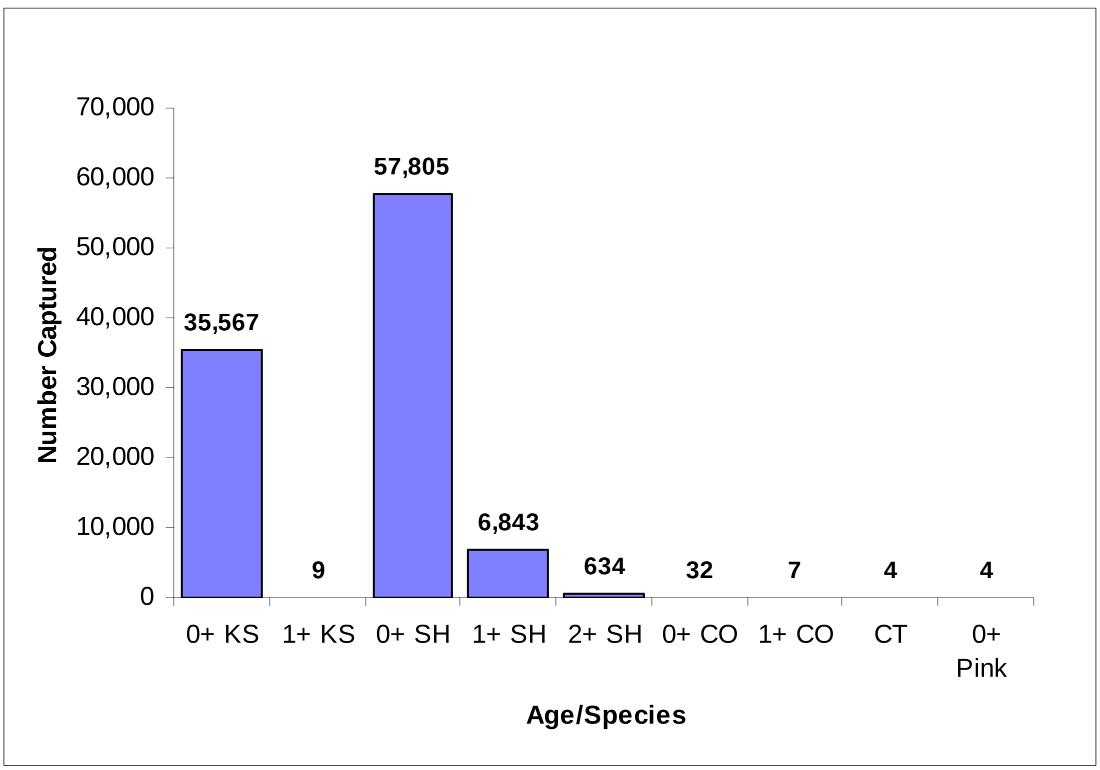

Figure 2. Total juvenile salmonid trap catches (n = 100,905) from March 24 through July 15, 2008, upper Redwood Creek, Redwood Valley, Humboldt County, CA. Numeric values above columns represent actual catches. 0+ KS = young-of-year Chinook salmon, 1+ KS = age 1 and older Chinook salmon, 0+ SH = young-of-year steelhead trout, 1+ SH = age 1 and older steelhead trout, 2+ SH = age 2 and older steelhead trout, 0+ CO = young-of-year coho salmon, 1+ CO = age 1 and older coho salmon, CT = cutthroat trout, 0+ Pink = young-of-year pink salmon.

The total trap catch of juvenile salmonids in YR 2008 was 1.12 times higher than catches in YR 2007, and much less (45%) than trap catches for the previous eight year average (Table 3). The greatest reduction (60%) in trap catches in YR 2008 occurred with 0+ Chinook salmon. 0+ steelhead trout made up a higher percentage (57%) of the total catch in YR 2008 compared to other juvenile salmonids. 1+ coho salmon smolts were captured in YR 2008 for the first time in nine consecutive years (Table 3).

Table 3. Comparison of juvenile salmonid trap catches in YR 2008 with YR 2007 and the previous eight year average catch (YRS 2000-07), upper Redwood Creek, Humboldt County, Ca.

	Actual Catches			
Age/species*	YR 2007	Previous eight year average	YR 2008	Percent reduction in YR 2008**
0+ KS	15,823	88,048	35,567	59.6
1+ KS	0	9	9	No Reduction
0+ SH	68,573	84,100	57,805	31.3
1+ SH	5,036	9,508	6,843	28.0
2+ SH	525	895	634	29.2
CT	2	4	4	No Reduction
0+ Pink	0	2	4	No Reduction
0+ CO	6	1	32	No Reduction
1+ CO***	0	0	7	No Reduction
Total:	89,965	182,567	100,905	44.7

* Age/species definitions are the same as in Figure 2.
** Comparisons are with the previous eight year average (YRS 2000-07).
*** First catch in nine consecutive years.

Miscellaneous Species

The trap captured several species besides anadromous salmonids in YR 2008, including: prickly sculpin (*Cottus asper*), 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 2008 were less than catches in YR 2007, and equal to catches for the previous eight year average.

Amphibian catches in YR 2008 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 2008 compared to catches in YR 2007 and the previous eight year average catch, upper Redwood Creek, Humboldt County, CA.

	Actual Catches		
Species Captured	YR 2007	Previous eight year average	YR 2008
Prickly Sculpin	0	4	1
Coast Range Sculpin	9	73	0
Sucker	9	8	1
3-Spined Stickleback	21	87	9
Brown Bullhead	0	1	0
Adult Pac. Lamprey	40	34	34
Juvenile Lamprey	547	1,792	788
Pac. Giant Salamander	121	122	57
Painted Salamander	1	1	0
Rough Skinned Newt	6	24	7
Red-Legged Frog	0	1	0
Yellow-Legged Frog	12	13	17
American Bullfrog	0	0	0
Tailed Frog*	4	14	3

* Includes both adult and tadpole stages.

Juvenile Salmonid Captures

Catches of 0+ Chinook salmon, 1+ Chinook salmon, 0+ steelhead trout, 1+ steelhead trout, 2+ steelhead trout, cutthroat trout, 0+ coho salmon, and 1+ coho salmon in YR 2008 were variable over time, with apparent multi-modal catch distributions for most species at age.

0+ Chinook salmon daily catches in YR 2008 (n = 35,567) ranged from 0 – 1,441 individuals, and averaged 312 fish per day. The previous eight year daily catch ranged from 0 - 10,700 and averaged 683 per day. Daily 0+ Chinook salmon captures in YR 2008 expressed as a percentage of total 0+ Chinook salmon catch in YR 2008 ranged from 0.0 – 4.1%, and averaged 0.9%. The peak catch in YR 2008 occurred 6/11/08 (n = 1,441).

1+ Chinook salmon daily catches in YR 2008 (n = 9) ranged from 0 – 3 individuals, and averaged 0.08 fish per day. The previous eight year daily catch ranged from 0 - 5 and averaged 0.06 per day. Daily 1+ Chinook salmon captures in YR 2008 expressed as a percentage of total 1+ Chinook salmon catch in YR 2008 ranged from 0.0 – 33.3%, and averaged 0.9%. The peak catch in YR 2008 occurred 5/30/08 (n = 3).

0+ steelhead trout daily catches in YR 2008 (n = 57,805) ranged from 0 – 3,170 individuals, and averaged 507 per day. The previous eight year daily catch ranged from 0 - 6,993 individuals and averaged 643 per day. Daily 0+ steelhead captures in YR 2008 expressed as a percentage of total 0+ steelhead catch in YR 2008 (n = 57,805) ranged from 0.0 - 5.5% and averaged 0.9%. The peak catch in YR 2008 occurred 6/11/08 (n = 3,170).

1+ steelhead trout daily catches in YR 2008 (n = 6,843) ranged from 0 - 338, and averaged 60 per day. The previous eight year daily catch ranged from 0 - 727 individuals and averaged 73 per day. Daily 1+ steelhead trout captures in YR 2008 expressed as a percentage of total 1+ steelhead trout catch in 2008 ranged from 0.0 – 4.9% and averaged 0.9%. The peak catch in YR 2008 occurred on 6/01/08 (n = 338).

2+ steelhead trout daily catches in YR 2008 (n = 634) ranged from 0 - 38, and averaged six individuals per day. The previous eight year daily catch ranged from 0 - 45 individuals and averaged seven per day. Daily 2+ steelhead trout captures in YR 2008 expressed as a percentage of total 2+ steelhead trout catches in YR 2008 ranged from 0.0 – 6.0%, and averaged 0.9%. The peak catch in YR 2008 occurred on 5/31/08 (n = 38).

Age-1 and older cutthroat trout catches in YR 2008 (n = 4) ranged from 0 – 1, and averaged 0.04 fish per day. The previous eight year daily catch ranged from 0 - 2 individuals and averaged 0.03 per day. Catches in YR 2008 occurred on 5/11, 5/20, 6/5 and 6/23.

0+ coho salmon daily catches in YR 2008 (n = 32) ranged from 0 – 3 individuals, and averaged 0.28 per day. The previous eight year daily catch ranged from 0 - 1 individuals and averaged 0.01 per day. Daily 0+ coho salmon captures in YR 2008 expressed as a percentage of total 0+ coho salmon catch in YR 2008 ranged from 0.0 – 9.4% and averaged 0.9%. The peak catch in YR 2008 occurred 4/22/08, 6/16/08, and 6/25/08 (n = 3 for each day).

1+ coho salmon were captured for the first time in nine consecutive years in YR 2008 (n = 7). Daily 1+ coho salmon captures in YR 2008 expressed as a percentage of total 1+ coho salmon catch in YR 2008 ranged from 0.0 – 28.6% and averaged 0.9%. The peak catch in YR 2008 occurred 5/30/08 and 5/31/08 (n = 2 for each day).

Days Missed Trapping

Unlike previous study years, there were no missed days of trapping in YR 2008.

0+ Chinook Salmon

Trap catches of 0+ Chinook salmon by month in YR 2008 were much lower than the previous eight year average catch by month; however, the pattern of monthly catches was similar (Figure 3).

The majority of 0+ Chinook salmon catches in YR 2008 occurred in May and June (n = 32,195 or 90.5% of total catch), as did the majority of catches for the previous eight year average (n = 64,254 or 73.0% of total average catch).

The correlation of 0+ Chinook salmon catches with study years indicated a non-significant negative relationship (n = 9, p = 0.11, r = 0.56, slope is negative, power = 0.32).

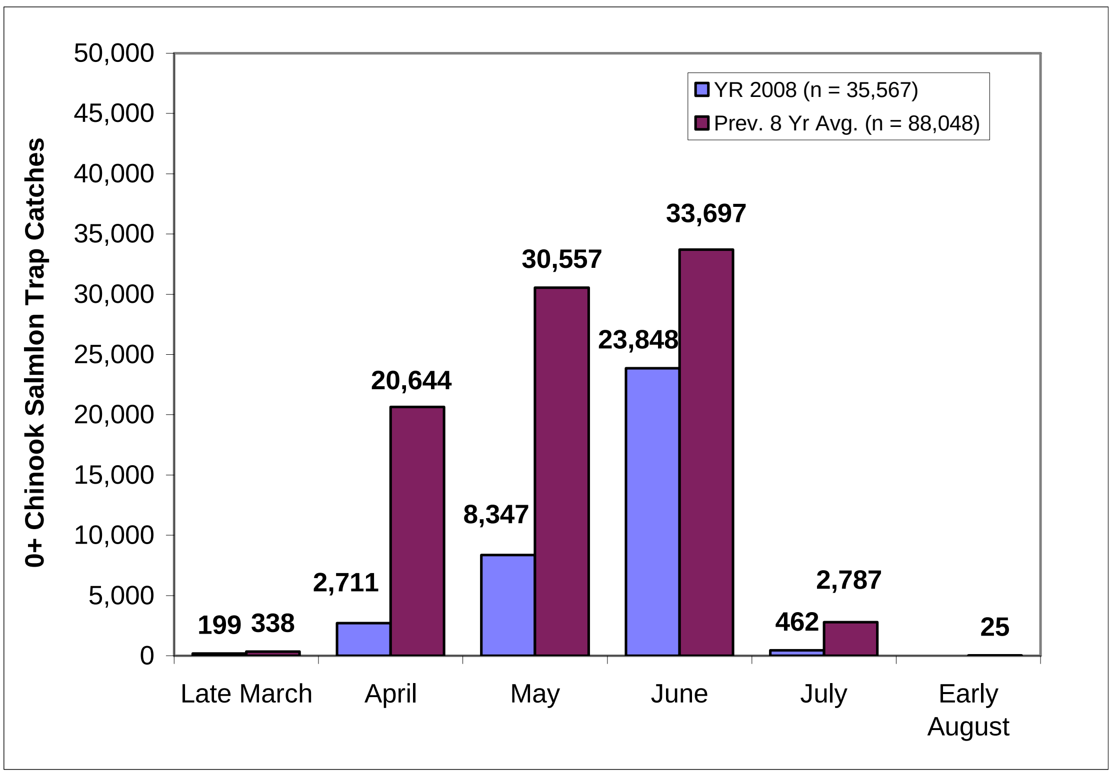

Figure 3. Comparison of total 0+ Chinook salmon trap catches by month in YR 2008 with the previous eight year average, upper Redwood Cr, Humboldt County, CA. Numeric values represent actual catches.

1+ Chinook Salmon

Most (89%) 1+ Chinook salmon in YR 2008 were captured in May, and 11% were captured in June.

0+ Steelhead Trout

Trap catches of 0+ steelhead trout by month in YR 2008 were lower than the previous eight 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 2008 occurred in May and June (n = 56.207 or 97.2% of total catch), compared to catches in June and July (n = 58,179 or 69.2% of total) for the previous eight year average. June was the month with the highest catches for both YR 2008 and the previous eight year average. The biggest reduction in catches in YR 2008 occurred in July (n = 22,652 less individuals, or 94% reduction).

The linear correlation of 0+ steelhead trout trap catches with study years indicated a non-significant negative relationship (n = 9, p = 0.27, r = 0.41, slope is negative, power = 0.18) (Appendix 6). The line of best fit using a polynomial relationship showed a negative trend over the nine study years, and was able to correlate 58% of the variation in trap catches to study years (Appendix 6).

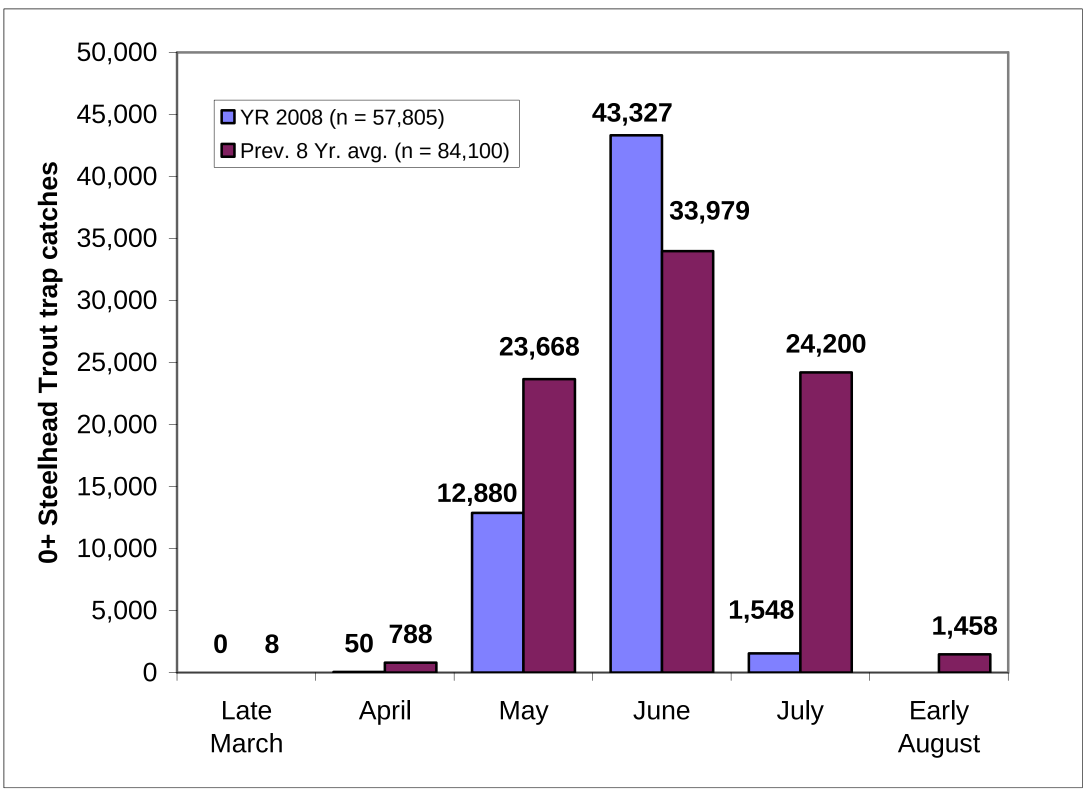

Figure 4. Comparison of total 0+ steelhead trout trap catch by month in YR 2008 with the previous eight year average, upper Redwood Creek, Humboldt County, CA. Numeric values above columns represent actual catches.

1+ Steelhead Trout

Trap catches of 1+ steelhead trout by month in YR 2008 were much lower than the previous eight year average catch by month, except for catches in May and June (Figure 5). The majority of 1+ steelhead trout catches in YR 2008 occurred in May and June (n = 5,861 or 85.6% of total catch), compared to the majority of catches in April and May (n = 7,145 or 75.1% of total) for the previous eight year average. The highest catches occurred in May for both YR 2008 and the previous eight year average. The greatest reduction in catches in YR 2008 occurred in April (1,660 individuals or 64% reduction).

The correlation of 1+ steelhead trout trap catches (transformed) with study years indicated a significant negative relationship (n = 9, p = 0.04, r = 0.68, slope is negative, power = 0.56).

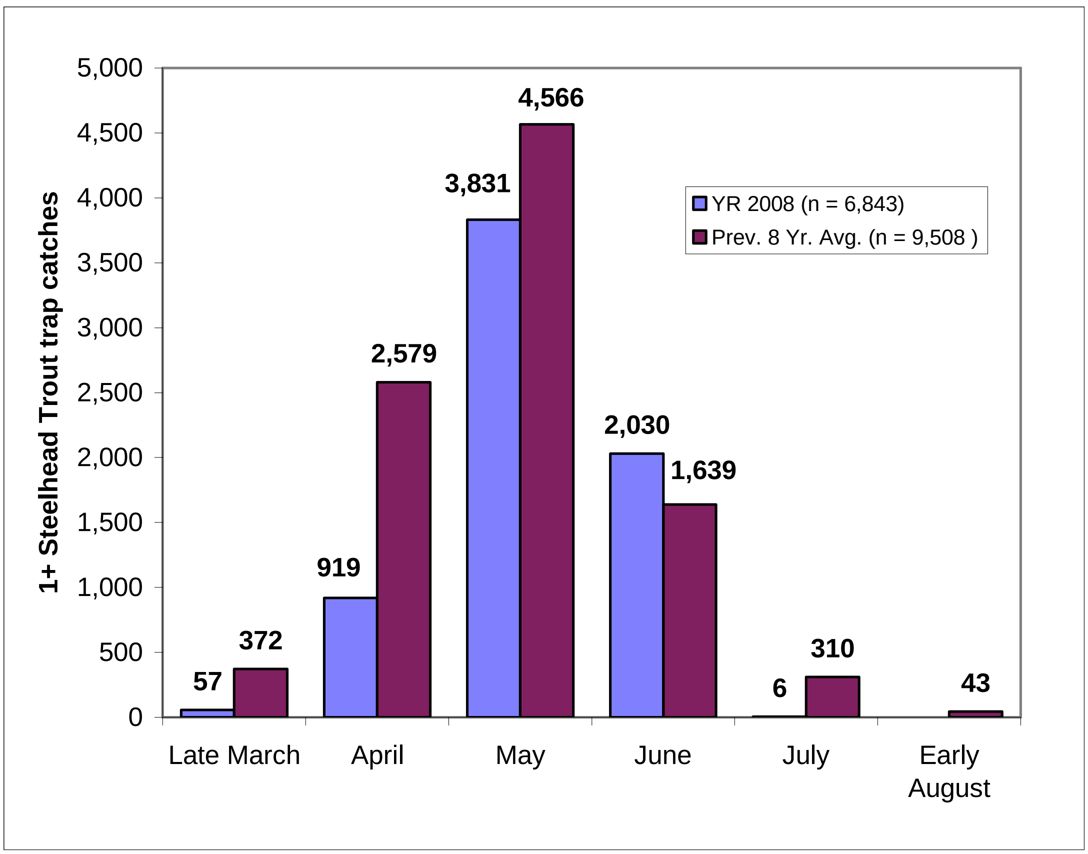

Figure 5. Comparison of total 1+ steelhead trout catches by month in YR 2008 with the previous eight year average, upper Redwood Creek, Humboldt County, CA. Numeric values represent actual catches.

2+ Steelhead Trout Catches

Trap catches of 2+ steelhead trout by month in YR 2008 were lower than the previous eight year average catch by month except for the month of June (Figure 6). The majority of 2+ steelhead trout catches in YR 2008 occurred in May and June (n = 485 or 76.5% of total catch), compared to April and May (n = 608 or 68.0% of total) for the previous eight year average. The highest monthly catch in YR 2008 occurred in June compared to May for the previous eight year average. The largest reductions in catch in YR 2008 occurred in April (161 individuals or 55% reduction) and July (68 individuals or 96% reduction).

The correlation of 2+ steelhead trout trap catches with study years indicated a non-significant negative relationship (n = 9, p = 0.12, r = 0.56, power = 0.34).

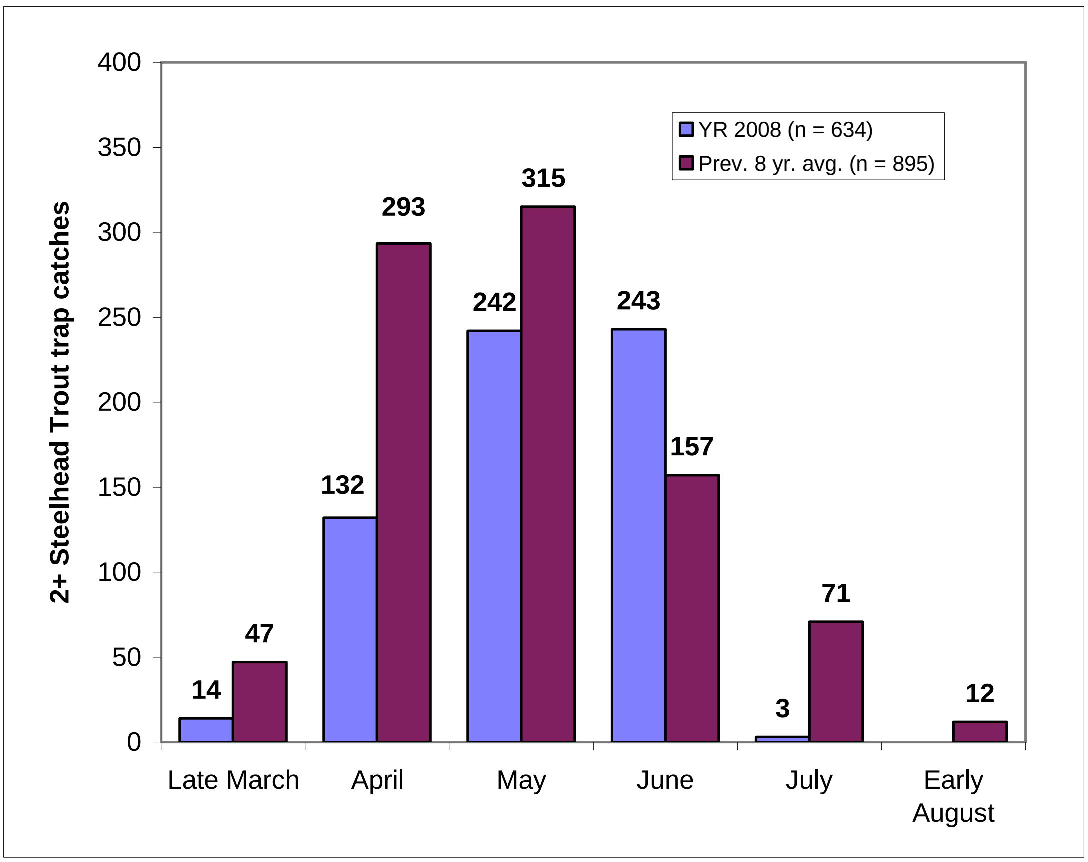

Figure 6. Comparison of total 2+ steelhead trout trap catches by month in YR 2008 with the previous eight year average, upper Redwood Creek, Humboldt County, CA. Numeric values represent actual catches.

Cutthroat Trout

In YR 2008, 50% of the cutthroat trout were captured in May, and 50% were captured in June.

0+ Coho Salmon

In YR 2008, 0+ coho salmon were captured in April – July. Forty seven percent were captured in April, and 38% were captured in June.

1+ Coho Salmon

In YR 2008, 86% of the 1+ coho salmon were captured in May, and 14% were captured in June.

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

By Day

Regressions of trapping day number, average daily water temperature, daily gage height, and lunar phase on total number of juvenile salmonids captured violated regression assumptions (even with transformations) and results were not valid.

Daily 0+ Chinook salmon captures were negatively related to daily gage height (R^2 = 0.24) and negatively related to average discharge (R^2 = 0.29); regression assumptions were not met for tests involving lunar phase and day number (NCSS 98). Transformed daily 0+ steelhead trout catches were positively related to day number (R^2 = 0.53), and positively related to transformed water temperature (R^2 = 0.49); regression assumptions were not met for tests involving gage height and lunar phase (NCSS 98). Regression assumptions were not met for tests involving 1+ steelhead trout or 2+ steelhead trout (NCSS 98).

Although statistical tests were not warranted for several 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 – 18.4 ^{o}C for Chinook salmon (98% of total 0+KS catch), 10.4 – 18.9 ^{o}C for 0+ Steelhead trout (99% of total 0+SH catch), 6.1 – 17.7 ^{o}C for 1+ Steelhead trout (99% of total 1+SH catch), and 6.4 to 17.2 ^{o}C for 2+ steelhead trout (94% of total 2+SH catch). The peak catch occurred during an average daily steam temperature of 15.2 ^{o}C for 0+ Chinook (n = 1,441), 15.2 ^{o}C for 0+ steelhead trout (n = 3,170), 14.2 ^{o}C for 1+ steelhead trout (n = 338), and 12.9 ^{o}C for 2+ steelhead trout (n = 38).

The peak catch of 0+ Chinook salmon consisted mostly of fingerlings (90%), and the peak catch of 0+ trout was mostly comprised (57%) of emergent fry (Avg. FL < 34 mm). The three largest peaks in 0+ Chinook salmon daily catches occurred during the descending limb of the hydrograph, and the four largest peaks in 0+ steelhead trout daily catches also occurred during the descending limb of the hydrograph. Most of the peaks in 1+ steelhead trout catches also occurred during the slowly descending limb; however, a smaller peak in catches occurred on 4/23/08 when the stream rose 9.7 inches. 2+ steelhead trout showed more variation than younger age classes: one smaller peak in catches occurred with a 2.8 inch increase in gage height, and a larger peak occurred when the stream rose 9.7 inches. The largest peak in catches occurred during the descending limb of the hydrograph.

By Week

Weekly catches of 0+ Chinook salmon were not significantly related to week number (Correlation, $p > 0.05$, $r = 0.44$, positive slope), stream temperature (Regression, $p > 0.05$, $R^2 = 0.10$, positive slope) or lunar phase (Regression, $p > 0.05$, positive slope). Weekly catches were negatively related to gage height (Regression, $p < 0.05$, $R^2 = 0.28$), and negatively related to stream discharge (Regression, $p < 0.05$, $R^2 = 0.34$), and positively related to trapping efficiencies (Regression, $p < 0.05$, $R^2 = 0.56$, positive slope) (Appendix 7).

Weekly catches of 0+ SH were negatively related to stream discharge (Regression, $p < 0.05$, $R^2 = 0.30$); no significant relationships were detected with gage height, stream temperature, week number, or lunar phase ($p > 0.05$ for each test) (Appendix 7).

1+ steelhead trout weekly catches were not significantly related to any variable tested ($p > 0.05$ for each test), and 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 partially fin clipped and released 3,581 young-of-year Chinook salmon upstream of the trap site during 44 efficiency trials over the course of trapping in YR 2008. The average number used in our weekly trials (includes 1 - 4 trials) equaled 224, and ranged from 10 - 300 (per week). Weekly trapping efficiencies in YR 2008 ranged from 8.4 – 60.0%, and averaged 27.2% (Table 5). Average weekly and seasonal (total number of recaptures/total number marked) trapping efficiencies in YR 2008 were much less than efficiencies for the previous eight year average (Table 5).

0+ Chinook salmon weekly trap efficiencies in YR 2008 significantly increased over time (Correlation, $p < 0.000001$, $r = 0.92$, positive slope, power = 1.00), were negatively related to gage height (Regression, $p < 0.000001$, $R^2 = 0.87$, negative slope, power = 1.00), and negatively related to average stream discharge (Regression, $p < 0.000001$, $R^2 =$

0.86, negative slope, power = 0.99). Assumptions were not met for the test of lunar phase on trapping efficiencies (Regression, NCSS 98).

Table 5. Comparison of 0+ Chinook salmon trapping efficiency in YR 2008 with the previous eight year average, Upper Redwood Creek, Humboldt County, CA.

	0+ Chinook salmon trap efficiency (percentage)		
	Weekly trapping efficiency		
Study Year	Range	Average	Seasonal
2008	8.4 - 60.0	27.2	28.3
2000-07	20.2 - 68.4*	40.6	40.2**

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

1+ Steelhead Trout

We partially fin clipped and released 1,496 1+ steelhead trout upstream of the trap site during 42 efficiency trials over the course of trapping in YR 2008. The average number used in our weekly trials (includes 1 - 4 efficiency trials) equaled 88, and ranged from 5 - 198 (per week). Weekly trapping efficiencies in YR 2008 ranged from 13.5 – 29.6%, and averaged 20.4% (Table 6). Average weekly and seasonal (total number of recaptures/total number of marked releases) trapping efficiencies in YR 2008 were less than efficiencies for the previous eight year average (Table 6).

1+ steelhead trout trap efficiencies in YR 2008 did not statistically change over time (Correlation, $p > 0.05$, negative slope, $r = 0.41$, power = 0.32). Trap efficiencies (transformed) were not statistically related to gage height (Regression, $p > 0.05$, positive slope, $R^2 = 0.20$, power = 0.39), stream discharge (Regression, $p > 0.05$, positive slope, $R^2 = 0.16$, power = 0.31), or lunar phase (Regression, $p > 0.05$, negative slope, power = 0.06)

Table 6. Comparison of 1+ steelhead trout trapping efficiency in YR 2008 with the previous eight year average, Upper Redwood Creek, Humboldt County, CA.

	1+ Steelhead Trout Trap Efficiency (percentage)		
	Weekly trapping efficiency		
Study Year	Range	Average	Seasonal
2008	13.5 – 29.6	20.4	20.6
2000-07	13.6 – 42.3*	24.4	20.6**

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

<u>2+ Steelhead Trout</u>

We partially fin clipped and released 405 2+ steelhead trout upstream of the trap site during 44 efficiency trials over the course of trapping in YR 2008. The average number used in our weekly trials (includes 1 - 4 efficiency trials) was 27, and ranged from 2 - 100 (per week). Weekly trapping efficiencies in YR 2008 ranged from 10.9 – 50.0%, and averaged 19.0% (Table 7). Average weekly and seasonal (total number of recaptures/total number marked) trapping efficiencies in YR 2008 were fairly close to the previous eight year average (Table 7). The regressions of week number, gage height, stream discharge, and lunar phase on 2+ steelhead trout trap efficiencies did not pass assumption tests, and results were not valid (NCSS 98).

Table 7. Comparison of 2+ steelhead trout trapping efficiency in YR 2008 with the previous eight year average, Upper Redwood Creek, Humboldt County, CA.

	2+ Steelhead Trout Trap Efficiency (percentage)		
	Weekly trapping efficiency		
Study Year	Range	Average	Seasonal
2008	10.9 – 50.0	19.0	16.5
2000-07	10.9 – 26.2*	17.8	18.7**

* 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 2008 equaled 115,427 with a 95% CI of 107,558 – 123,297. Population estimate error (or uncertainty) equaled $\pm$ 6.8% or about 7,869 individuals. Population emigration in YR 2008 was 1.7 times greater than emigration in YR 2007 (N = 68,283), and 56% less than the previous eight year average (Nav_8 = 261,077).

Correlation of time (study year) on population estimates indicated a significant, negative relationship ($p < 0.10$, r = 0.59, power = 0.38) (Figure 7). The best model describing population trends over time included year and whether or not a flood type flow occurred during the spawning season (Correlation, p = 0.03, r = 83, slope is negative for both variables, power = 0.42).

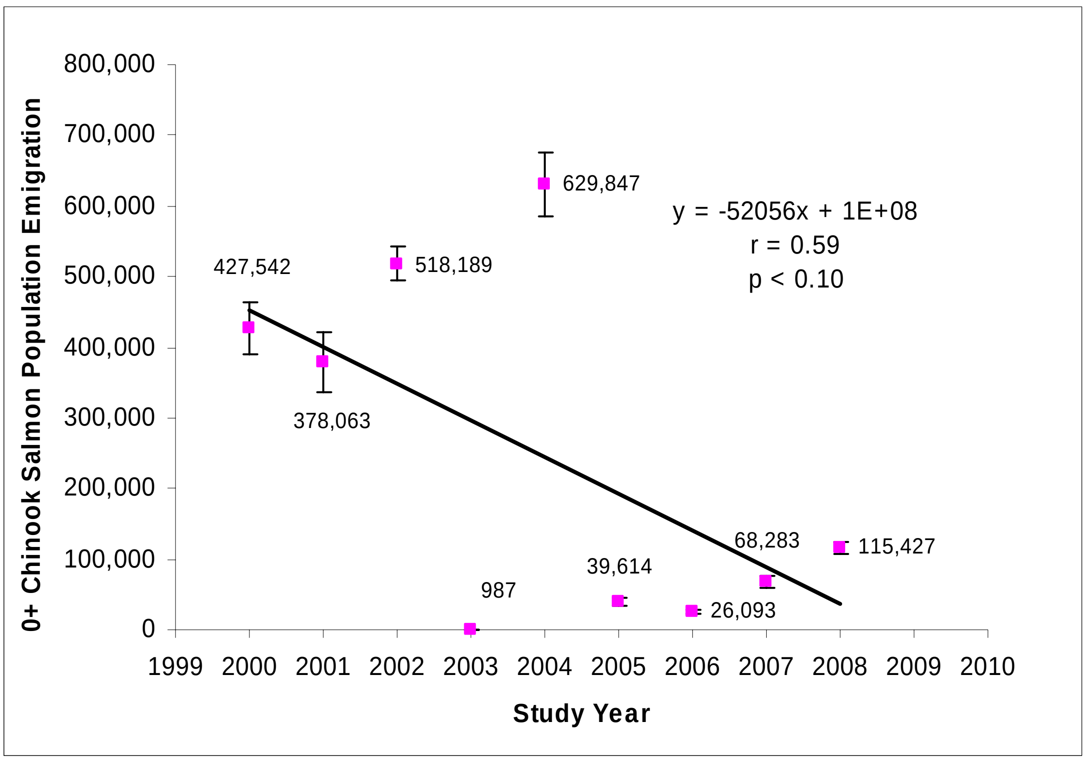

Figure 7. 0+ Chinook salmon population estimates (error bars are 95% confidence interval) in nine consecutive years. Lack of 95% CI for YRS 2003, 2005, 2006 - 2008 is due to scale of Y axis. Numeric values next to box represent number of individuals. Line of best fit is a regression line, with corresponding 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 2008 cohort. The greatest peak in stream flow occurred on 1/04/08 and equaled 4,480 cfs.

Using the regression equation modeled with data from YRS 2000-07 ($Y = -382153.5x + 404384.8$, 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 2008 ($\hat{Y}$) equaled 404,385 individuals. The mark/recapture estimate of 115,427 in YR 2008 was 71% less than the expected value. Thus, the model failed to accurately predict the numbers emigrating in YR 2008.

The overall model including all data (YRS 2000 – 08) 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 nine consecutive study years ($p < 0.05$, $R^2 = 0.47$, 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 47% 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 2008 was about 56% less than values for the previous eight year average (Table 8).

Table 8. Estimated population of 0+ Chinook salmon per stream mile, stream kilometer, and watershed acreage upstream of the trap site, YRS 2000 - 2008.

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
2007	1,845	1,148	1.05
Average:	7,056	4,388	4.02
2008	3,120	1,940	1.78

0+ Chinook salmon population emigration by month in YR 2008 was severely reduced compared to emigration by month for the previous eight year average (Figure 8). The biggest reductions in YR 2008 occurred in April (72% or 71,661 individuals), and May (58% or 50,219 individuals). The pattern of migration in YR 2008 contrasted the pattern for the previous eight year average (Figure 8).

The majority of 0+ Chinook salmon population emigration occurred in May and June in YR 2008 (73% of total) compared to April and May for the previous eight year average (71% of total) (Figure 8). Population emigration during April – June accounted for 97% of the total for YR 2008 compared to 96% of the total for the previous eight year average.

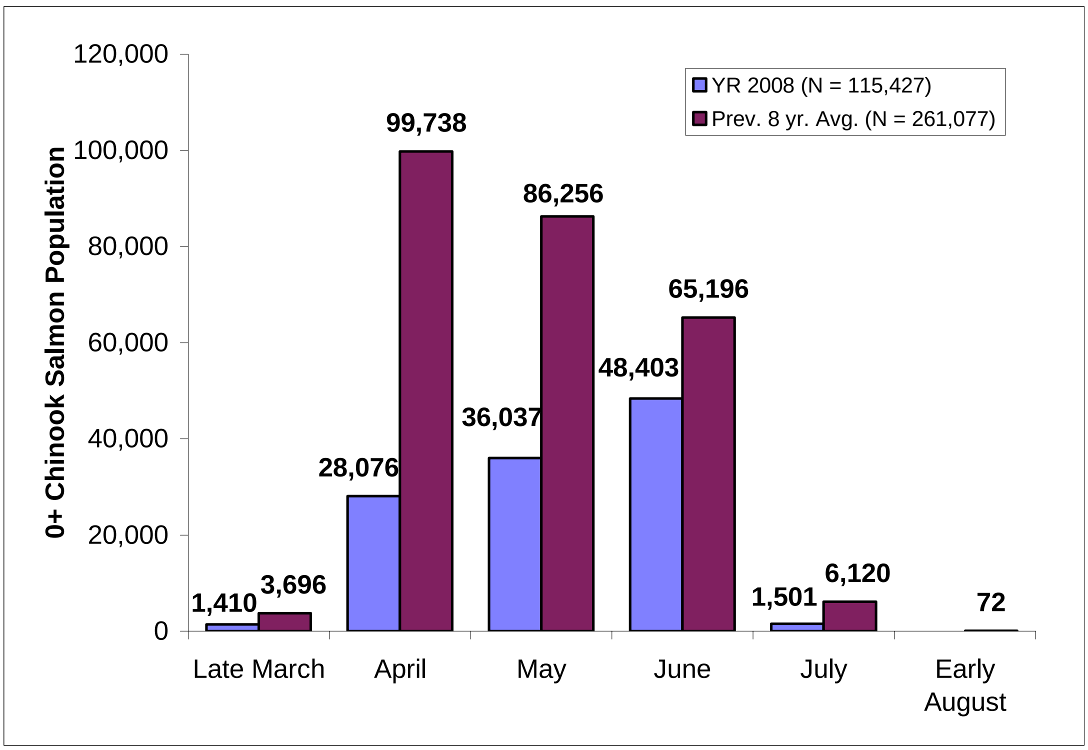

Figure 8. Comparison of 0+ Chinook salmon population emigration by month in YR 2008 with the previous eight year average, upper Redwood Creek, Humboldt County, CA. Numeric values above columns represent number of individuals.

The peak in weekly population emigration in YR 2008 occurred 6/04 – 6/10, the same week as for study years 2002 and 2007 (Table 9, Figure 9). For the nine years of data, two peaks occurred in April, one occurred in May, one occurred in late May/early June, and five peaks occurred in June (Table 9). The largest weekly peak occurred in YR 2004 (N = 165,782 individuals) and the smallest occurred in YR 2003 (N = 316 individuals) (Table 9). The average FL (mm) for 0+ Chinook salmon migrants during the two modes in emigration in YR 2008 equaled 37.4 mm for 4/09 – 4/15, and 54.8 mm for 6/04 – 6/10 (Figure 9).

Table 9. Date of peak weekly 0+ Chinook salmon population emigration by study year (number of individuals in parentheses).

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

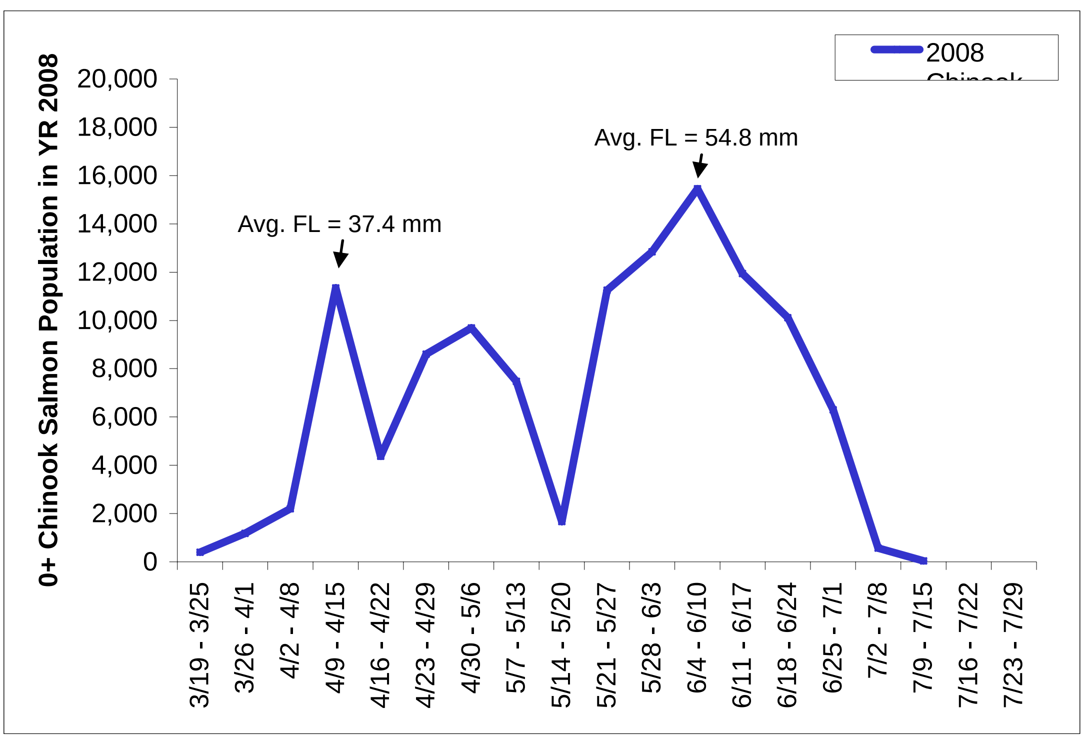

Figure 9. 0+ Chinook salmon population emigration by week in YR 2008, upper Redwood Creek, Humboldt County, CA.

The number and percentage of 0+ Chinook salmon migrants grouped into fry or fingerling categories varied among study years (Table 10). In YR 2008, 40% of the migrants were estimated as fry, and 60% were estimated as fingerlings. The previous eight year average (N = 261,077) consisted of 53% fry and 47% fingerlings. A statistically lesser proportion of fry and a higher proportion of fingerlings were present in YR 2008 compared to the previous eight year average (Chi-square, $p < 0.0001$). There was a significant, non-random distribution in the percentages of fry and fingerlings in YR 2008 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 10. 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)
2007	31,615 (46)	36,668 (54)
7 yr avg.	138,758 (53)	122,320 (47)
2008	45,946 (40)	69,481 (60)

0+ Chinook salmon fry and fingerling migrants showed differences in abundance and migration timing in YR 2008 and for the previous eight year average (Figure 10). For the previous eight 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 2008, fry (Avg. FL = 38.0 mm) migration also occurred near the onset of trapping, reached a peak value during the same week as for the previous eight year average (4/9 – 4/15), and decreased to low values by the end of May (last capture was on 6/25/08); fingerling (Ave. FL = 57.4 mm) migration began in late April/early May (first capture was on 4/22/08), reached a peak during the same week as for the previous eight year average (6/4 – 6/10), and descended to low values near the beginning of July (last capture was on 7/15/09) (Figure 10).

The noticeable two modes to the distributions for YR 2008 and the previous eight year average do not necessarily 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 4/09/08 – 4/15/08 was 37.4 mm, compared to the average fingerling FL of 54.8 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.

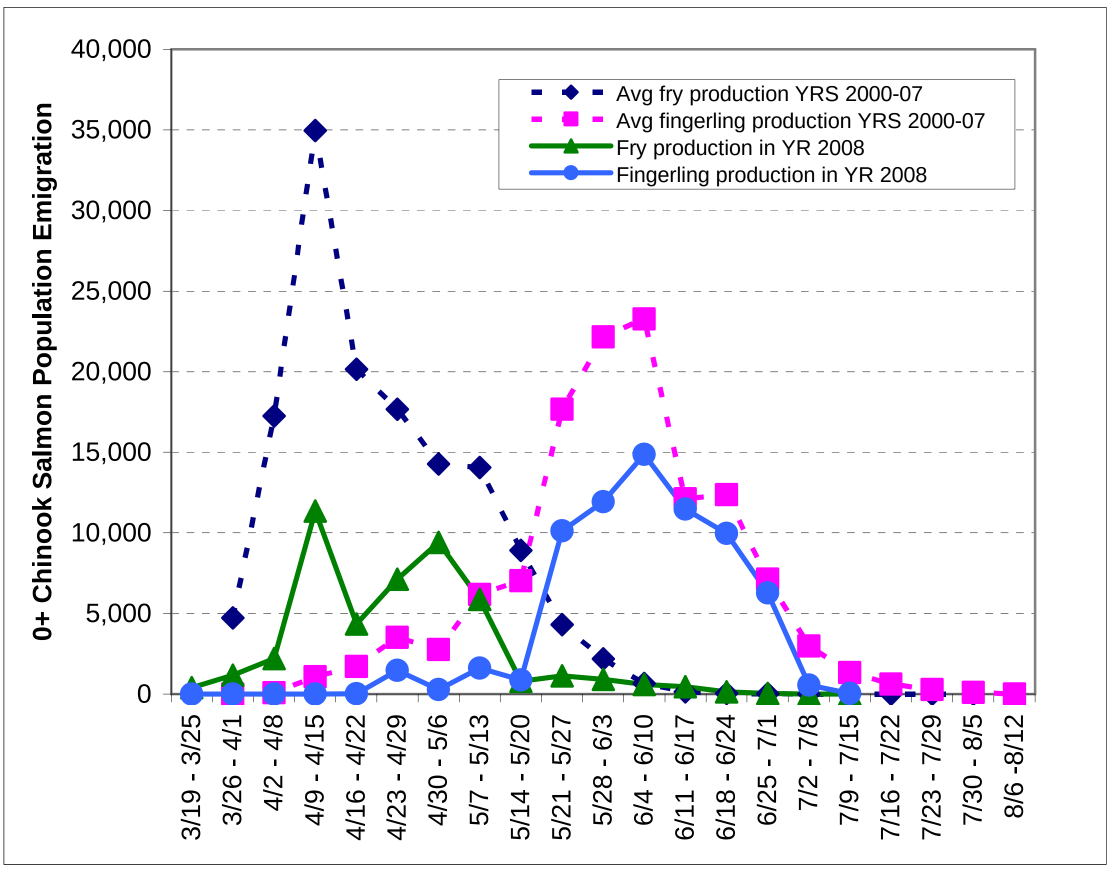

Figure 10. Comparison of 0+ Chinook salmon fry and fingerling abundance and migration timing in YR 2008 with previous eight year average, upper Redwood Creek, Humboldt County, CA.

1+ Steelhead Trout

The population estimate (or production) of 1+ steelhead trout emigrating from upper Redwood Creek in YR 2007 equaled 32,849 with a 95% CI of 29,177 – 36,522. Population estimate error (or uncertainty) equaled $\pm$ 11.2% or 3,672 individuals. Population emigration in YR 2008 was slightly lower (by 5%) than emigration in YR 2007 (N = 34,431), and 14% lower than the previous eight year average (N = 38,208).

Correlation of time (study year) on yearly population estimates showed a significant negative relationship ($p < 0.10$, $r = 0.65$, power = 0.50) (Figure 11).

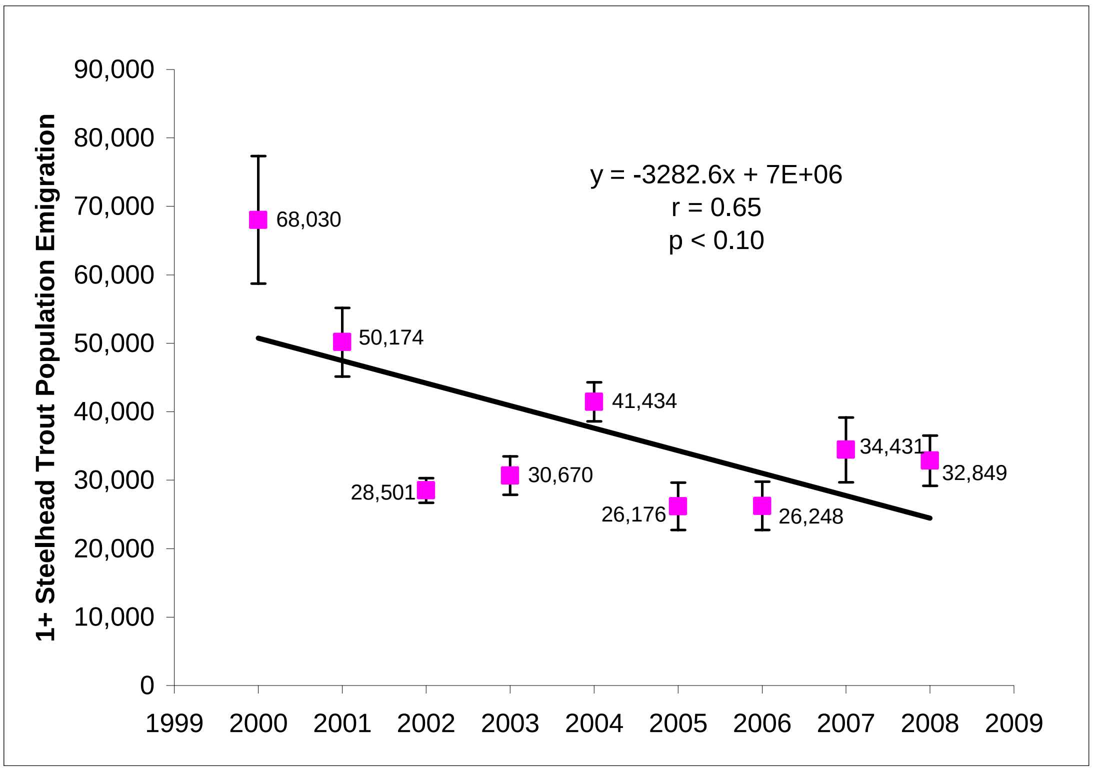

Figure 11. 1+ steelhead trout population estimates (error bars are 95% confidence interval) in nine consecutive years. Numeric values next to box represent number of individuals. Line of best fit is a regression line, with corresponding equation, correlation value (r), and p value.

The number of 1+ steelhead trout (at population level) per mile, kilometer, and watershed acreage upstream of the trap site in YR 2008 was about 14% less than values for the previous eight year average (Table 11). Highest values occurred in YR 2000 and lowest values occurred in YR 2005 (Table 11).

Table 11. Estimated population of 1+ steelhead trout per stream mile, stream kilometer, and watershed acreage upstream of the trap site, YRS 2000 - 2008.

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
2007	931	579	0.53
Average:	1,033	642	0.59
2008	888	552	0.51

1+ steelhead trout monthly population emigration in YR 2008 was much less than monthly emigration for the previous eight year average, except for the months of May and June (Figure 12). Emigration peaked in May in YR 2008 (N = 16,900 or 51% of total) and for the previous eight year average (N = 16,994 or 44% of total) (Figure 12). In YR 2008, 28,242 individuals (or 81% of total) emigrated in May and June, compared to 26,390 (or 69% of total) migrants that emigrated in May and June for the previous eight year average. The largest reduction in emigration in YR 2008 occurred during April (N = 4,878 or 53% less than previous eight year average for April; emigration during late March and July in YR 2008 was also reduced (reduction of 77 – 93%). The pattern of emigration in YR 2008 was similar to the pattern for the previous eight year average (Figure 12).

The peak in 1+ steelhead trout weekly emigration in YR 2008 occurred in late May/early June, and was the fifth highest in number (Table 12). For the nine study years, two peaks occurred during late April, six peaks occurred during May, and one peak occurred in late May/early June (Table 12). The largest weekly peak occurred in YR 2000 (N = 16,244), and the smallest occurred in YR 2006 (N = 4,062) (Table 12).

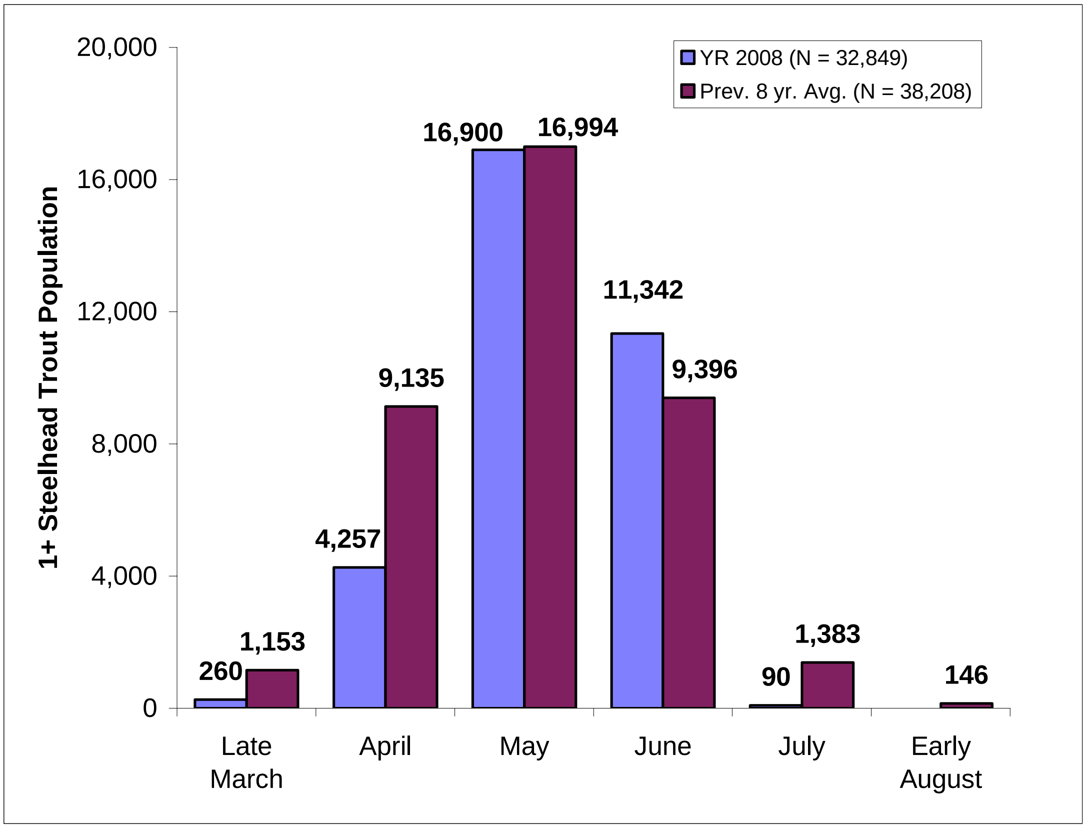

Figure 12. Comparison of 1+ steelhead trout population emigration by month in YR 2008 with the previous eight year average, upper Redwood Creek, Humboldt County, CA. Numeric values above columns represent number of individuals.

Table 12. Date of peak weekly 1+ steelhead trout population emigration by study year (number of individuals in parentheses).

Study Year	Date of peak in weekly out-migration (number in parentheses)
2000	5/07 – 5/13 (16,244)
2001	4/23 – 4/29 (6,963)
2002	5/14 – 5/20 (4,180)
2003	5/14 – 5/20 (4,483)
2004	5/14 – 5/20 (6,659)
2005	4/23 – 4/29 (4,834)
2006	5/21 – 5/27 (4,062)
2007	5/07 – 5/13 (6,777)
2008	5/28 – 6/03 (6,342)

2+ Steelhead Trout

The population estimate (or production) of 2+ steelhead trout emigrating from upper Redwood Creek in YR 2008 equaled 3,568 with a 95% CI of 2,769 – 4,366 (Figure 13). Population estimate error (or uncertainty) equaled ± 22.4% or 779 individuals. Population emigration in YR 2008 was 1.3 times greater than emigration in YR 2007 (N = 2,861), and 29% lower than the previous eight year average (N = 5,053).

Correlation of time (study year) on yearly population estimates showed a significant negative relationship ($p < 0.10$, $r = 0.61$, power = 0.42) (Figure 13). The best model describing population trends over time included year and whether or not a flood type flow occurred during the spawning season (Correlation, $p = 0.01$, $r = 87$, slope is negative for both variables, power = 0.56).

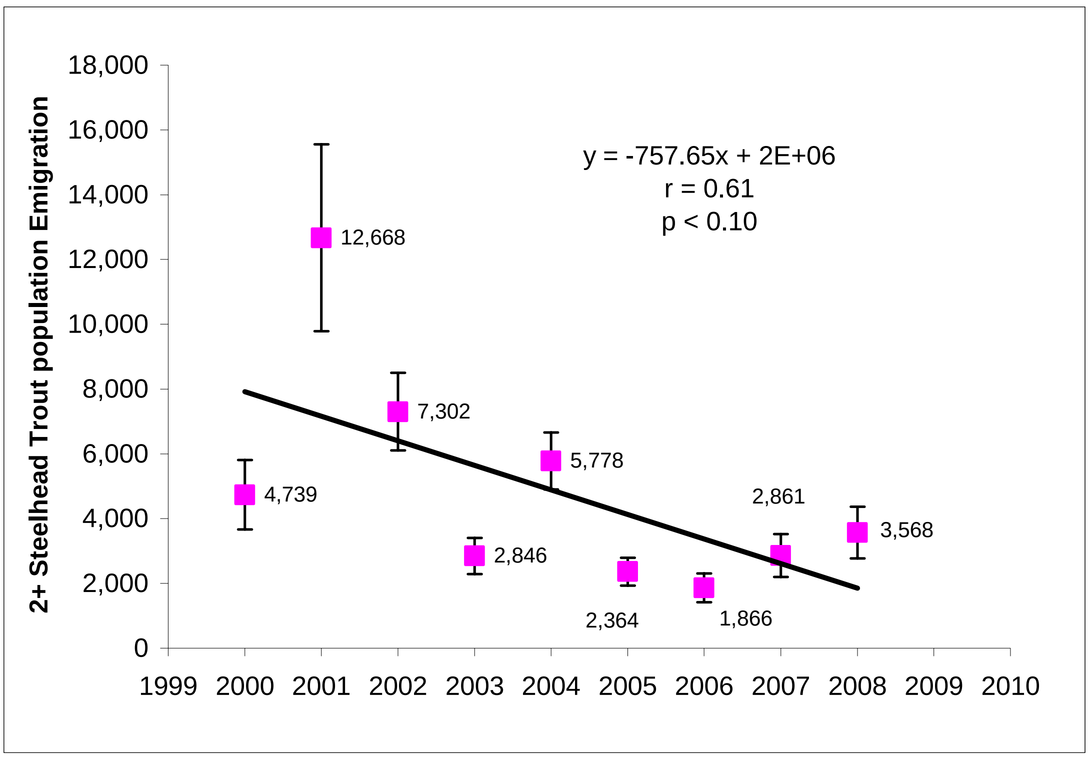

Figure 13. 2+ steelhead trout population estimates (error bars are 95% confidence interval) in nine consecutive years. Numeric values next to box represent number of individuals. Line of best fit is a regression line, with corresponding equation, correlation value (r), and p value.

The number of 2+ steelhead trout (at population level) per mile, kilometer, and watershed acreage upstream of the trap site in YR 2008 was about 29% less than values for the previous eight year average (Table 13). Highest values occurred in YR 2001 and lowest values occurred in YR 2006 (Table 13).

Table 13. Estimated population of 2+ steelhead trout per stream mile, stream kilometer, and watershed acreage upstream of the trap site, YRS 2000 - 2008.

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
2007	77	48	0.04
Average:	136	85	0.08
2008	96	60	0.05

2+ steelhead trout monthly population emigration in YR 2008 was less than monthly emigration for the previous eight year average, except for the month of June (Figure 14). Emigration peaked in May in YR 2008 (N = 1,430 or 40% of total) compared to April for the previous eight year average (N = 1,694 or 33% of total) (Figure 14). In YR 2008, 2,731 individuals (or 77% of total) emigrated in May and June, compared to 3,331 (or 66% of total) migrants that emigrated in April and May for the previous eight year average. The largest reduction in population emigration in YR 2008 occurred during April (927 individuals or 55% reduction); emigration during late March and July in YR 2008 was also severely reduced on a percent basis (reduction of 78 – 95%).

The peak in 2+ steelhead trout weekly emigration in YR 2008 occurred late May/early June, the same week as in YR 2001 (Table 14). For the nine study years, four peaks occurred during April, three peaks occurred during May, one peak on late May/early June, 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 14).

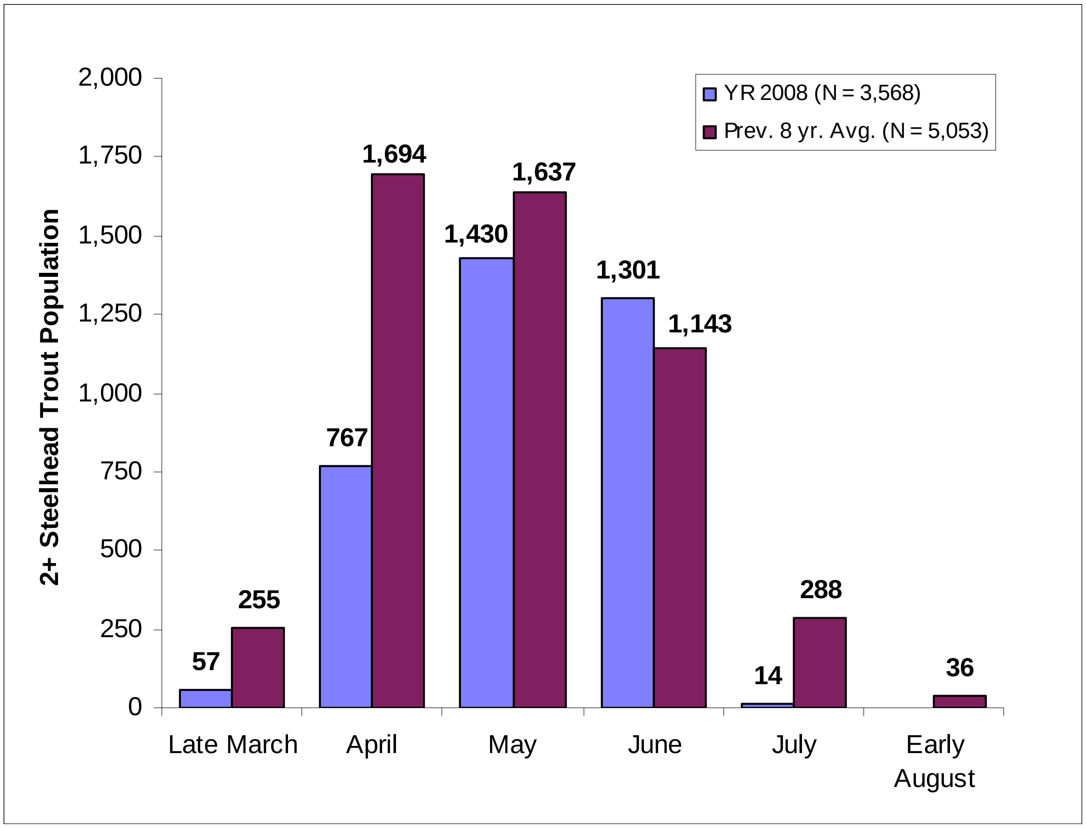

Figure 14. Comparison of 2+ steelhead trout population emigration by month in YR 2008 with the previous eight year average, upper Redwood Creek, Humboldt County, CA. Numeric values above columns represent number of individuals.

Table 14. Date of peak weekly 2+ steelhead trout population emigration by study year (number of individuals in parentheses).

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

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

0+ Chinook salmon, 1+ steelhead trout, and 2+ steelhead trout (transformed) weekly population emigration was not linearly related to gage height, stream discharge, lunar phase, stream temperature, or time (week) (Regression, $p > 0.10$ for all tests).

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 (Table 15). Using catch and population data, the ratio of 0+ steelhead trout to 1+ steelhead trout to 2+ steelhead trout in YR 2008 equaled 16:9:1 compared to the previous eight year average ratio of 17:8:1. In YR 2007, the ratio was 24:12:1. The ratio of 1+ steelhead trout to 2+ steelhead trout was 9:1 in YR 2008, and 8:1 for the previous eight year average.

Table 15. Comparison of 0+ steelhead trout, 1+ steelhead trout, and 2+ steelhead trout percent composition of total juvenile steelhead trout downstream migration in YR 2008 with the previous eight 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
2008	61.3	34.9	3.8
Prev. 8 yr Avg.	64.9	31.4	3.7
All years combined	65.6	30.4	4.0

* Uses actual catches instead of population estimate.

Relationships Between Juvenile Steelhead Age Classes

1+ steelhead trout population estimates (y variable, YRS 2001 - 2008) were not significantly related to the previous year's 0+ steelhead trout catches (x variable, YRS

2000 - 2007) (Regression, $p > 0.10$, $R^2 = 0.08$, slope sign is negative, power = 0.10); 2+ steelhead trout population estimates (y variable, YRS 2002 - 2008) were not related to 0+ steelhead trout catches in YRS 2000 – 2006 (x variable, Regression, $p > 0.10$, $R^2 = 0.08$, 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 = 0.98).

We detected a significant, positive correlation between 1+ steelhead trout population by week and 2+ steelhead trout population emigration by week (transformed) in YR 2008 (correlation, $p < 0.05$; $r = 0.72$; power = 0.97), 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 (12/16 or 75%) of the weeks. In addition, the peak in abundance occurred during the same week for both species at age (5/28 – 6/03).

Fork Lengths and Weights

0+ Chinook Salmon

We measured (FL mm) 2,937 and weighed (g) 2,001 0+ Chinook salmon in YR 2008 (Table 16). Average FL in YR 2008 was about 7% less than the average FL in YR 2007; average Wt in YR 2008 was about 15% less than the average Wt in YR 2007 (Table 16). Average FL and Wt in YR 2008 were lower than the previous seven year average (excludes YR 2003). The mode in YR 2008 was 39 mm for FL and 0.4 g for Wt, which corresponds to the size of fry in YR 2008.

Average FL did not significantly change over study years 2000 - 2002, and 2004 – 2008 (Correlation: FL, $p = 0.59$, $r = 0.23$, slope is negative, power = 0.08); correlation of average Wt and time (study year) violated model assumptions, and results were not valid (NCSS 97).

Using an adjusted alpha of 0.10 to account for low sample size ($n = 9$), no relationship between population abundance and average FL was detected (Regression, $p = 0.20$, $R^2 = 0.22$, power = 0.23), or with population abundance and average Wt (Regression, $p = 0.18$, $R^2 = 0.24$, negative slope, power = 0.25).

Table 16. 0+ Chinook salmon population estimates and average fork length (mm) and weight (g) for study YRS 2000 - 2008, upper Redwood Creek, Humblodt County, CA.

		0+ Chinook Salmon					
		Fork Length (mm)			Weight (g)		
Study Year	(N)*	n	Avg.	SEM**	n	Avg.	SEM**
2000	427,542	3,661	55.5	0.2	913	2.03	0.04
2001	378,063	2,719	51.9	0.2	778	1.73	0.04
2002	518,189	3,517	52.4	0.2	1,545	1.70	0.03
2003	987	573	67.3	0.3	499	3.43	0.05
2004	629,847	3,571	50.8	0.2	1,593	1.61	0.03
2005	39,614	2,489	60.4	0.3	1,751	3.09	0.05
2006	26,093	2,123	55.5	0.3	1,684	2.07	0.04
2007	68,283	2,811	51.6	0.2	2,127	1.55	0.03
7 yr Avg.***			55.7	2.0		2.15	0.25
2008	115,427	2,937	48.0	0.2	2,001	1.32	0.02

* "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.

Average weekly FL's in YR 2008 were numerically close to values for the seven year average, except for weeks beyond 6/25/08 (Figure 15). Average FL for the first eight weeks in YR 2008 were representative of newly emerged fry and post emergent fry, similar to previous study years. Average weekly FL (mm) significantly increased over time (weeks) in YR 2008 and for the seven year average (Correlation, $p < 0.0001$, $r = 0.97$ and 0.98, 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 3/26/08 – 7/15/08 0+ Chinook salmon grew 0.25 mm/d. Growth was 0.41 mm/d in YR 2005, 0.36 mm/d in YR 2006, and 0.34 mm/d in YR 2007. Median weekly FL in YR 2008 (46.9 mm) was not significantly different than the median weekly FL of the seven year average (55.4 mm) (Kruskal-Wallis One-Way ANOVA on Ranks, $p = 0.67$).

Average weekly Wt's in YR 2008 were also numerically close to values for the seven year average during early May and June (Figure 16). Average weekly Wt (g) significantly increased over time (weeks) in YR 2007 and for the seven 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 3/26/08 – 7/08/08 0+ Chinook salmon grew 0.02 g/d. Growth equaled 0.05 g/d in YR 2005, 0.04 g/d in YR 2006, and 0.03 g/d in YR 2007. Median weekly Wt (g) (1.00 g) in YR 2008 was significantly less than the median weekly Wt (1.93 g) for the previous seven year average (excludes YR 2003) (Kruskal-Wallis One-Way ANOVA on Ranks , $p = 0.03$).

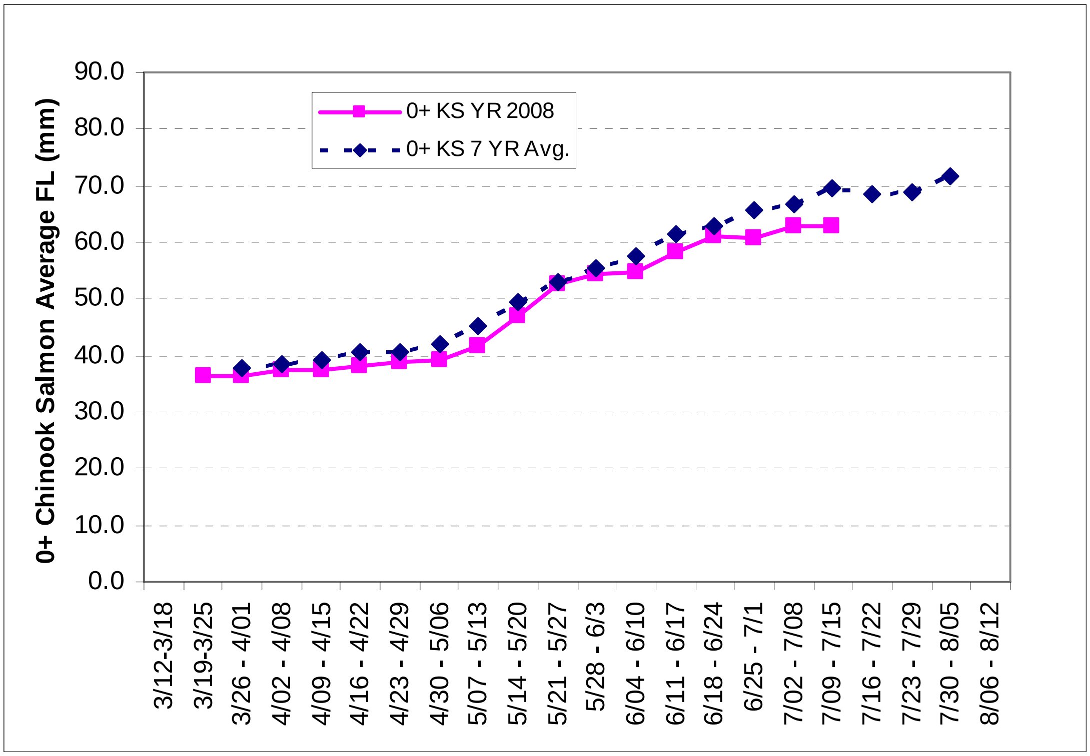

Figure 15. 0+ Chinook salmon average weekly fork lengths (mm) in YR 2008 and the average of seven years, upper Redwood Creek, Humboldt County, CA.

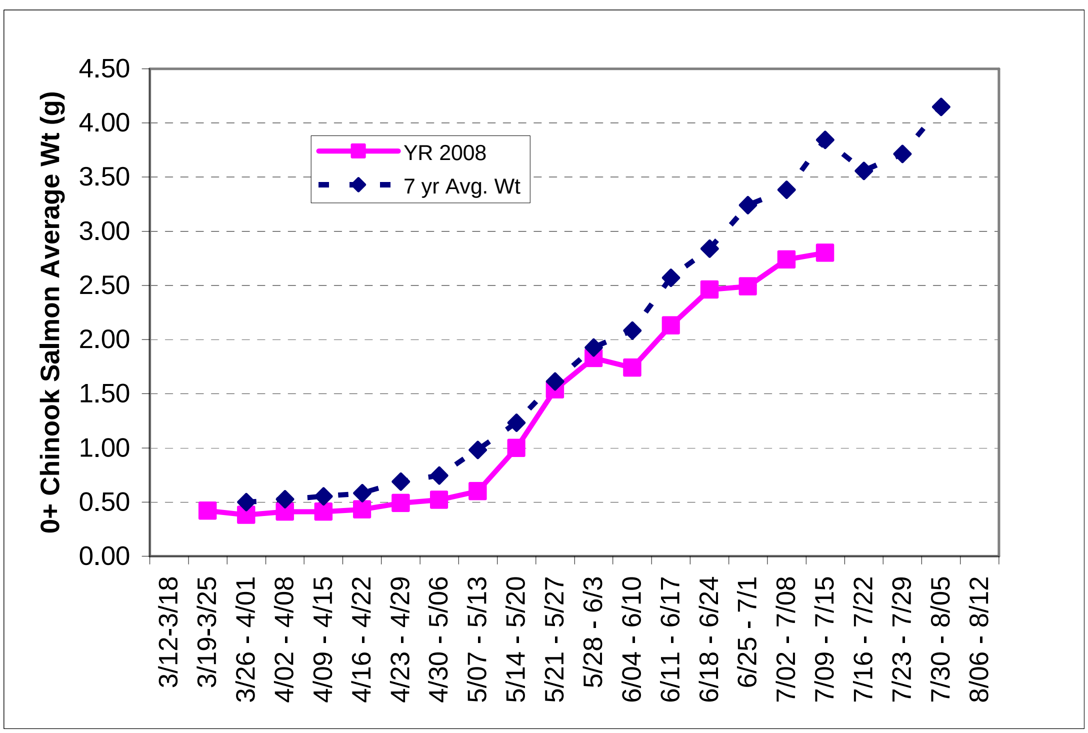

Figure 16. 0+ Chinook salmon average weekly weights (g) in YR 2008 and the average of seven years, upper Redwood Creek, Humboldt County, CA.

1+ Chinook Salmon

We measured (FL mm) and weighed (g) nine 1+ Chinook salmon in YR 2008 (Table 17). Average FL and Wt in YR 2008 was the second highest in four study years (Table 17). Average FL in YR 2008 was about 1.05 times greater than the previous three year average, and average Wt in YR 2008 was about 1.04 times greater than the previous three year average (Table 17).

Table 17. 1+ Chinook salmon trap catches and fork length (mm) and weight (g) for study years 2000 – 2008, upper Redwood Creek, Humboldt County, CA.

	1+ Chinook Salmon						
		Fork Length (mm)			Weight (g)		
Study Year	(Catch)	n	Avg.	SEM*	n	Avg.	SEM*
2000	-	-	-	-	-	-	-
2001	21	17	104.4	2.8	13	13.38	1.65
2002	18	17	108.5	3.9	17	16.62	1.96
2003	29	29	123.4	1.7	29	22.34	0.90
2004	-	-	-	-	-	-	-
2005	-	-	-	-	-	-	-
2006	-	-	-	-	-	-	-
2007	-	-	-	-	-	-	-
3 Yr Avg.			112.1	5.8		17.45	2.62
2008	9		118.2	1.8	9	18.19	0.78

0+ Steelhead Trout

We measured (FL mm) 2,076 0+ steelhead trout in YR 2008 (Table 18). Average FL in YR 2008 was 14.5% less than the previous eight year average (Table 18). The mode in FL in YR 2008 was 30 mm, which corresponded to the size of emergent fry.

The correlation of study years (n = 9) 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, $p = 0.97$, $R^2 = 0.0003$, power = 0.05). Average weekly FL (mm) significantly increased over time (weeks) in YR 2008 (Correlation, $p < 0.000001$, $r = 0.93$, power = 1.0) and for the previous eight year average (Correlation, $p < 0.000001$, $r = 0.96$, power = 1.0) (Figure 17).

The increases in average FL over time show growth was taking place, and from 4/30/08 – 7/15/08 0+ steelhead trout grew 0.15 mm/d. Growth in YR 2006 equaled 0.22 mm/d, and 0.17 mm/d in YR 2007. Average weekly FL (mm) (31.9 mm) in YR 2008 was significantly less than the average weekly FL (37.4 mm) for the previous eight year average (One-Way ANOVA, $p = 0.02$, power = 0.63).

Table 18. 0+ steelhead trout total catch and average fork length (mm) for study years 2000 - 2008, upper Redwood Creek, Humboldt County, CA.

	0+ Steelhead Trout						
		Fork Length (mm)			Weight (g)		
Study Year	(Catch)	n	Avg.	SEM*	n	Avg.	SEM*
2000	55,126	2,669	40.9	0.2	-	-	-
2001	102,408	1,136	39.0	0.3	-	-	-
2002	124,426	3,228	38.7	0.2	-	-	-
2003	102,954	3,338	38.5	0.2	-	-	-
2004	128,885	3,615	37.5	0.2	-	-	-
2005	41,671	3,661	42.3	0.2	-	-	-
2006	48,759	2,670	35.9	0.2			
2007	68,573	2,672	37.0	0.2			
7 yr Avg.			38.7	0.7		-	
2008	57,805	2,076	33.1	0.1	-	-	-

* Standard error of mean.

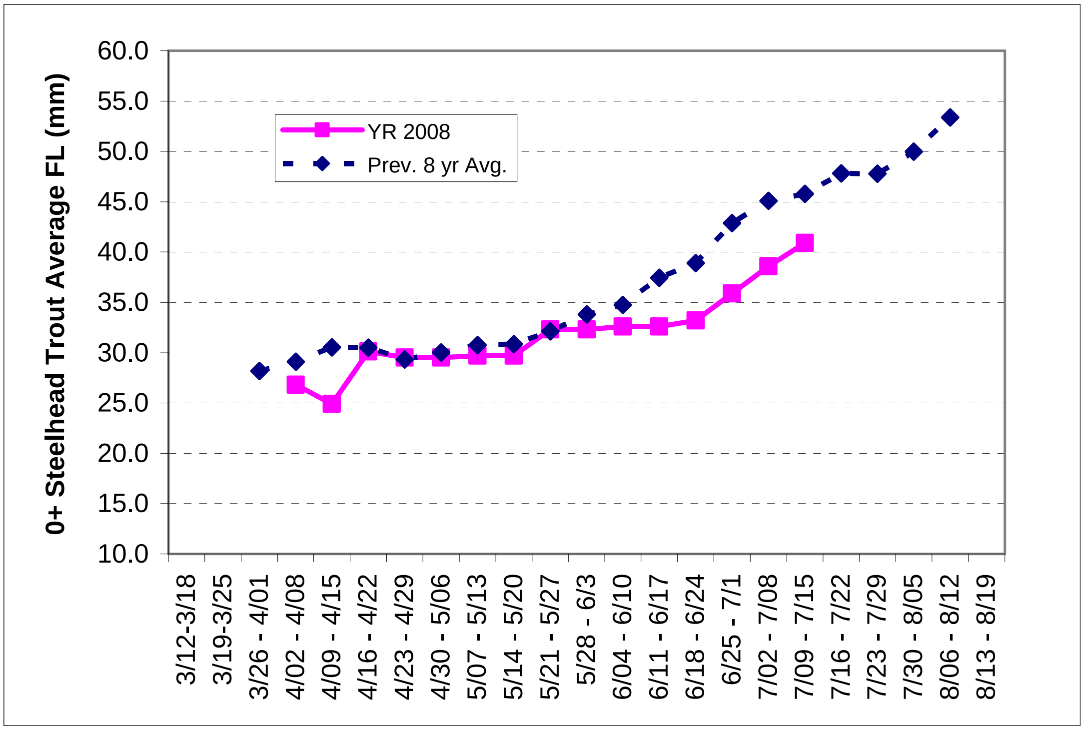

Figure 17. 0+ steelhead trout average weekly fork lengths (mm) in YR 2008 and the previous eight year average, upper Redwood Creek, Humboldt County, CA.

1+ Steelhead Trout

We measured (FL mm) 2,362 and weighed (g) 1,759 1+ steelhead trout in YR 2008 (Table 19). Average FL and Wt in YR 2008 were close to values in YR 2007, and 2.3 mm and 0.66 g less than values for the previous eight year average (Table 19). The mode in FL in YR 2008 was 80 mm, and the mode for Wt in YR 2008 was 5.6 g.

Average FL and Wt significantly decreased over study years 2000 - 08 (FL, Correlation, $p < 0.05$, $r = 0.73$, slope is negative, power = 0.69; Wt, Correlation, $p < 0.10$, $r = 0.66$, power = 0.52). Linear regression detected a significant positive relationship of population estimate on average FL ($p = 0.01$, $R^2 = 0.63$, power = 0.84, n = 9), and a non-significant positive relationship for average Wt ($p > 0.10$, $R^2 = 0.33$, power = 0.37, n = 9).

Table 19. 1+ steelhead trout population estimates and average fork length (mm) and weight (g) for study years 2000 - 2008, upper Redwood Creek, Humboldt County, CA.

	1+ Steelhead Trout						
		Fork Length (mm)			Weight (g)		
Study Year	(N)*	n	Avg.	SEM**	n	Avg.	SEM**
2000	68,030	2,721	92.4	0.2	1,455	8.29	0.09
2001	50,174	2,761	91.9	0.3	908	9.27	0.11
2002	28,501	3,049	86.7	0.3	1,356	7.79	0.14
2003	30,670	3,064	84.8	0.3	1,633	7.14	0.09
2004	41,434	3,191	85.7	0.3	1,441	7.57	0.10
2005	26,176	2,473	88.1	0.2	1,592	8.02	0.09
2006	26,248	1,961	85.7	0.3	1,683	7.48	0.09
2007	34,431	2,414	85.4	0.3	1,954	7.41	0.09
8 yr Avg.			87.6	1.1		7.87	0.24
2008	32,849	2,362	85.3	0.3	1,759	7.21	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 was similar to the previous eight year average (Figure 18). Average weekly FL (mm) (transformed) for 1+ steelhead trout in YR 2008 significantly increased over time (weeks) (transformed) (Correlation, $p < 0.00001$, $r = 0.93$, slope is positive, power = 1.00), as did the weekly FL (mm) for the previous eight year average (Correlation, $p < 0.05$, $r = 0.46$, slope is positive, power = 0.54) (Figure 18). Average weekly FL in YR 2008 (83.7 mm) was significantly less than the weekly FL of the previous eight year average (88.0 mm) (One-Way ANOVA, $p = 0.03$, power = 0.61).

The pattern of 1+ steelhead trout Wt over time also showed similarity to the previous eight year average (Figure 19). 1+ steelhead trout average weekly Wt (g) in YR 2008 significantly increased over time (weeks) (Correlation, $p < 0.0001$, $r = 0.92$, slope is positive, power = 1.00), as did the average Wt (g) by week for the previous eight year average (Correlation, $p < 0.05$, $r = 0.63$, slope is positive, power = 0.88) (Figure 19). Average weekly Wt in YR 2008 (7.13 g) was significantly less than the weekly Wt for the previous eight year average (8.18 g) (One-Way Anova, $p = 0.04$, power = 0.57).

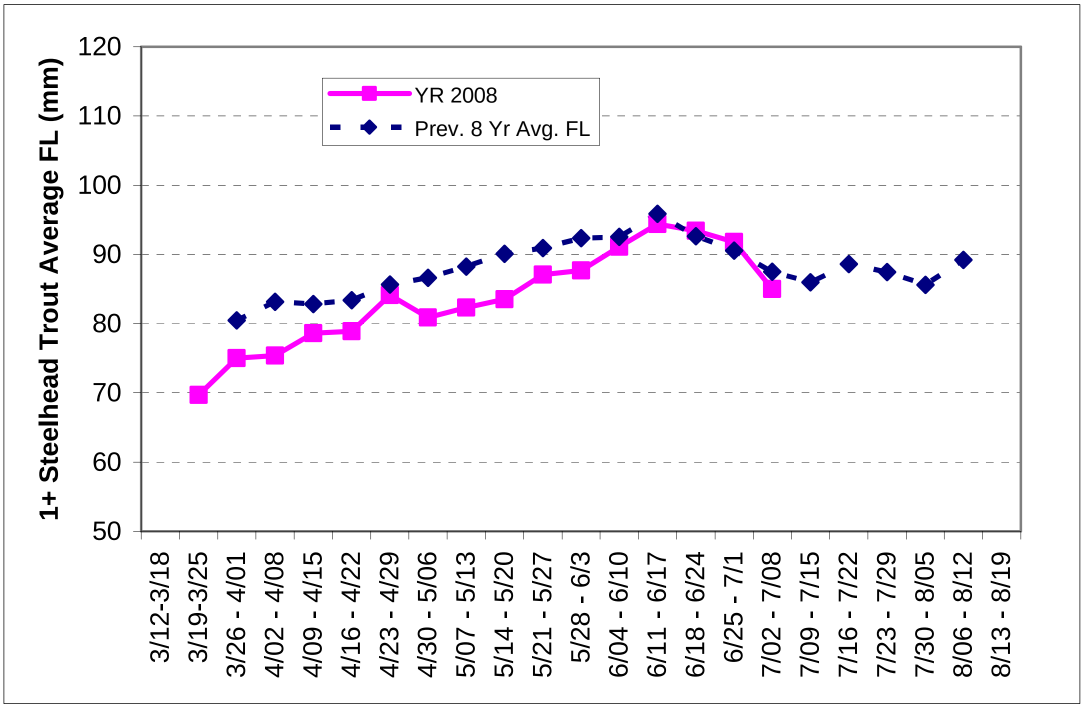

Figure 18. 1+ steelhead trout average weekly fork lengths (mm) in YR 2008 and the previous eight year average, upper Redwood Creek, Humboldt County, CA.

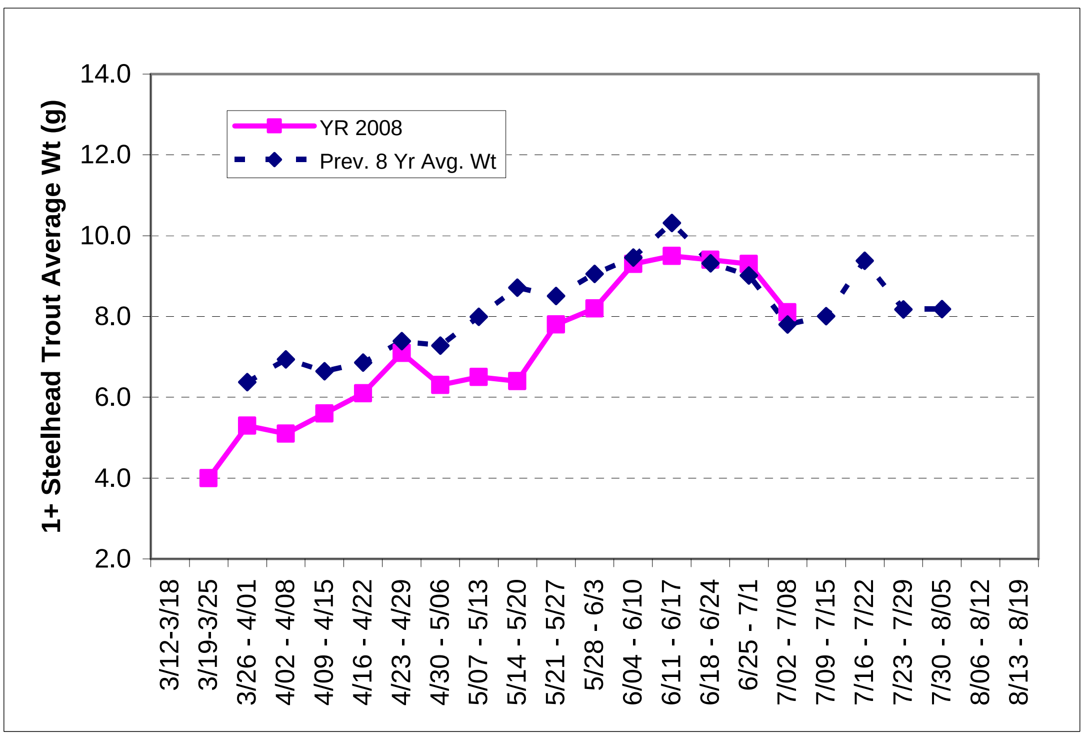

Figure 19. 1+ steelhead trout average weekly weights (g) in YR 2008 and the previous eight year average, upper Redwood Creek, Humboldt County, CA.

2+ Steelhead Trout

We measured (FL mm) 624 and weighed (g) 613 2+ steelhead trout in YR 2008 (Table 20). Average FL in YR 2008 was 4.6% less than average FL in YR 2007, and average Wt in YR 2008 was 8.8% less than average Wt in YR 2007 (Table 20). The mode in FL in YR 2008 was 120 mm, and the mode for Wt in YR 2008 was 20.3 g.

Average FL and Wt over study years 2000 - 2008 did not significantly change over time (Correlation: FL, $p > 0.10$, slope is negative, $r = 0.47$, power = 0.23; Wt, $p > 0.10$, $r = 0.51$, power = 0.28). Average FL and Wt by season was not influenced by population size (Regression, FL: $p > 0.10$, $R^2 = 0.0002$, slope is negative, power = 0.05; Wt: $p > 0.10$, $R^2 = 0.0002$, 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 - 2008, upper Redwood Creek, Humboldt County, CA.

	2+ Steelhead Trout						
		Fork Length (mm)			Weight (g)		
Study Year	(N)*	n	Avg.	SEM**	n	Avg.	SEM**
2000	4,739	710	164.4	0.6	480	49.12	0.61
2001	12,668	1,316	151.2	0.5	1,225	39.17	0.43
2002	7,302	1,528	147.5	0.6	1,463	37.87	0.51
2003	2,846	625	144.0	0.9	583	35.15	0.71
2004	5,778	1,277	144.1	0.7	1,244	35.44	0.47
2005	2,364	594	150.5	0.2	592	39.90	0.91
2006	1,866	396	159.8	1.4	391	44.86	1.06
2007	2,861	517	146.7	1.1	490	35.40	0.75
8 yr Avg.			151.0	2.6		39.61	1.77
2008	3,568	624	139.9	0.8	613	32.29	0.61

* "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 2008 as similar to the pattern for the previous eight year average (Figure 20). Highest values in YR 2008 occurred during the first five weeks of trapping, and the lowest value occurred during 6/11/08 – 6/17/08 (Figure 20). The transformed 2+ steelhead trout average weekly FL (mm) significantly decreased over transformed time (weeks) in YR 2008 (Correlation, $p < 0.0001$, $r = 0.93$, slope is negative, power = 1.00), as did the transformed previous eight year average FL (Correlation, $p < 0.01$, $r = 0.66$, slope is negative, power = 0.94). Average weekly FL in YR 2008 (145.0 mm) was not significantly different than the weekly FL for the previous eight year average (149.4 mm) (One-Way ANOVA, $p > 0.05$, power = 0.16). Average weekly 2+ steelhead trout FL (145.0) in YR 2008 was significantly greater than average weekly 1+ steelhead trout FL (83.7 mm) in YR 2008 (One-Way ANOVA, $p < 0.000001$, power = 1.00).

The pattern in 2+ steelhead trout average weekly Wt over the study period in YR 2008 was very similar to the previous eight year average Wt (Figure 21). Highest values in YR 2008 occurred during the first five weeks of trapping, and the lowest value occurred during 6/11/08 – 6/17/08 (Figure 21).

2+ steelhead trout average weekly Wt (g) significantly decreased over time (weeks) in YR 2008 (Correlation, $p < 0.0001$, $r = 0.90$, slope is negative, power = 1.00); as did the previous eight year average Wt (Correlation, $p < 0.05$, $r = 0.46$, slope is negative, power = 0.54) (Figure 21). Average weekly Wt in YR 2008 (36.21 g) was not significantly different than the average weekly Wt for the previous eight year average (38.73 g) (One-Way ANOVA, $p > 0.05$, power = 0.12). The transformed 2+ steelhead trout average weekly Wt in YR 2008 was significantly greater than the transformed 1+ steelhead trout average weekly Wt in YR 2008 (One-Way ANOVA, $p < 0.000001$, power = 1.00).

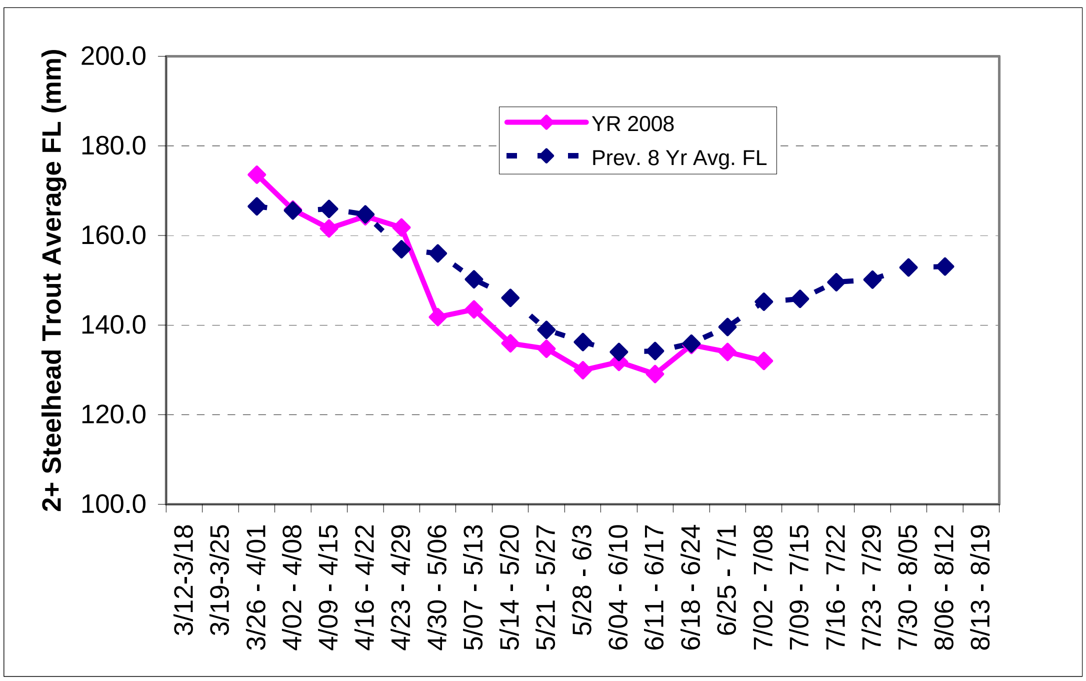

Figure 20. 2+ steelhead trout average weekly fork lengths (mm) in YR 2008 and the previous eight year average, upper Redwood Creek, Humboldt County, CA.

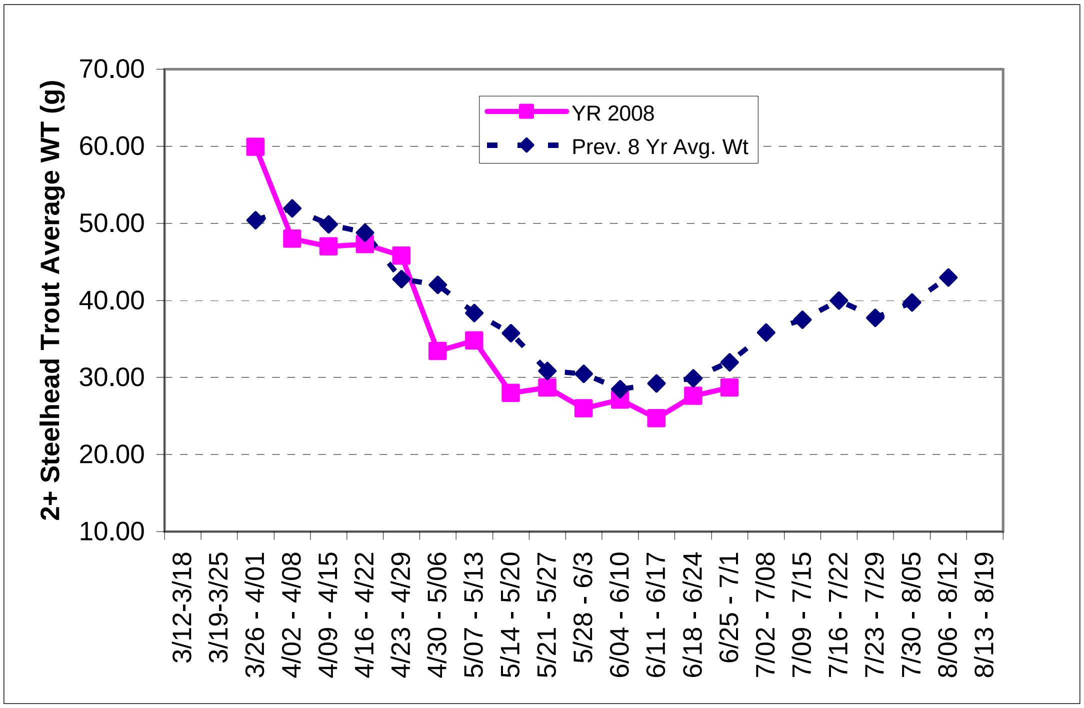

Figure 21. 2+ steelhead trout average weekly weights (g) in YR 2008 and the previous eight year average, upper Redwood Creek, Humboldt County, CA.

0+ Coho and 1+ Coho Salmon

0+ Coho salmon average FL and Wt in YR 2008 equaled 47.1 and 2.3 g, and 1+ coho salmon average FL and Wt in YR 2008 equaled 116 and 16.1 g (Table 21).

Table 21. 0+ coho salmon and 1+ coho salmon trap catches and fork lengths (mm) and weights (g) during study years 2000 – 2008, upper Redwood Creek, Humboldt County, CA.

		0+ Coho Salmon					
		Fork Length (mm)			Weight (g)		
Study Year	(Catch)	n	Avg.	SEM*	n	Avg.	SEM*
2007	6	6	63.8	5.1	6	3.20	0.87
2008	32	31	47.1	2.1	30	1.37	0.19
Avg.			55.5	8.4		2.29	0.92
		1+ Coho Salmon					
2008	7	7	116.1	2.8	7	16.09	1.24

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 2008 and for the previous eight year average (Table 22). A totally random distribution would equal 33.3% for each designation (parr, pre-smolt, smolt). Contingency tests (2x2) showed there were significant differences in the proportions of parr, pre-smolt and smolt designations for 1+ steelhead in YR 2008 compared to the previous eight year average (Chi-square, $p < 0.000001$). There were statistically less parr and pre-smolts, and more smolts in YR 2008 compared to the previous eight year average. For 2+ steelhead trout, there were statistically less pre-smolts and more smolts in YR 2008 compared to the previous eight 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, $p = 0.007$, $R^2 = 0.73$, power = 0.92).

For 2+ steelhead trout, the percentage of smolts in a given year was inversely related to the transformed population abundance (Regression, $p < 0.01$, $R^2 = 0.71$, power = 0.95), and inversely related to average daily stream temperature at the trapping site (Regression, $p < 0.05$, $R^2 = 0.61$, power = 0.73). No statistical relationships were found with average monthly stream discharge, average daily 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 2008 and for the previous eight year average was nearly 100% (Table 22).

Table 22. Developmental stages of captured 1+ and 2+ steelhead trout in YR 2008 and the previous eight 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
2008	< 0.1	8.1	91.9	0.0	0.3	99.7
8 Yr Avg.*	2.7	49.3	48.0	0.1	16.1	83.8

* Study years 2000 – 2007.

1+ Chinook Salmon and 1+ Coho Salmon

Every 1+ Chinook salmon captured during YRS 2001, 2002, 2003 and 2008 were classified as smolts, and all 1+ coho salmon captured in YR 2008 were classified as smolts.

Additional Experiments

Re-migration

In YR 2008, we did not recapture any of the pit tagged fish released from upper Redwood Creek in YR 2007 (Table 23). In YR 2007 we did not recapture any of the pit tagged fish released from upper Redwood Creek in YR 2006 (Table 23), and in YR 2006 we did not recapture any of the 1+ and 2+ steelhead trout marked and released with elastomer (n = 146 for 1+SH, 37 for 2+SH) in YR 2005. We also did not recapture any pit tagged fish released in YR 2005 (0+ Chinook, n = 555; 1+ steelhead, n = 147; 2+ steelhead, n = 46) in YR 2006 (Table 23).

Table 23. Data for testing re-migration of 0+ Chinook salmon, 1+ steelhead trout, and 2+ steelhead trout released from upper Redwood Creek to be recaptured in upper or lower Redwood Creek the following year, Humboldt County, CA.

		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
2007	0+ KS	691	0.00
2004	1+ SH	577	0.00
2005	1+ SH	293	0.00
2006	1+ SH	246	0.00
2007	1+ SH	484	0.00
2004	2+ SH	223	0.00
2005	2+ SH	83	0.00
2006	2+ SH	38	0.00
2007	2+ SH	48	0.00

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

Travel Time, Travel Rate, and Growth

0+ Chinook Salmon

We recaptured 27% of the pit tagged Chinook salmon smolts (released at the upper trap) with the smolt trap in lower Redwood Creek (Table 24). Percent recapture per release group ranged from 0.0 – 47% (Table 24).

Initial fork lengths of recaptured juveniles ranged from 67 – 83 mm, and averaged 73.0 mm (Appendix 7). Time to travel the 29 miles between traps ranged from 3.5 – 28.0 d, and averaged 11.6 d (median = 9.3 d, mode = 3.5 and 5.0 d) (Table 25). Average travel time in YR 2008 was greater than average travel time in YRS 2005 – 2007, however the greatest difference among years was 4.1 d (Table 25).

Travel time (transformed) in YR 2008 was not related to smolt size at time 2, stream discharge, or stream temperature (Regression, $p > 0.05$ for all tests). The regression of travel time on size at time 1 failed assumption tests, and results were not valid (NCSS 97). Travel time was positively related to lunar phase (Regression, $p = 0.0002$, $R^2 = 0.35$, power = 0.98); and negatively related to day of release (day number when groups were released) (Regression, $p = 0.005$, $R^2 = 0.21$, power = 0.83).

Table 24. 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., 2008.

Pit Tagged 0+ Chinook Salmon			
Release Group	Sample Size	No. of Recaptures	Percent Recapture
5/14/2008	1	0	0.0
6/03/2008	16	2	12.5
6/07/2008	25	7	28.0
6/10/2008	22	3	13.6
6/24/2008	24	9	37.5
6/27/2008	15	7	46.7
7/01/2008	23	8	34.8
7/05/2008	4	0	0.0
7/07/2008	3	0	0.0
Sum:	133	36	

Travel rate (mi/d) ranged from 1.0 – 8.3 mi/d, and averaged 3.9 mi/d (median = 3.2 mi/d, mode = 5.8 and 8.3 mi/d) (Table 25). Travel rate was positively related to FL at time 1 (Regression, $p < 0.05$, $R^2 = 0.11$, power = 0.52), negatively related to lunar phase (Regression, $p < 0.001$, $R^2 = 0.33$, power = 0.98), and positively related to day number when groups were released (Regression, $p = 0.003$, $R^2 = 0.24$, power = 0.88). The regressions of stream discharge and stream temperature on travel rate each failed regression assumption tests (even with transformations), and results were not valid (NCSS 97).

Similar to experiments in YRS 2005 – 07, multiple fish released from the same release group (n = 3 groups) in YR 2008 were frequently recaptured at the lower trap on the same day. For example, the group released on 6/27/2008 (n = 15), had three individuals recaptured on 7/02/2008. Fifty 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 36 total recaptures, 33% (n = 12) occurred on days when other pit tag fish were also recaptured; however none of the release groups had all of the recaptures occur on the same day. 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 = 7) from the 6/07/08 release group ranged from 5.0 – 28.0 days, and averaged 15.9 d.

The final average size (FL) of recaptured pit tagged 0+ Chinook ranged from 68 – 83 mm, and averaged 75.4 mm; final Wt ranged from 3.01 – 5.91 g, and averaged 4.43 g

(Appendix 7). Similar to previous study years (with exception to YR 2007), the final size of pit tagged fish was positively related to size at release (Regression: FL, $R^2 = 0.51$, $p < 0.00001$, power 1.0; Wt, $R^2 = 0.44$, $p < 0.0001$, power = 1.0).

Fifty percent (n = 18) of the 36 recaptured pit tagged 0+ Chinook salmon showed positive growth in FL and 50% (n = 18) showed no increase in FL. For the 36 recaptures where Wt was recorded, 47% (n = 17) showed an increase in Wt, 31% (n = 11) showed no change, and 22% (n = 8) lost Wt.

On average, the 0+ Chinook salmon gained 2.4 mm in length, and experienced a positive percent change in FL of 3.4% in YR 2008 (Table 25, Appendix 7). 0+ Chinook salmon showed, on average, positive growth in FL for absolute growth rate (Avg. = 0.13 mm/d), relative growth rate (Avg. = 0.002 mm/mm/d), and specific growth rate scaled [Avg. = 0.175 % (mm/d)] (Table 25, Appendix 7). Growth values in YR 2008 were less than values in YRS 2005 - 2007 (Table 25).

Table 25. Comparison of travel time (d), travel rate (mi/d), and various growth statistics in YRS 2005 - 2008 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)	YR 2008 (n = 36)
Emigrational				
Travel Time (d)	7.5 (5.5)	8.0 (6.5)	10.7 (8.5)	11.6 (9.3)
Travel Rate (mi/d)	8.2 (5.3)	5.5 (4.5)	4.0 (3.4)	3.9 (3.2)
Growth Index(FL)				
Δ in FL*	2.8 (2.0)	2.8 (2.0)	3.9 (3.0)	2.4 (1.0)
% Change in FL	3.65 (2.47)	3.87 (2.82)	5.48 (4.23)	3.35 (1.3)
AGR*	0.22 (0.19)	0.24 (0.30)	0.29 (0.33)	0.13 (0.06)
RGR*	0.003 (0.002)	0.003 (0.004)	0.004 (0.004)	0.002 (0.001)
SGRsc*	0.279 (0.232)	0.323 (0.395)	0.397 (0.430)	0.175 (0.080)

* 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 (86%) in percent change in FL (transformed) than any other variable tested (Figure 22). Travel rate (mi/d) was inversely related to various growth indices. Travel rate (mi/d) was negatively related to change in FL (transformed) (Regression, $p < 0.00001$, $R^2 = 0.73$, power = 1.0).

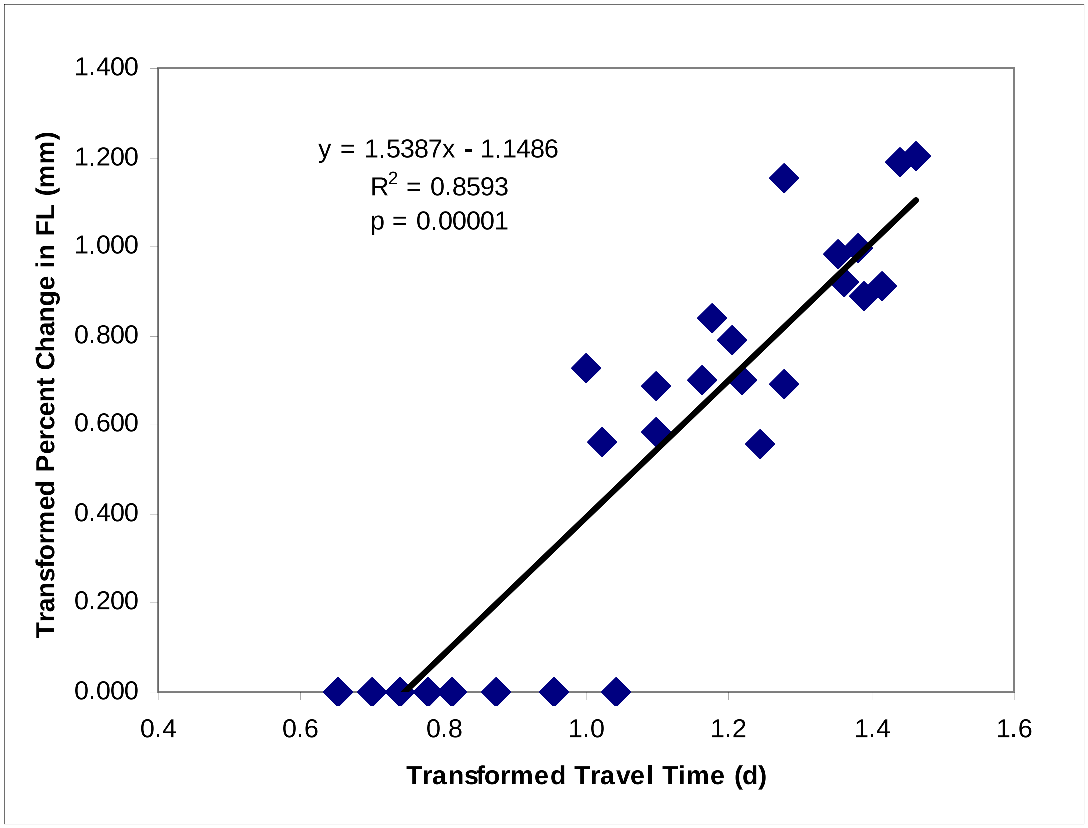

Figure 22. Linear regression of transformed travel time (d) on transformed percent change in FL (mm) for pit tagged 0+ Chinook salmon (n = 36) recaptured at the lower trap in Redwood Creek, Humboldt County, CA. 2008.

Separate growth statistics were determined for recaptured pit tagged 0+ Chinook salmon individuals showing only positive growth (Table 26). On average, pit tagged Chinook salmon absolute growth rate equaled 0.258 mm per day for FL, and 0.039 g per day for Wt (Table 26).

Table 26. Growth statistics for recaptured pit tagged 0+ Chinook salmon that showed only positive growth in FL (n = 18) and Wt (n = 17) while traveling 29 mi downstream to lower Redwood Creek, Humboldt County, CA., 2008.

	Positive Growth							
	% Change in		AGR*		SGRsc*		RGR*	
	FL	Wt	FL	Wt	FL	Wt	FL	Wt
Min.	2.6	4.1	0.121	0.016	0.155	0.346	0.002	0.003
Max.	14.9	57.0	0.500	0.073	0.691	1.857	0.007	0.022
Avg.	**6.7**	**20.4**	**0.258**	**0.039**	**0.350**	**0.920**	**0.004**	**0.010**
SEM**	0.9	3.7	0.021	0.004	0.030	0.107	0.0003	0.0014

* Abbreviations are the same as in Table 25
** Standard error of the mean.

We took detailed notes on whether the partial, upper caudal fin clips (secondary mark for pit tagged fish) and scars from pit tag surgery (scalpel) were visible to the observer (naked eye). Fish that fell within the not visible category spent a longer time traveling downstream, and exhibited higher growth than individuals in the two other categories (Table 27).

Table 27. 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., 2008.

	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	28	8.2	4.7	1.7	0.092
Barely Visible	4	21.3	1.4	6.6	0.221
Not Visible	4	25.6	1.1	11.4	0.299
Surgery Scar					
Visible	22	6.3	5.4	0.7	0.050
Barely Visible	6	15.5	1.9	5.6	0.250
Not Visible	8	23.1	1.3	9.0	0.260

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

1+ Steelhead Trout

We recaptured eight pit tagged 1+ steelhead trout at the lower trap in YR 2008 (Appendix 8). Percent recapture per release group ranged from 0.0 – 25.0%, and averaged 4.8% (Appendix 8).

Initial fork lengths of recaptured juveniles (n = 8) ranged from 70 – 112 mm, and averaged 87.3 mm (Appendix 9). The final size of recaptured pit tagged 1+ steelhead trout in YR 2008 ranged from 87 – 114 mm, and averaged 97.4 mm (Appendix 9). The final size (FL, Wt) was positively related to initial size at release (Regression, FL: $p < 0.01$, $R^2 = 0.75$, positive slope, power = 0.94; WT: $p < 0.01$, $R^2 = 0.75$, positive slope, power = 0.94).

Time to travel the 29 miles between traps in YR 2008 ranged from 2.5 – 44.0 d, and averaged 22.8 (median = 26.5 d) (Table 28). Travel time was significantly related to the size at time 1 (Regression, FL: $p < 0.05$, $R^2 = 0.68$, negative slope, power = 0.84; Wt: : $p < 0.05$, $R^2 = 0.60$, negative slope, power = 0.71). Unlike previous study years, travel time was not related to lunar phase, stream discharge, or stream temperature (Regression, $p > 0.10$ for each test).

Travel rate (mi/d) in YR 2008 ranged from 0.7 – 11.6 mi/d, and averaged 4.0 mi/d (median = 1.1 mi/d) (Table 28). Travel rate (mi/d) was positively related to FL at time 1 (Regression, $p < 0.10$, $R^2 = 0.39$, power = 0.38), stream discharge in upper Redwood Creek (Regression, $p < 0.10$, $R^2 = 0.39$, positive slope, power = 0.38), stream discharge in lower Redwood Creek (Regression, $p < 0.10$, $R^2 = 0.44$, positive slope, power = 0.45), and average stream discharge in upper and lower Redwood Creek (Regression, $p < 0.10$, $R^2 = 0.44$, positive slope, power = 0.44). The best model describing travel rate (mi/d) included FL at time 1 and transformed average stream discharge (Regression, $p = 0.02$, Adj. $R^2 = 0.73$, positive relationship for both variables, power = 0.55).

Seventy five percent (n = 6) of the 8 recaptured pit tagged 1+ steelhead trout showed positive growth in FL and 25% (n = 2) showed no change in FL; 75% (n = 6) showed an increase in Wt and 25% (n = 2) showed a decrease in Wt.

On average, the 1+ steelhead trout gained 10 mm in length, and experienced a positive percent change in FL of 13% in YR 2008 (Table 28). 1+ steelhead trout showed, on average, positive growth in FL for absolute growth rate (Avg. = 0.34 mm/d), relative growth rate (Avg. = 0.004 mm/mm/d), and specific growth rate scaled [Avg. = 0.376 %(mm/d)] (Table 28). Growth in YR 2008 was slightly greater than growth in YR 2006, and less than growth in YR 2007 (Table 28).

Table 28. Comparison of travel time (d), travel rate (mi/d), and various growth statistics in YRS 2005 – 2008 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)	YR 2008 (n = 8)
Emigrational				
Travel Time (d)	12.4 (10.0)	20.8 (15.5)	29.5 (29.0)	22.8 (26.5)
Travel Rate (mi/d)	5.8 (2.9)	4.0 (2.1)	1.59 (1.0)	4.0 (1.1)
Growth Index(FL)				
Δ in FL*	-	10.0 (6.5)	15.2 (15.0)	9.9 (12.0)
% Change in FL	-	12.60 (9.19)	18.74 (19.74)	12.63 (14.13)
AGR*	-	0.31 (0.32)	0.47 (0.49)	0.34 (0.44)
RGR*	-	0.004 (0.004)	0.006 (0.006)	0.004 (0.006)
SGRsc*	-	0.350 (0.398)	0.521 (0.571)	0.376 (0.462)

* Abbreviations are the same as in Table 25
** 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, $p < 0.05$) except for a non-significant relationship with AGR Wt; and travel rate on growth was significantly negative for each test (Regression, $p < 0.05$) with exception to non-significant relationships with AGR Wt, RGR Wt, and SGR Wt.

Travel time (d) explained more of the variation in delta FL and Wt, and percent change in FL and Wt than other variables; and travel rate explained more of the variation in AGR FL, SGRsc FL, and RGR FL than other variables. The variation in travel time (d) explained 97% of the variation in percent change in FL (Figure 23).

Several growth indices (delta FL, Wt; Percent change in FL, Wt; AGR Wt, SGR Wt; RGR Wt) were negatively related to size at time 1. The tests showed that smaller smolts grew more, and at a higher rate, than larger smolts.

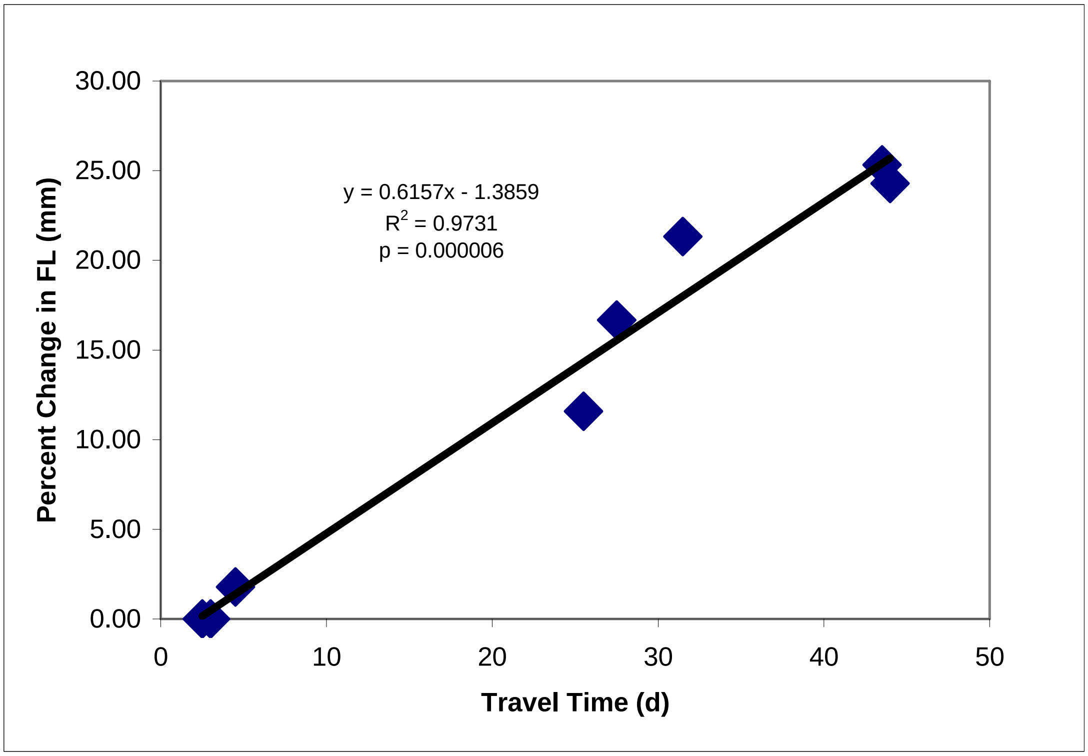

Figure 23. Linear regression of travel time (d) on change in FL (mm) for pit tagged 1+ steelhead trout (n = 8) recaptured at the lower trap in Redwood Creek, Humboldt County, CA., 2008.

2+ Steelhead Trout

We recaptured one pit tagged 2+ steelhead trout in YR 2008 that took five days to reach the lower trap, and in YR 2007 we recaptured one 2+ steelhead that took 18.5 d to reach the lower trap.

Delayed Mortality

0+ Chinook Salmon

A total of 22 delayed mortality experiments were conducted with 0+ Chinook salmon (n = 522) in YR 2008, with an overall mortality of 0.37% (Appendix 10). No mortalities attributable to fin clipping or handling occurred, however, two of the 133 pit tagged fish (which also includes anesthetization, FL and Wt measurements, and a small partial upper caudal fin clip) died within 36 hours of being held. These two 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 two fish that died collectively accounted for one out of nine 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 much less than 1.5%. Average sample size per test equaled 24 individuals, and average test duration equaled 28 hours.

0+ Steelhead Trout

A total of one delayed mortality experiments were conducted with 0+ steelhead trout (n = 30) in YR 2008, with an overall mortality of 0.00% (Appendix 11).

1+ Steelhead Trout

A total of 24 delayed mortality experiments were conducted with 1+ steelhead trout (n = 399) in YR 2008, with an overall mortality rate of 0.00% (Appendix 12). Average sample size per test equaled 17 individuals, and average test duration equaled 32 hours.

2+ Steelhead Trout

A total of 31 delayed mortality experiments were conducted with 2+ steelhead trout (n = 170) in YR 2008, with an overall mortality rate of 0.00% (Appendix 13). Average sample size per test equaled five individuals, and average test duration equaled 33 hours.

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 2008 ranged from 0.00 - 0.79%, and using all data, was 0.20% of the total captured and handled (Table 29). This level of trap mortality is very low, and considered negligible.

Juvenile salmonid trapping mortality in YR 2008 (0.20%) was much lower than the previous eight year average (0.42%) (Table 30).

Table 29. Trapping mortality for juvenile salmonids captured in YR 2008, upper Redwood Creek, Humboldt County, CA.

	Trap Mortality in YR 2008		
Age/spp.	No. captured	No. of mortalities	Percent mortality
0+ Chinook	35,567	51	0.14
1+ Chinook	9	0	0.00
0+ Steelhead	57,805	135	0.23
1+ Steelhead	6,843	9	0.13
2+ Steelhead	634	5	0.79
0+ Coho	32	0	0.00
1+ Coho	7	0	0.00
Cutthroat trout	4	0	0.00
0+ Pink	4	0	0.00
Overall:	100,905	200	0.20

Table 30. Comparison of trapping mortality of juvenile salmonids in nine 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
2007	89,965	199	0.22
2008	100,905	200	0.20
Average* (2000-07)			0.42

* Previous eight year average.

Stream Temperatures

The average daily (24 hr period) stream temperature from 3/24/08 – 7/15/08 was 13.0 ^{o}C (or 55.4 ^{o}F) (95% CI = 12.2 – 13.8 ^{o}C), with daily averages ranging from 6.2 – 21.9 ^{o}C (43.2 – 71.4 ^{o}F). In 2008, the average daily stream temperature exceeded 20 ^{o}C (68 ^{o}F) for 10 d (9%) out of 114 d of record. Average daily stream temperatures during the trapping periods have significantly decreased over YRS 2001 – 08 (Correlation, $p = 0.02$, $r = 0.78$, negative slope, power = 0.73).

Average, minimum, and maximum stream temperatures during the trapping period in YR 2008 were the lowest of the current eight consecutive years of data (Table 31).

Table 31. Average daily stream temperature (^{o}C) (standard error of mean in parentheses) with minimum and maximum recorded stream temperature during the trapping period in YR 2008 and previous seven years, upper Redwood Creek, Humboldt County, CA.

	Stream Temperature					
	Celsius			Fahrenheit		
Study Year	Avg.	Min.	Max.	Avg.	Min.	Max.
2001	16.3 (0.40)	5.7	28.2	61.3 (0.72)	42.3	82.8
2002	15.8 (0.39)	6.7	27.5	60.4 (0.71)	44.1	81.5
2003**	14.5 (0.46)	6.1	28.4	58.1 (0.82)	43.0	83.1
2004	15.8 (0.39)	6.7	28.8	60.4 (0.71)	44.1	83.8
2005**	13.5 (0.38)	6.2	25.8	56.4 (0.68)	43.2	78.4
2006**	14.9 (0.45)	5.7	29.5	58.8 (0.82)	42.3	85.1
2007	14.4 (0.39)	5.7	25.5	57.9 (0.70)	42.3	77.9
7 Yr. Avg.*	15.1 (0.37)	5.7	29.5	59.2 (0.65)	42.3	85.1
2008	13.0 (0.43)	4.4	25.2	55.4 (0.77)	39.8	77.3

* 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 2008 ranged from 8.4 – 19.9 ^{o}C (47.1 – 67.8 ^{o}F) (Table 32). Highest stream temperatures occurred in the later part of the trapping season (June and July) each study year. Median monthly temperatures among study years were not significantly different (Kruskal-Wallis One –Way ANOVA on RANKS, $p > 0.05$). Average monthly temperatures in YRS 2001 – 2008 were inversely related to average monthly discharge (Regression, $p < 0.05$, $R^2 = 0.58$, negative slope, power = 0.67).

Table 32. Average monthly stream temperature (^oC) (^oF in parentheses) at the trap site in study years 2001 - 2008, upper Redwood Creek, Humboldt County, CA.

Study Year	Average stream temperature in Celsius (^oF 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)
2008	8.4 (47.1)	12.2 (54.0)	16.1 (61.0)	19.9 (67.8)	14.2 (57.6)

The MWAT during the trapping period in YR 2008 at the trap site was 21.3 ^oC (70.3 ^oF) and occurred on 7/09/08 (Table 33). MWMT in YR 2008 was 24.5 ^oC (76.1 ^oF) and occurred on 7/09/08 (Table 33). The lowest values for MWAT and MWMT over eight years of temperature monitoring occurred in YR 2008 (Table 33). The highest MWAT occurred when stream temperatures were lethal to juvenile salmonids in YR 2006.

Table 33. Maximum weekly average temperature (MWAT) and maximum weekly maximum temperature (MWMT) for stream temperatures ^oC (^oF in parentheses) at the trap site in upper Redwood Creek, Humboldt County, CA., study years 2001 – 2008.

Study Year	MWAT**		MWMT***	
	Date of occurrence	^oC (^oF)	Date of occurrence	^oC (^oF)
2000	-	-	-	-
2001	7/25/01	21.8 (71.2)	7/25/01	27.9 (82.2)
2002	7/29/02	21.9 (71.4)	7/27/02	26.4 (79.5)
2003*	7/29/03	23.1 (73.6)	7/29/03	27.4 (81.3)
2004	7/25/04	23.3 (73.9)	7/25/04	28.2 (82.8)
2005*	8/05/05	21.9 (71.4)	8/05/05	25.7 (78.3)
2006*	7/25/06	24.1 (75.4)	7/25/06	28.0 (82.4)
2007	7/25/07	21.5 (70.7)	7/25/07	24.9 (76.8)
2008	7/09/08	21.3 (70.3)	7/08/08	24.5 (76.1)

* 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 daily stream temperature significantly increased over the study period in YR 2008 (Correlation, $p < 0.000001$, $r = 0.95$, slope is positive, power = 1.0) (Figure 24).

Similar to past study years, average daily stream temperature in YR 2008 was significantly related to the average daily stream gage height at the trapping site (Regression, $p < 0.000001$, $R^2 = 0.81$, slope is negative, power = 1.0); and inversely related to average daily stream discharge measured at the O'Kane gaging station (Regression, $p = 0.00001$, $R^2 = 0.75$, negative slope, power = 1.0).

The minimum stream temperature in YR 2008 was 4.4 °C (39.8 °F) and occurred on 3/31/08; the maximum stream temperature was 25.2 °C (77.3 °F) and occurred on 7/10/08 (Figure 24).

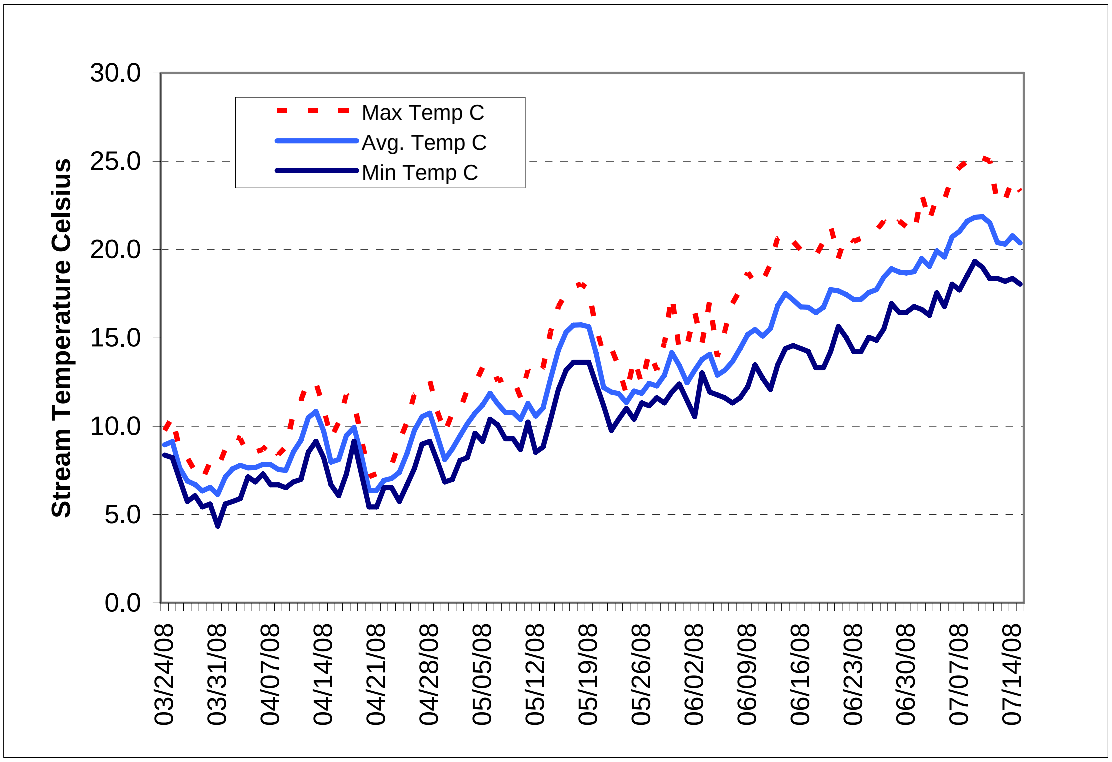

Figure 24. Average, minimum, and maximum stream temperature (Celsius) at the trap site, upper Redwood Creek, Humboldt County, CA., 2008.

The previous seven 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 2008 (12.24 °C) was significantly less than the median (15.6 °C) for the previous seven year average (Kruskal-Wallis One-Way ANOVA on Ranks, $p = 0.0001$).

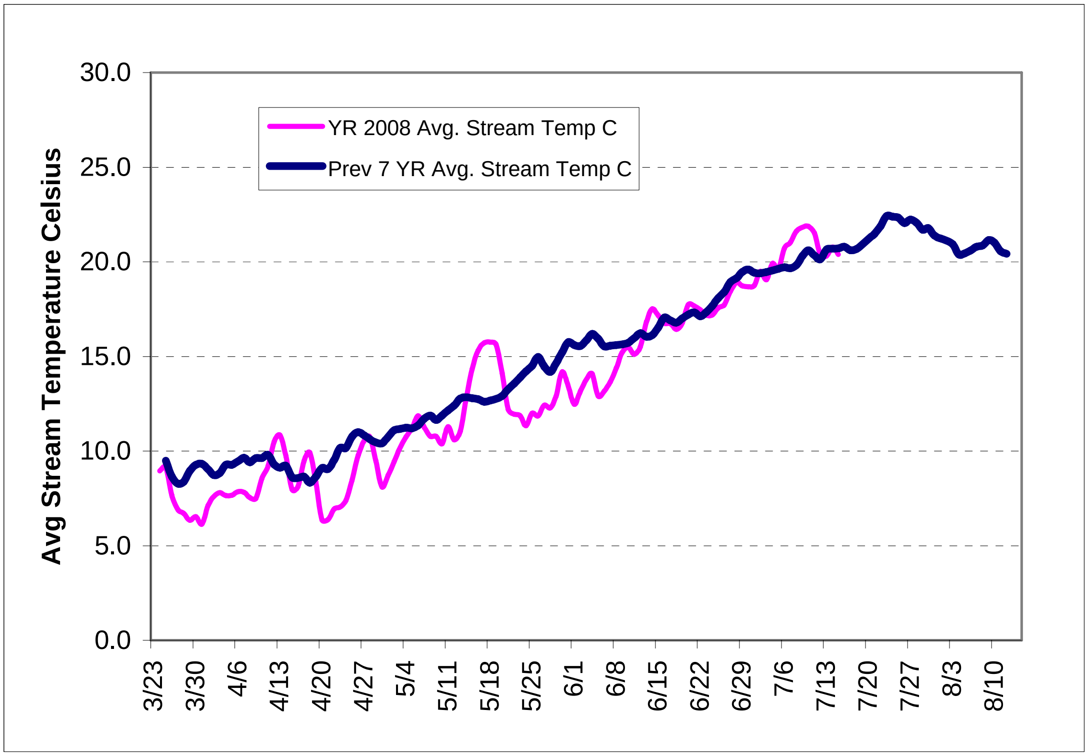

Figure 25. Average daily stream temperatures (Celsius) during the trapping period in YR 2008 and the average of previous seven study years, upper Redwood Creek, Humboldt County, CA.

<u>(Lethal) Stream Temperatures in late July</u>

There were no lethal stream temperatures recorded in study YR 2008, 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 ninth consecutive year of trapping in upper Redwood Creek occurred during an average water year with respect to rainfall amounts in Redwood Valley, and a slightly below water year with respect to average stream discharge measured at the O’Kane gaging station. During the majority of the trapping period, rainfall in YR 2008 was much less (37 – 39% reduction) than rainfall for the historic and previous eight 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 2008 were not as harsh or as difficult to operate the trap compared to previous study years. Although the hydrograph showed six distinctive rises in gage height and stream discharge, the largest increase (0.81 ft, 92 cfs) was easily handled by the modified, rotary screw trap. The trap did not miss a single day’s trapping in YR 2008, which is atypical since we normally miss an average of four days out of an average of 131 days of trapping. The study in YR 2008 was very successful at meeting study objectives, and the uncertainty or error in the population estimate for a given species at age ranged from 7 – 22%. 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 nine years. Low catches occurred in YRS 2003, 2005, 2006, 2007, and 2008; and the total catch in YR 2008 was 60% less than the average catch of the previous eight years (Avg. = 88,048).

The population of 0+ Chinook salmon emigrating from upper Redwood Creek was variable over the nine consecutive years of study; production was greater than 350,000 individuals for the first three years, less than 1,000 in the fourth year (cohort failure), and the fifth year experienced the greatest peak of 630,000. Production in YRS 2005 – 2007 was less than 70,000, and in YR 2008 production equaled 115,000. Population abundance in YR 2008 was higher than the past three years, yet much lower (by 56%) than the previous eight year average. The reduction in population emigration in YR 2008 could be due to: 1) change in adult spawner distribution in the watershed, 2) simple decrease in the total number of spawners upstream of the trap site, or 3) a combination of factors 1 and 2. Flood type flows were ruled out because none occurred during spawning and egg development for the YR 2008 cohort. The nine year trend in population abundance over time showed a significant, negative decline. The addition of flood type flows as a dummy variable in the trend regression decreased the p value, increased the r value, and increased the power of the test. Thus, the best model describing the trend of 0+ Chinook salmon over time included study year (-) and whether there was a flood type flow (-) during the spawning season for a given cohort.

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 2008. The emigrant population passing the rotary screw trap in lower Redwood Creek in YR 2007 (N = 173,758) does not give much supportive evidence for a change in population distribution because it was only 33,000 individuals higher than the low emigration observed in YR 2007. 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 passing through lower Redwood Creek in YR 2008 was not much higher than production passing through upper Redwood Creek. Unfortunately, peaks in stream flow (> 10,000 cfs) measured in lower Redwood Creek in January 2008 and February 2008 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 in upper Redwood Creek would also result in a noticeable reduction in juvenile production. Since there were no flows capable of mobilizing the streambed in WY 2008, the most plausible explanation for low juvenile production in YR 2008 is that fewer adults returned to spawn upstream of the trap site. Juvenile production in YR 2007 and YR 2008 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 2008 cohort, the relationship of flood flows on the production of juvenile Chinook salmon over nine years was significantly negative. The regression model was able to explain 47% 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 nine 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, and in YR 2008 only nine yearling Chinook salmon were captured from the YR 2007 cohort. Thus holding over is an unlikely explanation for the low production observed in YR 2008.

0+ Chinook salmon monthly population emigration in YR 2008 was severely reduced from the previous eight year average, with the biggest monthly reductions occurring in April (72% or 71,661 individuals) and May (58% or 50,219 individuals). The majority of juvenile Chinook salmon in YR 2008 migrated downstream during April - June (97% of total emigration), similar to the previous eight year average (April – June, 96% of emigration). However, highest numbers emigrated during June in YR 2008 (similar to YRS 2006 - 07), compared to April for the previous eight year average. Unlike previous study years, weekly population emigration in YR 2008 was not related to stream discharge, stream gage height, stream temperature, lunar phase or week number.

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 = 38 mm in YR 2008) are migrating shortly after emergence from spawning redds, and therefore are much smaller than the fingerlings (Avg. FL = 57 mm in YR 2008) 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 2008 occurred during 4/09/08 – 4/15/08 (N = 11,351), and consisted of fry with an average FL of 37 mm, and the largest peak during 6/04/08 – 6/10/08 (N = 15,451) and primarily consisted (96%) of fingerlings with an average FL of 55 mm. The two noticeable weekly peaks or modes to the distribution (both YR 2008 and previous eight year average) do not indicate two different runs (spring vs. fall/winter) of adult Chinook salmon entered upper Redwood Creek because of great differences in FL or WT. If the modes represented two different runs of adults, we would expect the FL's during each peak to be nearly the same. In other words, if the second mode represented 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 2008 began near the onset of trapping, peaked in mid April (same week as for the previous eight year average), and tapered off to very low values by the middle to end of June. Fingerling migration in upper Redwood Creek began in very low numbers in April, peaked near mid-June (same weeks as for the previous eight 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 emigrant Chinook salmon population abundance per study year (excluding YR 2003). The percentages of juvenile Chinook salmon migrating as fry (40% of total or 45,946 individuals) or fingerlings (60% of total or 69,481 individuals) in YR 2008 were statistically different than for the previous eight year average, such that a lesser proportion of fry and a higher proportion of fingerlings were present in YR 2008. As expected, the proportion of fry and fingerlings present in YR 2008 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 2008 was less than averages for the previous seven years. The inclusion of data from YR 2008 caused the previous density-dependent relationship of fish size and population abundance to become non significant. In contrast to previous study years, the average size in FL over nine years was inversely related to the percentage of fry in the population. Thus, populations with more fry compared to fingerlings had a smaller average size.

Although average size did not significantly change over the nine study years, average weekly FL and Wt in any given year increased over the study period. Average weekly FL and Wt in YR 2008 followed a similar pattern over time, starting out low and relatively stable for the first seven to eight 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 2008 was attributable to the increasing percentage of fingerlings in the catch over time compared to fry. Unwin (1985) reported a similar finding in his trapping studies in New Zealand.

The relationships of weekly FL and Wt in YR 2008 with the previous seven year average (excludes YR 2003) 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 2008 were generally less in value than the seven 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 (FL) from 3/26 – 7/15 equaled 0.25 mm/d, compared to 0.34 mm/d in YR 2007, 0.35 mm/d in YR 2006, and 0.41 mm/d in YR 2005. Growth rate in Wt (g) in YR 2008 was similar in comparison to the previous three study years.

A growth rate of 0.25 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 = 36) 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 seven 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, availability of prey items, the salmon stock in Redwood Creek, or variable cohort behavior.

The lower trap in Redwood Cr (RM 4) captured 27% 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 2008 (as well as YRS 2005 - 2007) was variable. For one release group (6/27/08, n = 15 released), three individuals were recaptured on the same day at the lower trap (7/02/08), which suggests these fish traveled together as a group. Of the six release groups where recaptures occurred, 50% 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, three separate release groups had multiple recaptures (from the same release group) that occurred on different days at the lower trap. For example, seven individuals from the 6/07/08 release group (n = 25) were recaptured at the lower trap anywhere from 5 – 28 d after release from the upper trap; these fish did not travel as a group.

Travel time for 0+ Chinook salmon smolts in YR 2008 to migrate the 29 miles downstream ranged from 3.5 – 28.0 d, and averaged 11.6 d; average travel time in YR 2008 was higher than YR 2005 (Avg. travel time = 7.5 d), YR 2006 (Avg. travel time = 8.0 d), and YR 2007 (Avg. travel time = 10.7 d). On average, 0+ Chinook salmon in YRS 2005 - 2008 moved downstream to the lower trap in fewer days than 2+ steelhead trout (n = 7, Avg. = 13 d) and 1+ steelhead trout (n = 9, 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), YR 2007 (n = 18, Avg. = 30 d), and YR 2008 (n = 8, Avg. = 23 d). Thus, for the past five 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 2008 was positively related to lunar phase and negatively related to day of release. Thus, smolts took a longer time to migrate downstream during higher moon illuminations, and smolts released at a later date took less time to migrate downstream. The best linear model included the single variable of moon illumination, however, the model left considerable amounts of variation unexplained (65%). Travel time was not related to: 1) stream temperature, 2) stream discharge, or size at Time 2. 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 2008 ranged from 1.0 – 8.3 mi/d (1.6 – 13.4 km/d), averaged 3.9 mi/d (6.3 km/d), and was less than travel rate in YR 2005 (8.2 mi/d), YR 2006 (5.5 mi/d), and YR 2007 (4.0 mi/d). The upper range in travel rate in YR 2008 (13.4 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 (6.3 km/d) from upper Redwood Creek in YR 2008 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. Travel rate in Redwood Creek in YR 2008 was successfully modeled using linear regression. Travel rate was positively related to fish size at time 1, negatively related to lunar phase, and positively related to day number when initially released. Thus, smolts that traveled faster were generally larger, migrated during lower moon illuminations, and released on a later date. 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 2008, 50% of the 36 recaptured pit tagged 0+ Chinook salmon showed positive growth in FL, 50% showed no change in FL, 47% showed positive growth in Wt, 31% showed no change in Wt, and 22% lost Wt. Absolute growth rate (FL) in YR 2008 ranged from 0.0 – 0.50 mm/d, and averaged 0.13 mm/d. The average value (0.13 mm/d) was much lower than the average AGR in YR 2005 (0.22 mm/d), YR 2006 (0.24 mm/d), and YR 2007 (Avg. 0.29 mm/d). With exception to YR 2008, AGRs for Chinook salmon in Redwood Creek were comparable to the group growth rate for Chinook salmon fingerlings in the Nitinat River (0.21 mm/d) yet much less (by 54 - 65%) than the group growth rate (0.62 mm/d) determined in the Cowichan River, 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 – 0.053 g/d, which was much higher than the average specific growth rate (un-scaled) we determined for Redwood Creek Chinook salmon in YR 2008 (0.002 g/d). The average absolute growth rate (FL) for recaptured pit tagged fingerlings (0.13 mm/d) in Redwood Creek was about 46% less than the group growth rate (0.24 mm/d) calculated for fry and fingerlings in YR 2008 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 0.12 - 0.50 mm/d and averaged 0.26 mm/d, which was slightly higher than the group estimate previously calculated (0.24 mm/d).

The growth (Percent Change in FL and Wt) of the 36 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 - 2007. Percent change in FL was positively related to travel time, and the variation in travel time explained 86% of the variation in growth. Percent change in FL was inversely related to travel rate, and the variation in travel rate explained 73% of the variation in growth. Change in FL (delta FL) was also positively related to lunar phase, however, only 38% of the variation was explained. Thus, 1) 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, 2) fish that migrated at a higher rate grew less than slower moving fish, and 3) fish that migrated during higher moon illuminations experienced greater growth. 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. Fish that migrated during higher moon illuminations had a better chance of detecting and capturing prey items due to increased stream visibility. 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. Monzyk et al. (2009) also found a positive relationship between travel time and growth for juvenile Chinook salmon in the upper reaches of the Snake River.

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. The total number of 1+ Chinook salmon juveniles captured over nine study years equaled 77 individuals, or 0.01% of the total juvenile Chinook salmon catch. Stream-type Chinook salmon are easily differentiated from ocean-type by size at time of downstream migration. For example, the average FL in May 2003 was 124 mm for 1+ Chinook salmon and 58 mm for 0+ Chinook juveniles. Average size in YR 2008 was 118 mm FL.

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 for Redwood Creek, is whether the one year old life history for juvenile Chinook salmon was more prevalent prior to the changes in the watershed associated with land use activities, flood events, and geomorphic processes.

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 nine consecutive study years we captured 730,607 individuals. 0+ steelhead trout were the most numerous juvenile salmonid captured in the trap for five out of nine years, and were the most numerous age class migrant for juvenile steelhead trout each study year. In YR 2008, the ratio of 0+ steelhead trout to 1+ and 2+ steelhead trout at the population level was 1.6:1. 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 2008 (n = 57,805) was greater than catches in YRS 2000, 2005 and 2006, yet 31% lower than the previous eight year average catch (Avg. = 84,100). Young-of-year steelhead trout were first captured on April 2nd in YR 2008, and low catches (< 30 individuals/d) occurred from 3/24 – 5/05/08. The average daily catch over the entire trapping period equaled 507. Peak catches occurred on 5/30/08 (n = 2,932), 6/06/08 (n = 3,095), and 6/11/08 (n = 3,170).

The monthly pattern in downstream migration in YR 2008 was similar to the previous eight 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 2008 the majority of catches occurred during May and June (97%) compared to June and July (69%) for the previous eight year average. The largest decrease in monthly catches in YR 2008 (compared to the average) occurred in July, similar to data in YRS 2006 and 2007. The total catch in July 2008 (n = 1,548) was 94% (or 22,652 individuals) less than the previous eight year average catch for July. This decrease was probably not due to ending the study near the middle of July because very low catches occurred after July 5th.

The average FL for 0+ steelhead trout in YR 2008 (Avg. = 33 mm) was the lowest of the current nine study years, and was probably influenced by the high percentage (85%) of fry (FL < 40 mm) migrating downstream. Emergent fry (newly emerged from spawning redds, FL < 32 mm) comprised 67% of the total catch. Fry were present in every week when 0+ steelhead trout were captured (including catches during 7/09/08 – 7/15/08), and the mode in FL for all measured 0+ steelhead trout in YR 2008 was 30 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 2008 followed the same pattern over time with the previous eight year average of starting out low for the first 6 – 8 weeks, and then gradually increasing over time. As in previous study years, average weekly FL's in April and May mostly represented emergent fry and post emergent fry. 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 2008 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 2008 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 2008 we observed adult steelhead on redds upstream of the trap site. In WY 2008, we had no peaks in streamflow that could have scoured steelhead trout redds, therefore, the decrease in catches compared to the eight 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 2008. 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 2009.

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 YRS 2007 and 2008, we observed some evidence of localized scour within the channel, but not where the seeps were located. In YR 2008 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 in YRS 2006 and 2007 offered direct evidence that 0+ steelhead trout may travel considerable distances in search of suitable rearing areas. In streams that are temperature impaired (many if not most in Humboldt County, CA are, including Redwood Creek; see CWA List, 2002), out-migration prior to times when streams or sections of streams reach high (or maximum) temperatures (July/August) or dry up can be viewed as an advantageous life history strategy.

1+ Steelhead Trout

Fairly large numbers of 1+ steelhead trout emigrate from upper Redwood Creek during the spring/summer emigration period. Population emigration from YRS 2000 – 2007 ranged from 26,176 – 68,030 and averaged 38,208 individuals. Population emigration in YR 2008 (N = 32,849) was greater than emigration in YRS 2002, 2003, 2005, and 2006; yet 14% less than the previous eight year average. The population of 1+ steelhead trout declined over the nine 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 4/09/08 – 4/15/08 (N = 1,605), 5/07/08 – 5/13/08 (N = 4,618), and 5/28/08 – 6/03/08 (N = 6,342). The largest peak occurred three weeks after the largest peak for the previous eight year average. The monthly peak in emigration occurred in May for YR 2008 and for the previous eight year average. The largest reduction (by 53% in emigration in YR 2008 occurred in April (4,878 individuals).

The average size of 1+ steelhead trout in YR 2008 (FL = 85.3 mm, Wt = 7.21 g) was the second lowest of the current nine study years, and about 2.3 mm and 0.66 g less than the previous eight year average. Average FL and Wt in YR 2008 were significantly less than the previous eight year average, thus these differences in size were significant. Whether such differences will equate to increased survival to adulthood is unknown.

The general trend in FL and Wt over study years was significantly negative, thus the size of 1+ steelhead trout has declined over the nine study years. A significant positive relationship of population abundance on size (FL) was detected, which contrasts the normal viewpoint of density-dependent relationships in which higher fish densities (or abundances) 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 2008 (92%) was significantly greater than the percentage (48%) for the previous eight 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 = 9), abundance and fish size did not have any influence on the seasonal percentage of smolt designations. However, average daily stream temperature during the trapping periods 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 - 2008) 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), 2006 (n = 246), and 2007 (n = 484). 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 eight 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 2008 2.5 – 44.0 d, and averaged 22.8 d. Average travel time in YR 2008 was greater than average travel time for YRS 2005 and 2006, and less than the value for YR 2007. Travel time in YR 2008 was significantly related (-) to size at time 1, which indicates that larger smolts traveled downstream in less time than smaller smolts. The variation in smolt size at time 1 explained 68% of the variation in travel time.

Travel rate (mi/d) in YR 2008 ranged from 0.7 – 11.6 mi/d, averaged 4.0 mi/d. Travel rate in YR 2008 was equal in value to YR 2006, lower in value to YR 2005 (by 1.8 mi/d), and much greater (by 2.4 mi/d) in value than YR 2008. Travel time was positively related to size at time 1 and stream discharge. The best model describing travel rate included both size at time 1 and average stream discharge (Adj. $R^2 = 0.73$).

Most (75%) of the 1+ smolts in YR 2008 showed positive growth, and on average gained 10 mm and 2.0 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 97% of the variation in delta FL. This 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. Growth in YR 2008 was nearly equal to growth in YR 2006, and much less than growth in YR 2007.

Each study year the population of 1+ steelhead trout emigrating from upper Redwood Creek was far larger than 2+ steelhead trout population emigration. The ratio of 1+ to 2+ steelhead trout in YRS 2000 - 2007 ranged from 4:1 to 14:1 and averaged 10:1; in YR 2008 the ratio was 9:1. 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. More recently, data collected from adults in YR 2007 showed that 50% of the adults had entered the ocean as a one year old smolt. 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 2008 the ratio of 0+ steelhead trout to 2+ steelhead trout equaled 16:1, and the ratio of 1+ steelhead trout to 2+ steelhead trout equaled 9:1.

2+ steelhead trout population emigration during 2000 – 2007 ranged from 1,866 – 12,668, and averaged 5,053 individuals. Population emigration in YR 2008 (N = 3,568) was the fifth lowest in nine consecutive years, and 29% less than the average emigration over the previous eight years. Population emigration in YR 2008 was greater than YRS 2003, 2005, 2006, and 2007; however, the pattern or trend in population size over the nine study years was significantly negative. Thus, the 2+ steelhead trout populations are decreasing over time.

Population emigration peaked during 5/28/08 – 6/03/08 (N = 871), with a smaller peak occurring 4/23/08 – 4/29/08 (N = 486); the smaller peak coincided with the peak for the previous eight year average. Emigration in YR 2008 was delayed compared to the previous eight year average; the most important month in YR 2008 was May compared to April for the previous eight year average. The majority of migration occurred during May and June in YR 2008 compared to April and May for the previous eight 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 2008 the reduction in emigration (55% reduction, or 927 individuals) in April contrasted these relationships.

The average size of 2+ steelhead trout in YR 2008 (FL = 140 mm, Wt = 32 g) was the lowest of nine 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 eight 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 eight year average; highest values occurred during the first weeks of trapping, and the lowest values occurred near the mid point of the trapping period. Both weekly FL and Wt in YR 2008 (and for the previous eight year average) significantly decreased over time (weeks). The decrease in average FL and Wt by week during YR 2008 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 2008 (99.7%) was about 16 percentage points greater than the previous eight 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 61% of the variation in smolt percentages over nine 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, 2005; and pit tagged releases in YRS 2004 - 2007. 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 eight years of study (0.50% of 2+ steelhead trout population) and in YR 2008 (1.0% 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. In YR 2008 we captured four individuals.

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. In YR 2008, the greatest discovery was the capture of seven 1+ coho salmon and 32 0+ coho salmon. The capture of 1+ coho salmon was the first time in nine consecutive years, and indicates that freshwater conditions were sufficient enough to allow some of 0+ coho salmon in YR 2007 to successfully survive the summer and winter periods.

Coho salmon 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 whether they can persist over time, which will be evidenced by trap captures.

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 2009 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 nine study years (< 9 individuals each year, total = 33), and only four individuals were captured in YR 2008. 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 nine 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 2,749:1. The ratio in YR 2008 was 1,8691:1. 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 nine years that could have been hybrid juveniles. Thus, out of 90,702 1+ and 2+ steelhead trout catches, only 0.004% appeared to show hybrid characteristics. Based upon visual identification, the number of potential hybrids (age 1 and greater) is extremely rare in upper Redwood Creek.

Stream Temperatures

Similar to past study years, average daily stream temperature in YR 2008: 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 0.81, which indicates that 81% of variation in temperature can be explained by the variation in gage height over time. Average daily stream temperature over study years 2001 – 2008 significantly declined over years, with a correlation coefficient of 0.78; this negative trend may indicate the riparian zone is maturing, and providing more shade compared to previous study years.

The average stream temperature (13.0 °C) during the trapping period in YR 2008 was the lowest of the eight consecutive years of temperature data, and less than the previous seven year average by 2.1 °C. Average monthly stream temperatures in YR 2008 ranged from 8.4 – 19.9 °C (47.1 – 67.8 °F) and median monthly temperatures did not show significant variation among study years. Stream temperatures in YR 2008 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 2008 (25.2 °C, or 77.3 °F) was the lowest on record, and occurred on 7/10/08. The maximum temperature in YR 2008 appeared to be about two weeks earlier than previous years. MWAT (21.3 °C or 70.3 °F) and MWMT (24.5 °C or 76.1 °F) in YR 2008 were also the lowest on record, and occurred about two weeks before previous study years. MWAT associated with the fish kill in YR 2006 equaled 24.1 °C, and the MWAT metric appears to be the best one for assessing lethal temperatures for juvenile salmonids.

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 have influenced the migration of juvenile salmonids from upper Redwood Cr in previous years. However, in YR 2008 no such relationships were detected. 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 in previous years 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 may 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 species of 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 nine years show significant, negative trends in abundance for 0+ Chinook salmon, 1+ steelhead trout smolts, and 2+ steelhead trout smolts. 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 decline as well. 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 a major source of sediment input into Redwood Creek (Greg Bundros, pers. comm. 2008). 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. However, clear cut patches can also provide significant sediment yields to the stream with resultant increases in stream turbidity (Klein, 2009). Klein (2009) reported that the rate of timber harvest (using clear cut patches) averaged over the 15 preceding years in various Northern California watersheds explained more of the variation in chronic stream turbidity than road variables. Klein (2009) also reported that the clear cut equivalent area was also an important explanatory variable.

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 (eg less than 1.5% per year, Klein 2009), 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, 6) decommissioning roads when no longer needed, 7) deferral of logging in riparian zones, especially in inner gorges, until riparian areas are fully stocked with mature conifers, and 8) 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. In addition, recent investigations of the impacts of clear cut logging on stream turbidity show that harvest rates above 1.5% may result in exceeding the regulatory limit for Northern California streams (20% above background) by 369% (Klein, 2009).

Stream Habitat Conditions/Management

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).

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 sections 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 and channel aggredation.

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).

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 majority of 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 nine study years. I recommend studies be undertaken to specifically determine Dg and percent fines in redds using gravel sample techniques.

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 older 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; and would require operating 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 previous 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, cease logging in riparian zones, and decrease harvest areas and harvest rates, the stream might become more functional and hospitable to salmonids by having cleaner gravels, deeper pools, cooler stream temperatures, and increased habitat complexity.

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.

ACKNOWLEDGEMENTS

I thank CDFG's AFRAMP and the Steelhead Report Restoration Card Program, and the Fisheries Restoration Grant Program (Project No. P0710541) for funding this study in YR 2008; and I thank the California Cooperative Fishery Research Unit, Humboldt State University State Sponsored Programs Foundation, and CDFG for their assistance in managing the grant contract. I would also like to thank the National Park Service for providing a part time technician to assist with data collection. I am particularly thankful to Bob Barnum for access to his property, and for his continued interest in salmon and steelhead trout in upper Redwood Creek. I thank Don Chapman for his interest in the study and for his helpful comments. I would also like to thank Doug Parkinson for his contribution to the study. Lastly, and by no means in the least, I thank the field crew (Russell Enriquez, Matt Bryant, Bret Diehl, Carl Meredith, and Kelly Strachan, among others) who counted and examined every fish we captured and marked, for removing debris from the livebox in the evenings and nights, for helping me monitor the trap during high flow events, and for their positive attitudes.

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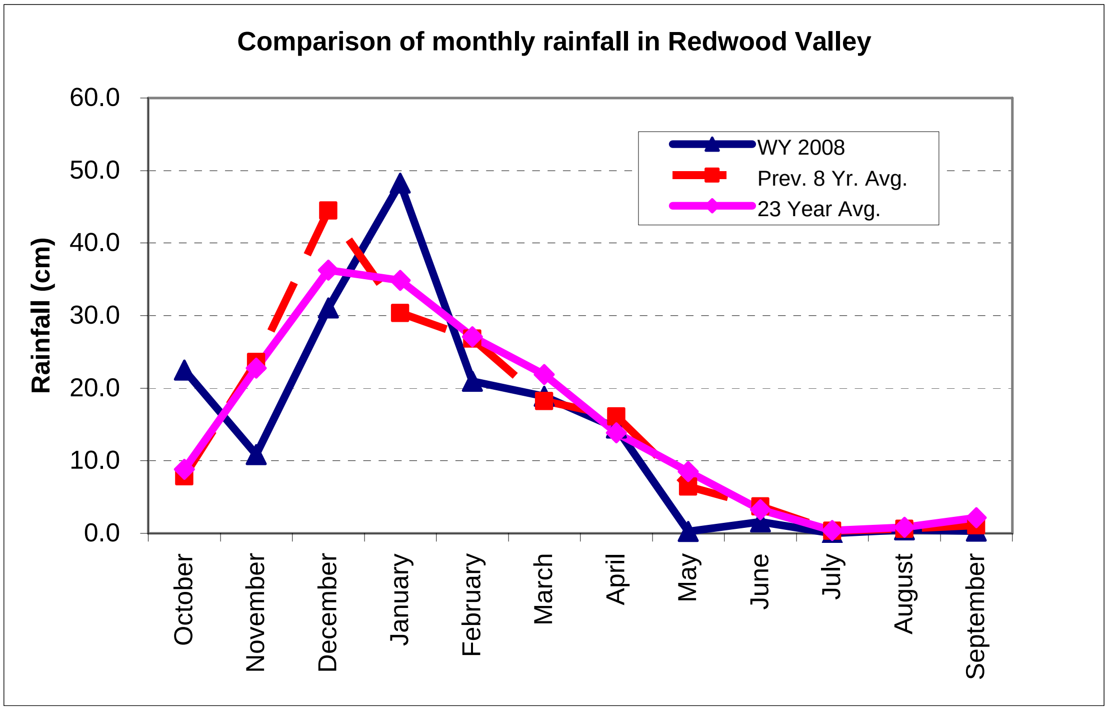
APPENDICES

Appendix 1. Comparison of 23 year average monthly rainfall (Historic) with average of previous eight water years (2000 - 2007), water year 2007, and water year 2008 at Hinz family residence, Redwood Valley, Redwood Creek, Humboldt County, California.

	Annual Rainfall* (cm)			
Month	Historic Average	Average of previous 8 water years (2000-07)	WY 2007	WY 2008
Oct.	8.2	8.6	2.4	22.5
Nov.	22.8	21.6	37.6	10.8
Dec.	36.3	44.8	41.8	31.0
Jan.	34.9	31.5	22.1	48.3
Feb.	27.1	23.5	50.6	21.0
Mar.	21.9	18.3	17.3	18.9
Apr.	13.9	16.2	15.2	14.5
May	8.5	6.6	5.0	0.3
June	3.2	3.9	2.6	1.6
July	0.4	0.0	2.5	0.0
Aug.	0.8	0.7	0.3	0.5
Sept.	2.2	1.1	1.7	0.3
Total:	180.7	176.9	199.2	169.6

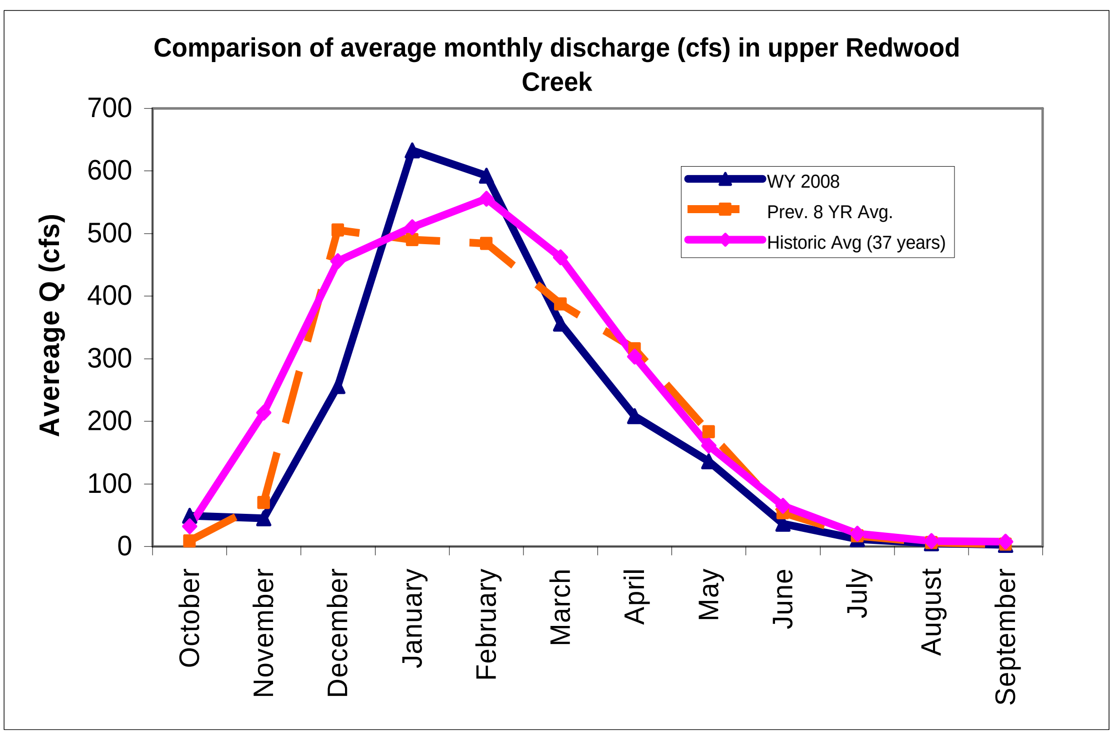
* Data courtesy of Redwood National Park, Vicki Ozaki pers. comm. 2008.



Appendix 2. Comparison of 37 year average monthly discharge (cfs) with average of previous eight water years, water year 2007, and water year 2008, O'Kane gaging station, upper Redwood Creek, Humboldt County, CA. (USGS 2008).

	Average Monthly Discharge* (cfs)			
Month	Historic Average	Average of previous 8 water years (2000-07)	WY 2007	WY 2008
Oct.	32	9	4	49
Nov.	214	70	157	45
Dec.	456	505	494	256
Jan.	510	490	302	633
Feb.	556	484	454	593
Mar.	462	387	536	356
Apr.	304	316	286	208
May	161	183	140	136
June	65	54	32	36
July	21	17	16	12
Aug.	9	6	6	5
Sept.	8	4	4	2
Avg:	233	210	203	194

* Data courtesy of Vicki Ozaki, pers. comm. 2008.



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.

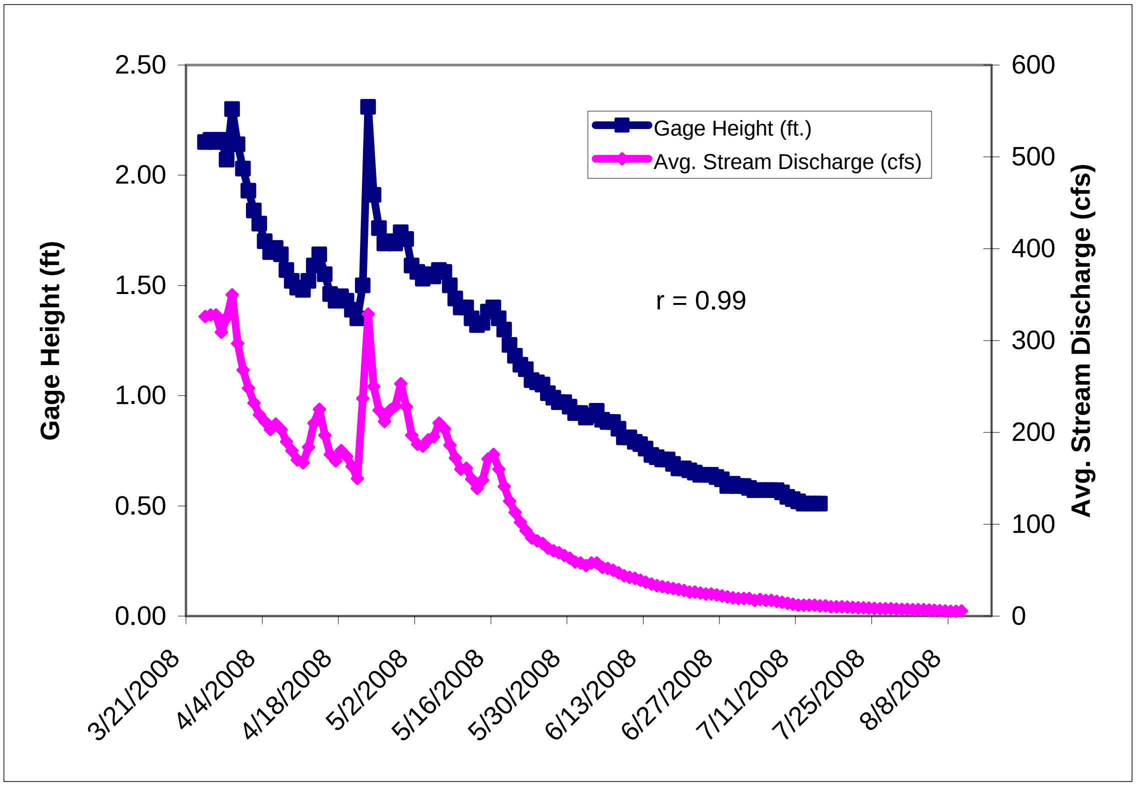
Coho Salmon

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.

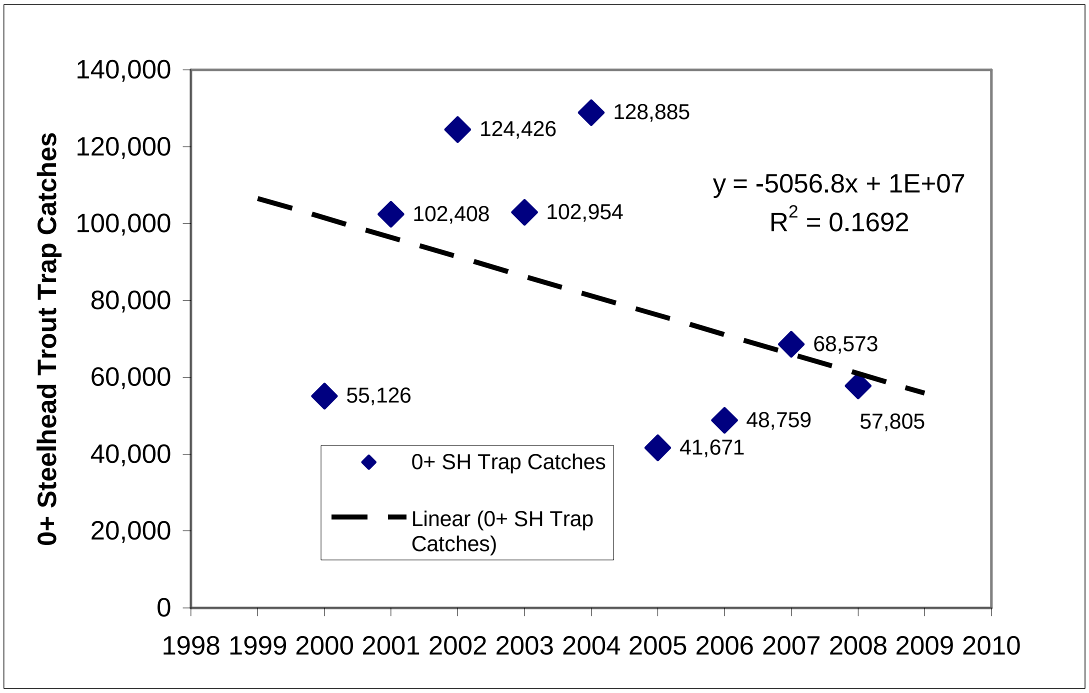
Both Species:

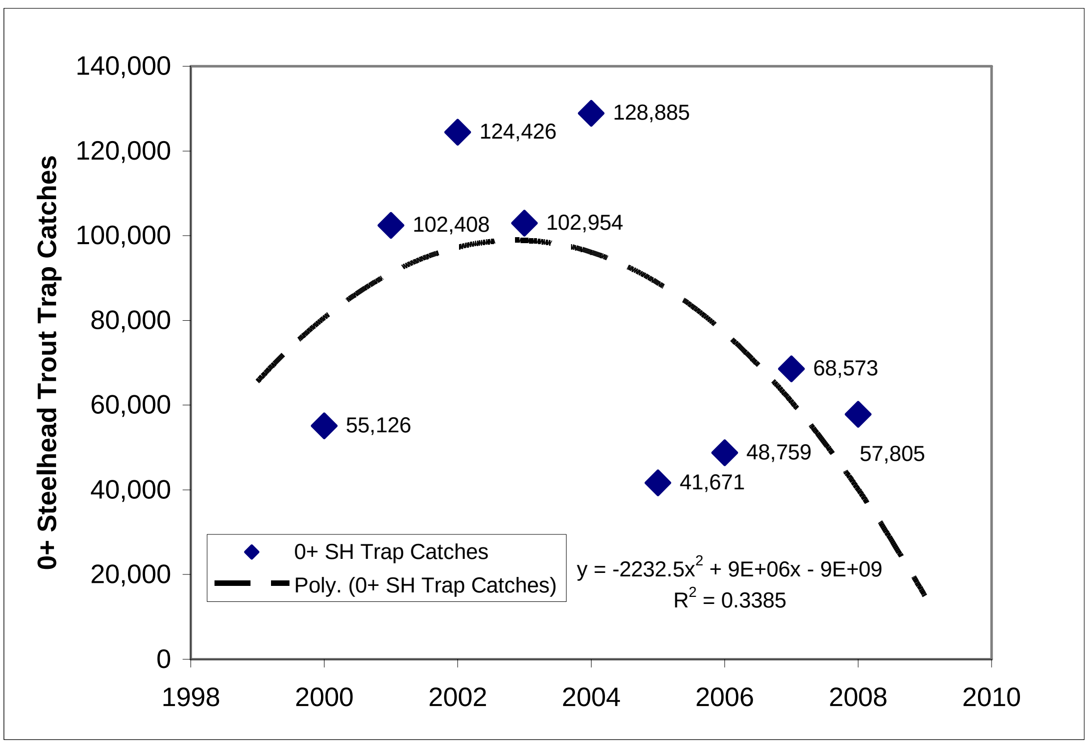
1. To test for possible genetic differences between fish captured in the lower basin and upper basin.
2. To construct a genetic data base for future comparisons and analyses.

Appendix 4. Graphical representation of daily stream gage height (ft.) at trap site and average daily stream discharge (cfs) measured at O'Kane gaging station (USGS 2008), upper Redwood Creek, Humboldt County, CA., YR 2008.



Appendix 5. Linear (top graph) and polynomial (bottom graph) trend lines for 0+ steelhead trout trap catches over nine consecutive study years, upper Redwood Creek, Humboldt County, CA.





Appendix 6. 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., 2008.

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*	0.28	Negative	0.59
0+ KS	Discharge	*0.02*	0.34	Negative	0.70
0+ KS	Temperature	0.22	0.10	Positive	0.22
0+ KS	Week number	0.09	0.44*	Positive	0.41
0+ KS	Trap efficiency	*0.001*	0.56	Positive	0.97
0+ KS	Lunar phase	0.75	0.01	Positive	0.06
0+ SH	Gage height	0.05	0.25	Negative	0.51
0+ SH	Discharge	*0.03*	0.30	Negative	0.63
0+ SH	Temperature	0.24	0.10	Positive	0.21
0+ SH	Week number	0.10	0.42	Positive	0.37
0+ SH	Lunar phase	0.60	0.02	Negative	0.08
1+ SH**	Gage height	0.29	0.08	Positive	0.17
1+ SH**	Discharge	0.44	0.04	Positive	0.11
1+ SH**	Temperature	0.08	0.01	Negative	0.42
1+ SH**	Week number	0.19	0.34*	Negative	0.25
1+ SH**	Trap efficiency	0.72	0.01	Positive	0.06
1+ SH**	Lunar phase	0.96	0.00	Positive	0.05
2+ SH**	Gage height	0.38	0.06	Positive	0.14
2+ SH**	Discharge	0.53	0.03	Positive	0.10
2+ SH**	Temperature	0.09	0.19	Positive	0.40
2+ SH**	Week number	0.26	0.30*	Negative	0.20
2+ SH**	Trap efficiency	0.05	0.28	Negative	0.51
2+ SH**	Lunar phase	0.79	0.00	Positive	0.06

* 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 7. Descriptive statistics of size at time 1 (T1) and time 2 (T2), change in size (FL, Wt), percent change in size (FL, Wt), absolute growth rate (FL, Wt), relative growth rate (FL, Wt) and specific growth rate scaled (FL, Wt) for pit tagged 0+ Chinook salmon recaptured (n = 36) at the lower trap in Redwood Creek in YR 2008, Humboldt County, CA.

	Descriptive Statistics			
Variable	Min.	Max.	Avg. (median)	SEM**
Size at T1				
FL mm	67	83	73.0 (73.0)	0.68
Wt g	3.0	6.4	4.19 (4.4)	0.12
Size at T2				
FL mm	68	83	75.4 (76.0)	0.62
Wt g	3.0	5.9	4.43 (4.41)	0.11
Change in				
FL mm	0	10	2.4 (1.0)	0.50
Wt g	-0.69	1.71	0.27 (0.00)	0.10
% change in				
FL mm	0.00	14.93	3.35 (1.3)	0.73
Wt g	-15.33	57.00	7.87 (0.00)	2.71
AGR*				
FL mm	0.00	0.50	0.13 (0.06)	0.02
Wt g	-0.13	0.07	0.023 (0.00)	0.008
RGR*				
FL mm	0.000	0.007	0.002 (0.001)	0.0003
Wt g	-0.027	0.022	0.002 (0.000)	0.002
SGR*				
FL mm	0.00	0.69	0.175 (0.080)	0.033
Wt g	-2.89	1.86	0.081 (0.000)	0.120

* Abbreviations are the same as in Table 24.
** SEM = standard error of mean.

Appendix 8. 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., 2008.

Pit Tagged 1+ Steelhead Trout			
Release Group	Sample Size	No. of Recaptures	Percent Recapture
4/03/08	4	1	25.00
4/10/08	12	0	0.00
4/17/08	18	1	5.56
4/22/08	10	1	10.00
4/24/08	3	0	0.00
4/26/08	30	3	10.00
4/29/08	20	0	0.00
5/01/08	11	0	0.00
5/02/08	23	0	0.00
5/06/08	18	0	0.00
5/09/08	20	1	5.00
5/14/08	20	0	0.00
5/27/08	14	1	7.14
Sum:	203	8	

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 1+ steelhead trout recaptured (n = 8) at the lower trap in Redwood Creek in YR 2008, Humboldt County, CA.

	Descriptive Statistics			
Variable	Min.	Max.	Avg. (median)	SEM**
Size at T1				
FL mm	70	112	87.3 (86.0)	5.00
Wt g	3.4	15.0	7.63 (6.65)	1.43
Size at T2				
FL mm	87	114	97.4 (95.5)	3.14
Wt g	7.2	13.9	9.66 (9.26)	0.89
Change in				
FL mm	0.0	20.0	9.9 (12.0)	2.86
Wt g	-1.09	5.41	2.04 (2.46)	0.80
% change in				
FL mm	0.00	25.32	12.63 (14.13)	3.84
Wt g	-7.27	115.00	46.45 (38.63)	17.54
AGR*				
FL mm	0.00	0.51	0.338 (0.435)	0.075
Wt g	-0.24	0.16	0.033 (0.093)	0.053
RGR*				
FL mm	0.000	0.007	0.004 (0.006)	0.0010
Wt g	-0.016	0.026	0.012 (0.020)	0.0063
SGRsc*				
FL mm	0.000	0.614	0.376 (0.462)	0.086
Wt g	-1.676	1.952	0.791 (1.621)	0.545

* Abbreviations are the same as in Table 24.
** SEM = standard error of the mean.

Appendix 10. 0+ Chinook salmon delayed mortality test results (n = 22), upper Redwood Creek, Humboldt County, CA., 2008.

					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.
0+KS	3/27 – 3/28	3	36	6.9	0/3	0.00				
0+KS	3/29 – 3/30	6	24	6.2			0/6	0.00		
0+KS	4/01 – 4/02	18	31	7.4			0/18	0.00		
0+KS	4/08 – 4/09	39	36	7.6	0/39	0.00				
0+KS	4/19 – 4/20	37	36	7.2	0/37	0.00				
0+KS	4/25 – 4/26	68	36	9.5	0/68	0.00				
0+KS	5/01 – 5/02	30	24	9.3			0/30	0.00		
0+KS	5/08 – 5/09	30	24	10.8			0/30	0.00		
0+KS	5/16 – 5/17	29	24	15.4			0/29	0.00		
0+KS	5/19 – 5/20	44	36	15.2	0/44	0.00				
0+KS	5/21 – 5/22	30	36	12.2	0/30	0.00				
0+KS	6/01 – 6/02	30	24	12.2			0/30	0.00		
0+KS	6/03 – 6/04	16	12	14.2					0/16	0.00
0+KS	6/06 – 6/07	25	24	13.1					0/28	0.00
0+KS	6/09 – 6/10	21	24	15.7					0/21	0.00
0+KS	6/23 – 6/24	25	24	17.1			0/25	0.00		
0+KS	6/24 – 6/24	24	12	19.0					0/24	0.00
0+KS	6/26 – 6/27	15	24	18.0					0/15	0.00
0+KS	6/30 – 7/01	24*	36	19.0					2/24	8.33
0+KS	7/03 – 7/04	2	36	20.0	0/2	0.00				
0+KS	7/04 – 7/05	4	24	19.6					0/4	0.00
0+KS	7/06 – 7/07	2	48	20.8					0/2	0.00

* Died immediately after tagging.

Appendix 11. 0+ steelhead trout delayed mortality test results (n = 1), upper Redwood Cr, Humboldt County, CA., 2008.

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.
0+SH	6/27 – 6/28	30	24	1839			0/30	0.00

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

Appendix 12. 1+ steelhead trout delayed mortality test results (n = 24), upper Redwood Creek, Humboldt County, CA., 2008.

					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.
1+SH	3/25 – 3/26	12	34	8.4	0/12	0.00				
1+SH	3/27 – 3/28	8	34	6.9	0/8	0.00				
1+SH	3/29 – 3/30	9	34	6.5	0/9	0.00				
1+SH	3/31 – 4/01	5	24	7.0			0/5	0.00		
1+SH	4/01 – 4/02	7	34	7.6	0/7	0.00				
1+SH	4/09 – 4/10	23	34	8.3	0/23	0.00				
1+SH	4/10 – 4/10	12	12	9.7					0/12	0.00
1+SH	4/16 – 4/17	17	36	9.3	0/17	0.00				
1+SH	4/17 – 4/17	18	12	10.6					0/18	0.00
1+SH	4/19 – 4/20	16	36	7.2	0/16	0.00				
1+SH	4/21 – 4/22	7	36	6.9	0/7	0.00				
1+SH	4/25 – 4/26	30	36	9.6					0/30	0.00
1+SH	4/28 – 4/29	20	36	10.4	0/20	0.00				
1+SH	4/29 – 4/29	20	12	9.3					0/20	0.00
1+SH	4/30 – 5/01	11	24	8.7					0/11	0.00
1+SH	5/01 – 5/02	23	36	9.6					0/23	0.00
1+SH	5/05 – 5/06	18	36	12.0					0/18	0.00
1+SH	5/08 – 5/09	20	36	11.1					0/20	0.00
1+SH	5/12 – 5/14	20	60	11.8					0/20	0.00
1+SH	5/19 – 5/20	15	36	15.2	0/15	0.00				
1+SH	5/21 – 5/22	50	36	12.2	0/50	0.00				
1+SH	5/26 – 5/27	14	36	12.3					0/14	0.00
1+SH	6/20 – 6/21	12	24	18.5	0/12	0.00				
1+SH	6/27 – 6/28	12	36	19.0	0/12	0.00				

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

Appendix 13. 2+ steelhead trout delayed mortality test results (n = 31), upper Redwood Creek, Humboldt County, CA., 2008.

					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.
2+SH	3/25 – 3/26	1	32	8.4	0/1	0.00				
2+SH	3/27 – 3/28	3	34	6.9	0/3	0.00				
2+SH	3/29 – 3/30	5	34	6.5	0/5	0.00				
2+SH	4/01 – 4/02	1	34	7.0	0/1	0.00				
2+SH	4/04 – 4/05	1	34	7.7	0/1	0.00				
2+SH	4/14 – 4/15	9	36	8.6	0/9	0.00				
2+SH	4/17 – 4/17	2	12	10.8					0/2	0.00
2+SH	4/19 – 4/20	3	36	7.2	0/3	0.00				
2+SH	4/21 – 4/22	2	36	6.9	0/2	0.00				
2+SH	4/25 – 4/26	11	36	9.6	0/11	0.00				
2+SH	4/28 – 4/29	6	36	10.4	0/6	0.00				
2+SH	4/30 – 5/01	1	24	8.7					0/1	0.00
2+SH	5/01 – 5/02	3	36	9.6	0/3	0.00				
2+SH	5/01 – 5/02	2	36	9.6					0/2	0.00
2+SH	5/05 – 5/06	10	36	12.0					0/10	0.00
2+SH	5/08 – 5/09	6	36	11.1	0/6	0.00				
2+SH	5/12 – 5/13	4	36	11.2	0/4	0.00				
2+SH	5/15 – 5/16	4	30	15.2					0/4	0.00
2+SH	5/16 – 5/17	4	36	15.9	0/4	0.00				
2+SH	5/18 – 5/19	2	24	15.6	0/2	0.00				
2+SH	5/19 – 5/20	2	24	15.2					0/2	0.00
2+SH	5/19 – 5/20	3	36	15.2	0/3	0.00				
2+SH	5/21 – 5/22	10	36	12.2	0/10	0.00				
2+SH	5/24 – 5/25	15	36	11.8	0/15	0.00				
2+SH	5/26 – 5/27	15	36	12.3	0/15	0.00				
2+SH	5/28 – 5/29	12	36	12.8	0/12	0.00				
2+SH	5/30 – 5/31	13	36	14.5	0/13	0.00				
2+SH	6/07 – 6/08	9	36	14.8	0/9	0.00				
2+SH	6/23 – 6/24	1	24	17.8			0/1	0.00		
2+SH	6/26 – 6/27	7	36	18.8	0/7	0.00				
2+SH	6/27 – 6/28	3	36	18.8	0/0	0.00				

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