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2005 ANNUAL REPORT

UPPER REDWOOD CREEK
JUVENILE SALMONID (SMOLT) DOWNSTREAM MIGRATION STUDY
2000 - 2005 Seasons
PROJECT 2a5

Prepared by

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Northern California, North Coast Region

Anadromous Fisheries Resource Assessment and Monitoring Program

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

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ABSTRACT

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

The trap operated 146 nights out of 154 nights possible, and captured 9,329 0+ Chinook salmon, zero 1+ Chinook salmon, 41,671 0+ steelhead trout, 4,912 1+ steelhead trout, 628 2+ steelhead trout, 2 cutthroat trout, 2 0+ pink salmon, and zero juvenile coho salmon. Catches in YR 2005 were markedly less than previous study years, with the greatest reduction (93%) occurring for 0+ Chinook salmon. Average weekly trapping efficiency was 33% for 0+ Chinook salmon, 23% for 1+ steelhead trout, and 26% for 2+ steelhead trout. Trapping efficiency was inversely related to stream discharge and stream gage height for 0+ Chinook salmon, 1+ steelhead trout and 2+ steelhead trout. The total 0+ Chinook salmon population estimate with 95% confidence intervals in YR 2005 equaled 39,614 (34,961 - 44,268), and was 94% less than emigration in YR 2004 and 90% less than emigration for the previous five year average. The large decrease in YR 2005 may be attributable to: 1) high bedload mobilizing flows during egg incubation in spawning redds, which could account for 89% of the variation in emigration over the six study years, 2) large decrease in adult spawners upstream of the trap site, or 3) a combination of the two factors. The population estimate for 1+ steelhead trout equaled 26,176 (22,726 – 29,625) and was 37% less than emigration in YR 2004 and 40% less than emigration for the previous five year average. 2+ steelhead trout population emigration equaled 2,364 (1,933 – 2,796) and was 59% less than emigration in YR 2004 and 64% less than emigration for the previous five year average. 0+ Chinook salmon, 1+ steelhead trout, and 2+ steelhead trout showed a negative trend (preliminary) over study years, however, significance was only detected with 1+ steelhead trout. Twenty-seven pit tagged 0+ Chinook salmon fingerlings released at the upper trap site were recaptured 29 miles downstream at the second trap in lower Redwood Creek. Travel time ranged from 1.5 – 19.5 d and averaged 7.5 d, and travel rate ranged from 1.5 – 19.3 mi/d and averaged 8.2 mi/d. On average, 0+ Chinook salmon migrated 29 miles downstream faster than 1+ and 2+ steelhead trout did in YR 2004. Fifty-two percent of the recaptured 0+ Chinook salmon fingerlings in YR 2005 showed positive growth in FL and Wt, 18% showed a decrease in Wt, 48% showed no change in FL, and 30% showed no change in Wt. Growth was positively related to travel time and travel time explained more of the variation in growth than any other variable tested. The percent change in FL ranged from 0.0 – 17.1 and averaged 3.6. The final size of recaptured pit tagged 0+ Chinook salmon was positively related to the initial size at tagging and release. Thus, for the pit tagged Chinook salmon juveniles, larger fish released at the upper trap were more likely to be the larger fish at the lower trap.

[1/] This paper should be referenced as: Sparkman MD. 2005. Upper Redwood Creek juvenile salmonid (smolt) downstream migration study, study year 2005. CDFG AFRAMP, 2005 Annual Report 2a5: 115 p.

INTRODUCTION

This report presents results of the sixth consecutive year of juvenile salmonid downstream migration trapping in upper Redwood Creek, Redwood Valley, Humboldt County, California during the spring/summer emigration period. The study began in YR 2000, and was funded by the Redwood Creek Landowners Association (RCLA). Study years 2001 – 2005 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. AFRAMP and RCLA plan on continuing the study for a longer period of time (>10 yrs) in order to more fully address biological and environmental variability, and to determine the status and trends of smolt production in upper Redwood Creek.

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

Redwood Creek is a difficult stream to monitor adult salmon and steelhead populations because the adult fish migrate upstream during late fall, winter and early spring. Thus, when the adults are present, the stream flow is often high and unpredictable, which limits the reliability and usefulness of any adult weir. Additionally, the stream flow during this time period often carries large amounts of suspended sediments, which render visual observations of adult fish and redds (eg spawning surveys) unreliable and unlikely for long term monitoring. Scientific studies which focus on salmonids in tributaries to Redwood Creek are less affected by these processes, however, the tributaries are less likely to adequately represent or account for the majority of the salmonid populations in Redwood Creek because the majority of adult salmon and steelhead spawn in the mainstem. A possible exception is the Prairie Creek watershed which probably accounts for a considerable amount of the coho salmon production in Redwood Creek. Tributaries to Redwood Creek are often steep, with limited anadromy (RNP 1997, Brown 1988). Additionally, some of the tributaries can dry up prior to late summer, which cause the juvenile fish to migrate into the mainstem Redwood Creek

Determining and tracking smolt numbers over time is an acceptable, useful, and quantifiable measure of salmonid populations which many agencies (both state and federal), universities, consultants, tribal entities, and timber companies perform each year. Juvenile salmonid out-migration can be used to assess: 1) the number of parents that produced the cohort (Roper and Scarnecchia 1999, Ward 2000, Sharma and Hilborn 2001, Ward et al. 2002, Bill Chesney pers. comm. 2005), 2) redd gravel conditions (Cederholm et al. 1981, Holtby and Healey 1986, Hartman and Scrivener 1990), 3) in-stream habitat quality and watershed health (Tripp and Poulan 1986, Hartman and Scrivener 1990, Hicks et al. 1991, Bradford et al. 2000, Sharma and Hilborn 2001, Ward et al. 2002), 4) restoration activities (Everest et al. 1987 *in* Hicks et al. 1991, Slaney et al. 1986, Tripp 1986, McCubbing and Ward 1997, Solazzi et al. 2000, Cleary 2001, Ward et al 2002, McCubbing 2002, Ward et al. 2003), 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, Ward and Slaney 1988, Ward et al. 1989, Unwin 1997, Ward 2000).

This paper will present the results of trapping in study year 2005 with comparisons to the average of the previous five study years (YRS 2000 - 2004).

Site Description

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

Geology

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

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

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

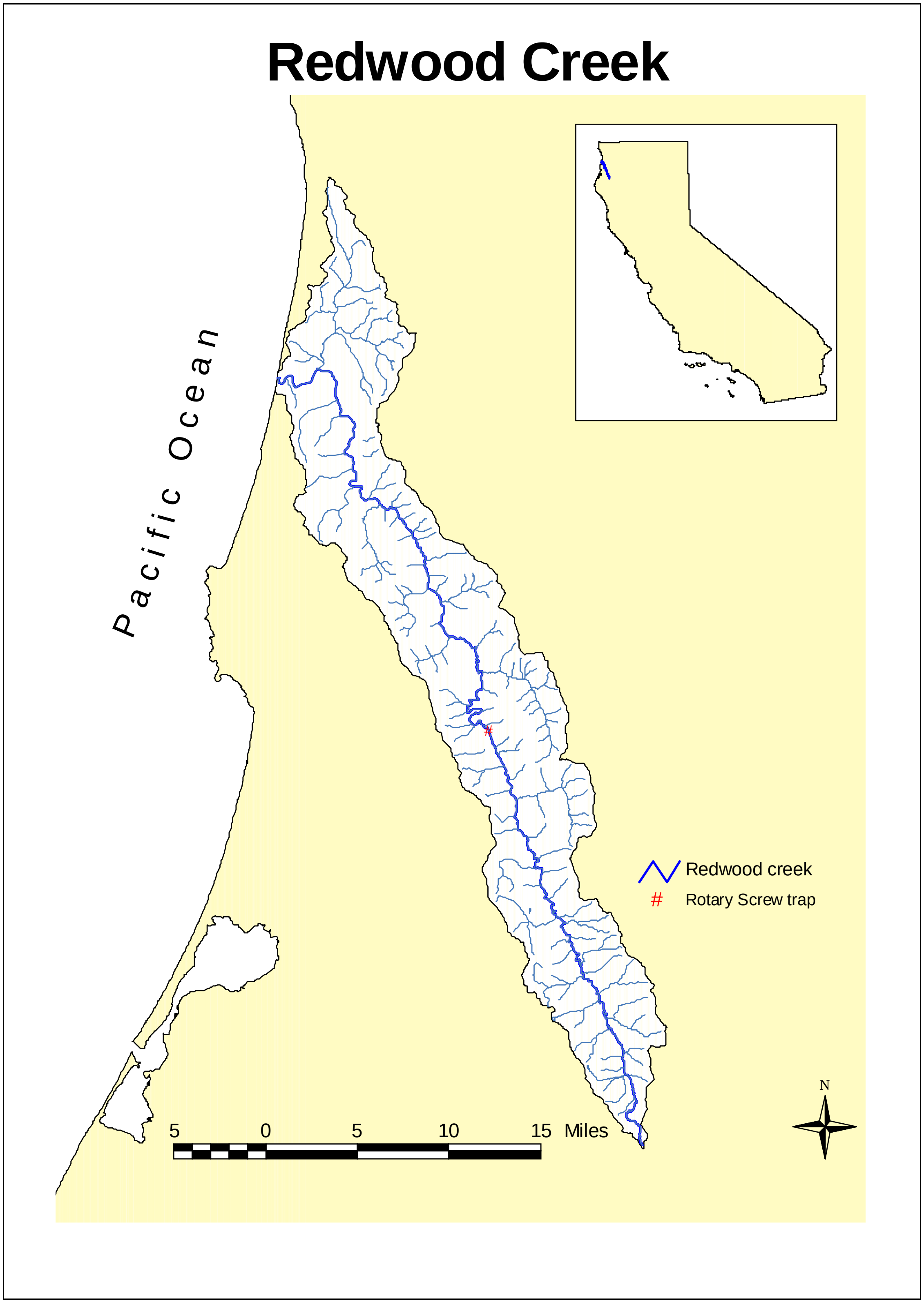

Figure 1. Redwood Creek watershed with rotary screw trap location in Redwood Valley, Humboldt County, CA. (scale is slightly inaccurate due to reproduction process; Charlotte Peters pers. comm. 2001).

ocean, and differ from inland areas (i.e. upper Redwood Creek) which experience high and low temperatures. Summers are typically cool and moist on the coast, and hot and dry inland. Ambient air temperatures in Redwood Valley often exceed 32 ^{o}C (or 90 ^{o}F) during summer months. Upper Redwood Creek experiences cold temperatures during the winter, and snowfall is common. In study year 2005, snowfall occurred as late as May. 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 miles downstream of the trap site. Rainfall records cover the period from 1986 to the present to total 20 years (Redwood National Park, in house data, 2005; Vicki Ozaki pers. comm. 2005). Annual precipitation ranges from 90 cm (35.4 in.) to 238 cm (93.7 in.), and averages 177 cm (69.7 in.). Most (97%) of the rainfall in Redwood Creek occurs from October through May**,** with peak monthly rainfall occurring in December and January (Appendix 1). However, in some years relatively large amounts of rainfall may occur in November, February, April, and May (eg. YR 2005) as well. Rainfall in WY 2005 was about 185 cm (73 in.), and 8 cm (3.1 in.) greater than the 20 year average (Appendix 1).

The 20 year average monthly rainfall during the majority of the trapping season (April – July) totaled 26.7 cm (10.5 in.) (Table 1). Total monthly rainfall during this period of trapping in YR 2005 (60.5 cm or 23.8 in.) was considerably greater than rainfall for the historic average (by a factor of 2.3) and the average of the previous five study years (by a factor of 2.9) (Table 1). Rainfall in May 2005 was 2.2 times greater than the historic average for May; and rainfall in June 2005 was 4.8 times greater than the historic average for June (Table 1).

Table 1. Comparison of 20 year average monthly rainfall and monthly rainfall during the majority of the trapping period, Redwood Creek, Redwood Valley, Humboldt County, California.

	Rainfall* (centimeters)		
Month	Historic Average	Average of previous 5 study years (2000-04)	YR2005
Apr.	13.7	14.9	23.8
May	9.2	4.2	19.9
June	3.5	1.6	16.8
July	0.3	0.0	0.0
Total:	26.7	20.7	60.5

* Data courtesy of Redwood National Park, Vicki Ozaki pers. comm. 2005.

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 – 2005 to total 34 years (Thomas Haltom pers. comm. 2005, USGS 2005). 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 2005). However, in WY 2005, peaks in average monthly flow occurred March - May, with the greatest average monthly flow occurring in April. Low flows in WY 2005 occurred October - November, and August - September. Using all years' data, mean monthly discharge in upper Redwood Creek is 232 cfs (or 6.6 m^3/sec), and ranges from 8 - 553 cfs (USGS 2005). Average monthly discharge in WY 2005 was 197 cfs (5.6 m^3/sec) and greater than the previous five year average (187 cfs) (Appendix 2, USGS 2005).

The 34 year average monthly discharge during the majority of the trapping season (April - July) equaled 138 cfs (Table 2). Average monthly discharge from April – July, 2005 (272 cfs) was much higher than the historic average (by a factor of 1.97) and the average of the previous five study years (by a factor of 2.41) (Table 2, data from USGS 2005). The probability that the average flow during April – July would exceed 272 cfs (based upon 54 years of record) equaled 5.6%.

Table 2. Comparison of 34 year average monthly discharge and average monthly discharge in upper Redwood Creek (O'Kane station) during the majority of the trapping period (USGS 2005).

	Average Discharge (cfs)		
Month	Historic	Previous 5 study years (2000-04)	YR2005
Apr.	302	250	511
May	162	153	377
June	67	38	153
July	21	12	47
Ave:	138	113	272

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, of the remaining old growth Redwood is contained within Redwood National Park, which is downstream of the trap site. In conjunction with clear-cut logging, associated road building, geology types and geomorphic processes (eg debris slides and earthflows), and flood events in 1955 and 1964, large amounts of sediments were delivered into the stream channel (Madej and Ozaki 1996) with a resultant loss of stream habitat complexity (filling in of pools and flattening out of the stream channel, Marlin Stover pers. comm. 2000). Additional high flows occurred in 1972, 1975, and 1995 as well, and have helped influence the current channel morphology of Redwood Creek. Currently, Redwood Creek within the study area appears to have experienced channel incision in flood gravel deposits, scouring of pools to increase depth, riparian growth, and input of woody debris (small), which collectively increase stream complexity. However, in YR 2005 relatively large amounts of sands were deposited at the trap site and areas downstream of the trap site.

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 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 emigrant population sizes for wild 0+ (young-of-year) Chinook salmon (Ocean type), 1+ (between 1 and 2 years old) steelhead, 2+ (2 years old and greater) steelhead, and 1+ coho salmon smolts. 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, and 0+ Chinook salmon.
3) Record fork length (mm) and weight (g) of captured fish.
4) Investigate 0+ Chinook salmon, 1+ steelhead trout, and 2+ steelhead trout travel time and growth as they migrate from the upper trap to the lower trap (or estuary) using passive integrated transponder tags (Pit Tags).
5) Collect and handle fish in a manner that minimizes mortality.
6) Statistically analyze data for significance and trends.
7) 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 25, 2005 at the same location as in previous study years (i.e. downstream of a moderately high gradient riffle). The 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 with 2 mm holes was then used to close the downstream end where the debris wheel once was 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. 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.

The rotary screw trap operated continually (24 hrs/day, 7 days a week) from March 25th through August 26th except when stream flows and debris loads were too high to trap safely. The trapping season in YR 2005 was extended compared to previous trapping years because juvenile salmonids were outmigrating beyond August 5th, which is normally when out-migration has tapered off considerably.

When stream flows were too high to operate the rotary screw trap, we used a winch attached to a 4x4 truck and a cable gripper (attached to one of the main cables connected to the rotary screw trap) to move the trap to the side of the steam to raise the cone. The trap was re-set as soon as possible, and placed back into the thalweg of the stream. Every attempt was made to maintain the trap's position in the thalweg. Trapping in higher than normal flows in YR 2005 (similar to YR 2003) required operating the trap in and out of the thalweg at various times during the high flow periods. During some of the high flows within which we trapped, the trap was set partially out of the thalweg to reduce cone revolutions to less than 45 per 3 minutes (considered an upper limit for the modified version) and to reduce excessive debris loading. We also moved the trap completely out of the thalweg to determine if any fish (primarily 0+ Chinook salmon) were moving along the margin areas of the stream (few were). Additionally, we operated the trap in the thalweg during some of the high flows (eg in April and May) to make sure that we were not 'missing' fish (few fish were caught). On one high flow event on May 17th, we stayed overnight and operated the trap fully in the thalweg. We used a winch (attached to a truck) and pulled the trap into shallower water every 2.5 hours so that we could access the livebox. Trap efficiency trials were on-going throughout these events. A major benefit to the upper Redwood Creek trapping site is a relatively narrow channel width which causes the stream to rise vertically more than spread out horizontally during high rainfall and stream flow periods. The channel morphology reduces the amount of space fish could pass by the trap without being captured.

During periods of lesser 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 July to further increase flow into the cone area. 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 increase in stream discharge and apparent increase in summer base flow in YR 2005, we were able to complete the study using the rotary screw trap.

The YR 2005 trapping season, particularly March - May, can be characterized as working in and out of high flow events. In YR 2005, we experienced the most difficult flow conditions to trap in compared to previous study years (2000 - 2004).

Biometric Data Collection

Fishery technicians carefully removed debris (e.g. alder cones, leaves, sticks, detritus, large 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 the stream water into the ice chest, and the other to drain excess water. The water lines to the recovery buckets were elevated above the recovery buckets so that the fresh water would also provide increased aeration. The system worked very well, did not require additional battery operated aerators, and decreased total fish processing time.

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), 1+ and greater cutthroat trout (CT), 0+ steelhead trout, 1+ steelhead trout (1+ SH), and 2+ and greater steelhead trout (2+ SH). Although both fork lengths and weights were taken for 0+ steelhead trout (0+ SH), only FL data is reported. 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 - 4 times per week, 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 calibrated every day prior to data collection. After biometric data was collected, fish were placed into 5 gal. recovery buckets which received continuously pumped fresh stream water. Young of year fish were kept in separate recovery buckets from age 1+ and older fish to decrease predation or injury. When fully recovered from anesthesia, 0+ juvenile fish were transported 157 m downstream of the trap site, and aged 1 and older fish were transported 170 m downstream of the trap site and released into the river.

Developmental Stages

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

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

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

- Smolt designated fish that were very silver in coloration (i.e. smoltification), had little to no parr marks present, and had blackish colored caudal fins**.** Smolts are also known to 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.

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 mark-recapture methodology described by Carlson et al. (1998). The approximately unbiased estimate equation for a 1-site study was used to determine total population size (U_h) in a given capture and trapping efficiency period (h). Variance was computed, and the value was used to calculate 95% confidence intervals (CI) for each weekly population estimate. The weekly population estimate (U_h) does not include catches of marked releases in the “C” component (or ‘u_h’) of the equation, and any short term handling mortality was subtracted (Carlson et al. 1998). Trap efficiency trials were conducted two to five times a week for 0+ Chinook salmon, 1+ steelhead trout, and 2+ steelhead trout. Data was combined and run through the equation to determine the weekly estimate (for a complete description of estimation methods and model assumptions see Sparkman 2004a, study 2a5).

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 and 2005). 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). The number of efficiency trials per week for a given species at age ranged from 2 – 5. 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 were released upstream of the trap after the livebox was emptied (eg 1300 – 1800), and 1+ steelhead and 2+ steelhead trout were released upstream of the trap site at night. We released the fish at night either manually or by using a live cage with a battery operated lever system that opened the trap door at any given time (eg 2200). Night releases generally occurred from 2000 – 2300.

Additional Experiments

Re-migration

In YR 2004, we marked and released 223 2+ steelhead trout and 577 1+ steelhead trout with a plastic elastomer (Northwest Marine Technology, P.O. Box 427, Ben Nevis Loop Road, Shaw Island, Washington 98286 USA) to investigate travel time between the upper trap (RM 33) and lower trap (RM 4) in Redwood Creek. These marks also served to show if any marked 1+ or 2+ steelhead trout that migrated downstream in YR 2004 re-migrated back upstream of the upper trap to be caught in YR 2005 as two or three year old fish (we did this in YR 2001-02 as well). Every 1+ and 2+ steelhead trout captured in YR 2005 was examined for elastomer marks. Mark retention was assumed to be nearly 90% within 16 months (Fitzgerald et al. 2004).

Travel Time and Growth

We marked 37 2+ steelhead trout and 146 1+ steelhead trout with plastic elastomer in YR 2005 to investigate travel time from the upper trap to the lower trap (a distance of 29 miles). We applied the elastomer marks subdermally using a hypodermic needle on the underside of both lower jaws while fish were under anesthesia (MS-222). 0+ Chinook salmon were generally too small to safely mark. Marked fish were treated as batches, with a unique color combination for each week of release. Each batch of marked fish was held in the stream for 24 hours to test for any delayed mortality prior to release, and released into the stream at the downstream release site.

Plastic elastomer has limitations because individual fish cannot be uniquely identified when marks are used for batches of fish, and the mark is rather difficult to apply for fish under 85 mm (FL). Pit tags offer the ability of individual recognition by using numbers unique to each tag (and marked fish). In YR 2005 we used Pit Tags to investigate both travel time and growth of tagged fish as they migrated downstream to be later caught at the lower trap (Sparkman 2006) or estuary (David Anderson, pers. comm. 2005). We found pit tagging to be easier and faster than applying elastomer. A more thorough examination of the pit tag data and subsequent results can be found in Sparkman (In progress). 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 = 147), 2+ steelhead trout (n **=** 46) and 0+ Chinook salmon smolts (FL $\geq$ 70 mm**,** n = 555) using techniques shown by Seth Ricker (CDFG, pers. comm. 2005). Fish were anesthetized with MS-222, and measured for FL (mm) and Wt (g) prior to tagging. A scalpel (sterilized with a 10:1 solution of water to Argentyne; Argent Chemical Laboratories, 8702 152nd Ave. N.E., Redmond, WA, 98052) was used to make a small incision (2 - 3 mm long) into the body cavity just posterior (about 3 - 5 mm) to a pectoral fin. The incision was dorsal to the ventral most region of the fish to help prevent the tag from exiting the incision. Tags were also sterilized with Argentyne, and then inserted by hand into the body cavity via the incision. Glue was not used to close the incision after tag placement because previous experience with tagging showed it was unnecessary (Seth Ricker, pers. comm. 2005). Pit tagged 0+ Chinook salmon were also given a small partial upper caudal fin clip to aid in recognizing a tagged fish so that technicians at the lower trap and estuary did not have scan every 0+ Chinook salmon they captured. Some of the 1+ and 2+ steelhead trout also had partial fin clips because we tagged recaptures from trap efficiency trials to increase sample size. After tag application, fish were held in a livecar in the stream for a period of 34 hrs to test for delayed mortality. 0+ Chinook salmon were kept separately from 1+ and 2+ steelhead trout. All pit tagged fish were released at night downstream of the trap site at the normal downstream release site. Field crews at the upper trap, lower trap, and estuary had hand held pit tag readers (ALLFLEX USA, Inc., PO BOX 612266, Dallas/Ft Worth Airport, Texas) so that they could scan and identify pit tag fish; and perform necessary fork length and weight measurements.

Delayed Mortality

We conducted several delayed mortality tests for captured 0+ Chinook salmon (n = 28 tests), 1+ steelhead trout (n = 31 tests), and 2+ steelhead trout (n = 41 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 78 for 0+ Chinook salmon, 86 for 1+ steelhead trout, and 37 for 2+ steelhead trout. The duration of each test was 24 hrs for 0+ Chinook salmon, 1+ steelhead trout, and 2+ steelhead trout. Elastomer tests were for 1+ and 2+ steelhead trout that were anesthetized and given an elastomer mark (some fish were also measured for FL and Wt due to low sample size); total sample size was 146 for 1+ steelhead trout and 37 for 2+ steelhead trout. The duration of each test was 24 hrs. Pit tag tests were for fish that were anesthetized, measured for FL (mm) and Wt (g), tagged with a pit tag, and for 0+ Chinook salmon and a few 1+ and 2+ steelhead trout, given a partial upper caudal fin clip. Total sample size was 555 for 0+ Chinook salmon, 147 for 1+ steelhead trout, and 46 for 2+ steelhead trout. The duration of each test was 34 hrs (eg 7/1/05 1100 – 7/2/05 2100).

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 26th – August 26th, 2005. 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 2005) is given in Appendix 3.

Stream temperatures were recorded with an Optic StowAway® Temp data logger (Onset Computer Corporation, 470 MacArthur Blvd. Bourne, MA 02532) placed behind the rotary screw trap. A second probe was deployed at the same location for comparison. Both probes gave similar results (Ave. = 14.7 ^{o}C), therefore only data from one probe is reported. The probes were placed into a PVC cylinder with holes to ensure adequate ventilation and to prevent influences from direct sunlight. Probes were set to record stream temperatures (^{o}C) every 60 minutes and recorded about 3,700 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 - 2005 were determined following methods described by Madej et al. (1995). 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. 2005).

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) 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 0.72 – 0.95). Regression and correlation were also used to test for influences of average weekly stream temperature, stream discharge, gage height, 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 average weekly stream temperature, stream discharge, gage height, 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, $p = 0.000001$, r ranged from 0.84 – 0.95).

Linear correlation was used to determine if weekly trapping efficiencies for 0+ Chinook salmon, 1+ steelhead trout, and 2+ steelhead trout changed over time (weeks). Regression was used to test for influences of physical variables (average weekly gage height and average weekly stream discharge) on weekly trapping efficiencies for a given species at age. One week (stratum) for 2+ steelhead trout trap efficiency was omitted in the analysis because only two marked fish were released with one subsequent recapture; the weekly trap efficiency was considered an outlier for the regression test. As in previous tests, gage height and stream discharge were not combined together in the models due to high correlation ($p = 0.000001$, $r = 0.95$).

Linear correlation slope and equation line were used to determine if population size of a given species at age was increasing, or decreasing over the six 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 (YRS 2003 and 2005) and non-bedload mobilizing flows as 0 (YRS 2000 - 2002, and 2004) (Zar 1999). Flows considered great enough to mobilize the bedload in upper Redwood Creek (> 4,500 cfs) were identified by Redwood National Park Hydrologists and Geologists (Randy Klein, Greg Bundros, Vicki Ozaki, Mary Ann Madej, pers comm. 2003). High flows for the 2005 cohort occurred 12/08/04, when stream flow reached 6,350 cfs (USGS 2005).

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 fork lengths 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 five years of trapping in upper Redwood Creek (FL nadir ranged from 42 – 45 mm, mean = 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 six years of data collection. Data for 0+ Chinook salmon in YR 2003 was omitted from analysis because so few measurements were taken due to the year class failure in 2003. Additionally, the majority of measurements were taken in June and did not include the smaller fry that normally emigrate in late March, April, and May. Removal of data did not change the test conclusion.

I determined a ' rough' estimate of growth rate in FL and Wt for 0+ Chinook salmon in YR 2005 generally following methods by Bendock (1995). I used the first weekly average in FL and Wt with a sample size ≥ 25 (week 4/02 - 4/08) and the last weekly average in the season (7/23 - 7/29) with a sample size ≥ 25. The first average was subtracted from the last average, and divided by the number of days from the first day after the first weekly average to the last day of the last weekly average. For the example above, the number of days used in the growth calculation equaled 112. 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.

Linear correlation was also used to test if the average weekly FL and Wt of each species at age increased over the study period in YR 2005 and for the previous five year average (excluding 0+ steelhead weight). 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 FL's and Wt's in YR 2005 with the four year average for 0+ Chinook salmon, and five year average for 0+, 1+, and 2+ steelhead trout.

Chi-square was 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 2005 with the previous five year average. Parr stage was not included in the tests because at least one of the values in the contingency tables was less than 5, which can cause the tests to be inaccurate (NCSS 97).

Descriptive statistics were used to characterize FL, Wt, travel time (d), travel rate (mi per d), and various growth indices (Percent Change in Growth, Absolute Growth Rate, Specific Growth Rate, and Relative Growth Rate) for all pit tagged fish recaptured at the lower trap. Average growth values were also determined for recaptured pit tagged fish that showed positive (excludes negative and zero growth) and negative (excludes positive and zero growth) growth. 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). For the following equations, t_1 is the initial date, t_2 is the ending or recapture date, Y_1 is fish size at t_1, and Y_2 is the fish size at t_2 (Busacker et al. 1990).

Percent change in growth is defined as (Busacker et al. 1990):

1) $\%\ \text{change in growth} = ((Y_2 - Y_1)/ Y_1) \times 100$

Absolute growth rate (AGR) is defined as (Busacker et al. 1990):

2) $\text{Absolute growth rate} = (Y_2 - Y_1)/(t_2 - t_1)$

where $t_2 - t_1$ equals the number of days from initial release (at the upper trap) to subsequent recovery at the lower trap. Thus, absolute growth rate is expressed as mm per day or g per day.

Specific growth rate (SGRsc) is defined as (Busacker et al. 1990):

3) $\text{Specific growth rate (scaled)} = [(\log_e Y_2 - \log_e Y_1)/(t_2 - t_1)] \times 100$

Specific growth rate 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 (RGR) is defined as (Busacker et al. 1990):

4) Relative Growth Rate = $(Y_2 - Y_1)/[Y_1(t_2 - t_1)]$

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 are in 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 all recaptured pit tagged 0+ Chinook salmon smolts (n = 27) were modeled using linear regression. These parameters for 1+ and 2+ steelhead trout could not be modeled due to low recaptures. 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), and stream discharge during a specific migration period (average of data from both traps). Independent variables for modeling growth (dependent variable) included travel time, travel rate, average water temperature, and average stream discharge. Stream temperature and stream discharge were not included together in any regression models because they were highly correlated ($p < 0.001$). During the travel time and growth experiments (6/3 – 8/10), average daily stream temperatures at the upper trap site ranged from 11.0 – 22.4 ^{o}C (51.8 – 72.3 ^{o}F) and average daily stream discharge ranged from 13 - 309 cfs. Average daily stream temperatures at the lower trap site ranged from 12.2 – 20.0 ^{o}C (54.0 – 68.0 ^{o}F) and average daily stream discharge ranged from 63 - 1,620 cfs. 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. 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 average monthly stream temperature among YR 2005 and the previous four year average (YRS 2001-2004). 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 correlations were used to test if the average daily (24 hour) stream temperature increased or decreased over the study period (March - August) in YR 2005; the same test was applied to the previous four year average. Regression was used to examine the relationship of the daily stream gage height on average daily stream temperature for YR 2005, and the relationship of average discharge during each trapping season on average stream temperature each season (n = 5) (excluding YR 2000).

If data violated tests of statistical assumptions, data was transformed with Log (x+1) to approximate normality (Zar 1999). Power is defined as the probability of correctly rejecting the null hypothesis when it is false (Zar 1999). The level of significance (Alpha) for tests with six 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 six data points, alpha was set at 0.05.

RESULTS

The rotary screw trap operated from 3/25/05 - 8/26/05 and trapped 146 nights out of a possible 154. The trapping rate in YR 2005 was 94% compared to 97% for the previous five year average (ranged from 92 - 99%). Days missed trapping in YR 2005 occurred in March (n = 2), April (n = 2), May (n = 3), and June (n = 1).

Species Captured

Juvenile Salmonids

Species captured in YR 2005 included: juvenile Chinook salmon (*Oncorhynchus tshawytscha*), juvenile steelhead trout (*O. mykiss*), coastal cutthroat trout (*O. clarki clarki*), and juvenile pink salmon (*O. gorbuscha*). No juvenile coho salmon (*O. kisutch*) were captured for the sixth consecutive year. A total of 56,544 juvenile salmonids were captured in YR 2005 (Figure 2).

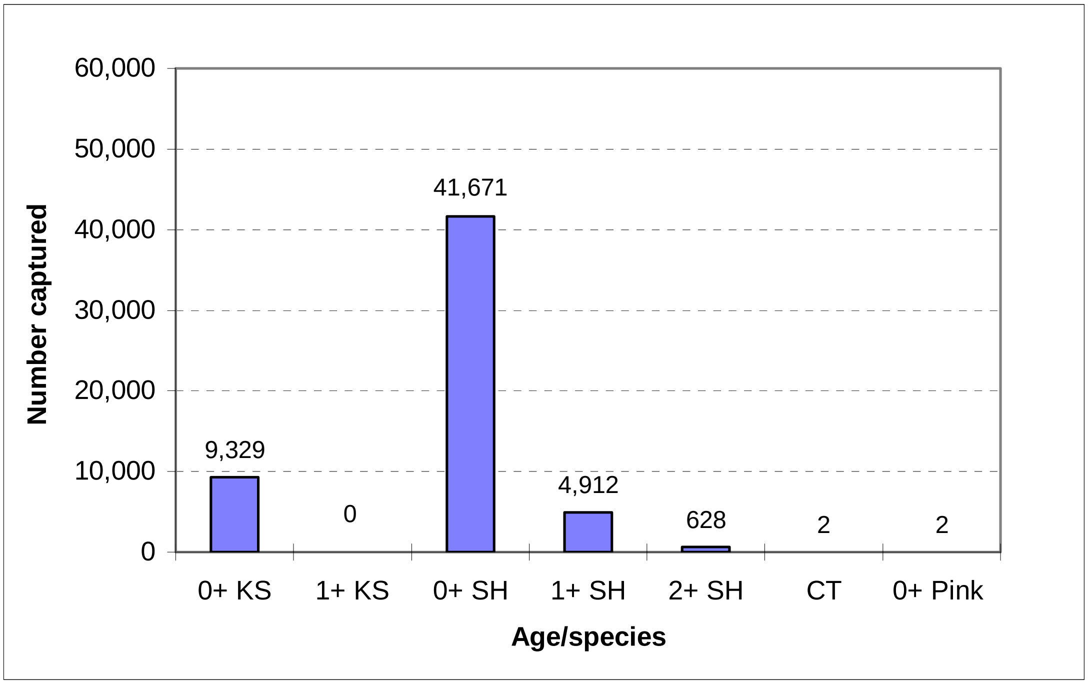

Figure 2. Total juvenile salmonid actual catches (n = 56,544) from March 26 through August 26, 2005, upper Redwood Creek, Redwood Valley, Humboldt County, CA. Numeric values above columns represent actual catches. 0+ KS = young-of-year Chinook salmon, 1+ KS = age 1 and older Chinook salmon, 0+ SH = young-of-year steelhead trout, 1+ SH = age 1 and older steelhead trout, 2+ SH = age 2 and older steelhead trout, CT = cutthroat trout, 0+ Pink = young-of-year pink salmon.

Trap catches of 0+ Chinook salmon, 0+ steelhead trout, 1+ steelhead trout, 2+ steelhead trout, and cutthroat trout in YR 2005 were much less (77%) than trap catches for the previous five year average (Table 3). The greatest reduction (93%) in catches in YR 2005 occurred with 0+ Chinook salmon.

Table 3. Comparison of juvenile salmonid trap catches in YR 2005 with the previous five year average catch, upper Redwood Creek, Humboldt County, CA.

	Actual Catches		
Age/species*	YR 2005	Previous five year average	Percent reduction in YR 2005**
0+ KS	9,329	134,880	93.1
1+ KS	0	14	-
0+ SH	41,671	102,760	59.4
1+ SH	4,912	12,583	61.0
2+ SH	628	1,121	44.0
CT	2	4	50.0
0+ Pink	2	3	33.3
Total:	56,544	251,365	77.5

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

** Comparison is with the previous five year average.

Miscellaneous Species

The trap caught numerous species besides juvenile anadromous salmonids in YR 2005, including: prickly sculpin (*Cottus asper*), coast range sculpin (*Cottus aleuticus*), sucker (*Catostomidae* family), three-spined stickleback (*Gasterosteus aculeatus),* brown bullhead (*Ameiurus nebulosus*), juvenile (ammocoete) lamprey and adult Pacific Lamprey (*Entosphenus tridentatus*) (Table 4). The brown bullheads likely escaped from a farm pond which drains into upper Redwood Creek.

Amphibian catches included coastal (Pacific) giant salamander (*Dicamptodon tenebrosus*), rough skinned newt (*Taricha granulosa granulosa*), yellow legged frog (*Rana muscosa*), tailed frog tadpole (*Ascaphus truei*) and American bullfrog (*Rana catesbeiana*), among other species (Table 4). Numerous aquatic and semi-aquatic invertebrates were also captured in the trap.

Table 4. Miscellaneous species captured in YR 2005 compared to the previous five year average, upper Redwood Creek, Redwood Valley, Humboldt County, CA.

	Number Captured	
Species Captured	YR 2005	Previous five year average
Prickly Sculpin	1	6
Coast Range Sculpin	13	109
Sucker	3	8
3-Spined Stickleback	92	101
Brown Bullhead	3	< 1
Adult Pac. Lamprey	9	40
Juvenile Lamprey	2,210	2,186
Possible River Lamprey*	1	3
Pac. Giant Salamander	147	105
Painted Salamander	1	1
Rough Skinned Newt	18	33
Red-Legged Frog	2	1
Yellow-Legged Frog	25	12
Tailed Frog**	4	4
American Bullfrog	0	< 1

* Has not been keyed to species.
** Includes both adult and tadpole stages.

Juvenile Salmonid Captures

Catches of 0+ Chinook salmon, 0+ steelhead trout, 1+ steelhead trout, and 2+ steelhead trout in YR 2005 were variable over time, with apparent multi-modal catch distributions for each species at age.

0+ Chinook salmon daily catches in YR 2005 (n = 9,329) ranged from 0 - 371 individuals, and averaged 65 fish per day. The previous five year daily catch ranged from 0 - 10,700 and averaged 1,096 per day. Daily 0+ Chinook salmon captures in YR 2005 expressed as a percentage of total 0+ Chinook salmon catch in YR 2005 (n = 9,329) ranged from 0.0 - 4.0%, and averaged 0.6%. The peak catch in YR 2005 occurred 5/2/05.

0+ steelhead trout daily catches in YR 2005 ranged from 0 - 2,109 individuals, and averaged 271 per day. The previous five year daily catch ranged from 0 - 6,993 individuals and averaged 799 per day. Daily 0+ steelhead captures in YR 2005 expressed as a percentage of total 0+ steelhead catch in YR 2005 (n = 41,671) ranged from 0.0 - 5.1% and averaged 0.6%. The peak catch in YR 2005 occurred 7/16/05.

1+ steelhead trout daily catches in YR 2005 ranged from 0 - 200, and averaged 32 per day. The previous five year daily catch ranged from 0 - 727 individuals and averaged 98 per day. Daily 1+ steelhead captures in YR 2005 expressed as a percentage of total 1+ steelhead catch in 2005 (n = 4,912) ranged from 0.0 - 4.1% and averaged 0.6%. The peak catch in YR 2005 occurred on 5/3/05.

2+ steelhead trout daily catches in YR 2005 ranged from 0 - 23, and averaged four individuals per day. The previous five year daily catch ranged from 0 - 45 individuals and averaged nine per day. Daily 2+ steelhead trout captures in YR 2005 expressed as a percentage of total 2+ steelhead trout catches in YR 2005 (n = 628) ranged from 0.0 - 3.7%, and average 0.6%. The peak catch in YR 2005 occurred on 4/19/05 and 4/27/05.

Days Missed Trapping

Eight days were not trapped during the course of the study due to high flow events and high debris loads in the livebox. Days missed trapping did not appear to influence the total catch or population estimate of any species at age to any large degree (Table 5).

Table 5. The estimated catch and expansion (population level) of juvenile anadromous salmonids considered to have been missed due to trap not being deployed (n = 8 d) during the emigration period of March 25 through August 26 (as a percentage of total without missed days in parentheses), upper Redwood Creek, Humboldt County, CA., 2005.

Age/spp.*	Catch	Population Level
0+ KS	88 (0.95%)	347 (0.88%)
0+ SH	311 (0.75%)	-
1+ SH	193 (4.1%)	1002 (4.0%)
2+ SH	22 (3.7%)	96 (4.3%)

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

Note: Regression methods were used to estimate the number of fish caught when the trap was not operating. The estimated catches were then added to the known catches for a given stratum (week) and used in the population estimate for that stratum (Roper and Scarnecchia 1999).

0+ Chinook Salmon

The majority of 0+ Chinook salmon catches in YR 2005 occurred in June and July (63% of total), compared with May and June (80% of total) for the previous five year average (Figure 3). The percentage of total catch in late March, April, and August 2005 were similar to the previous five year average. The percentage of total catches in July 2005 was markedly higher than July for the previous five year average.

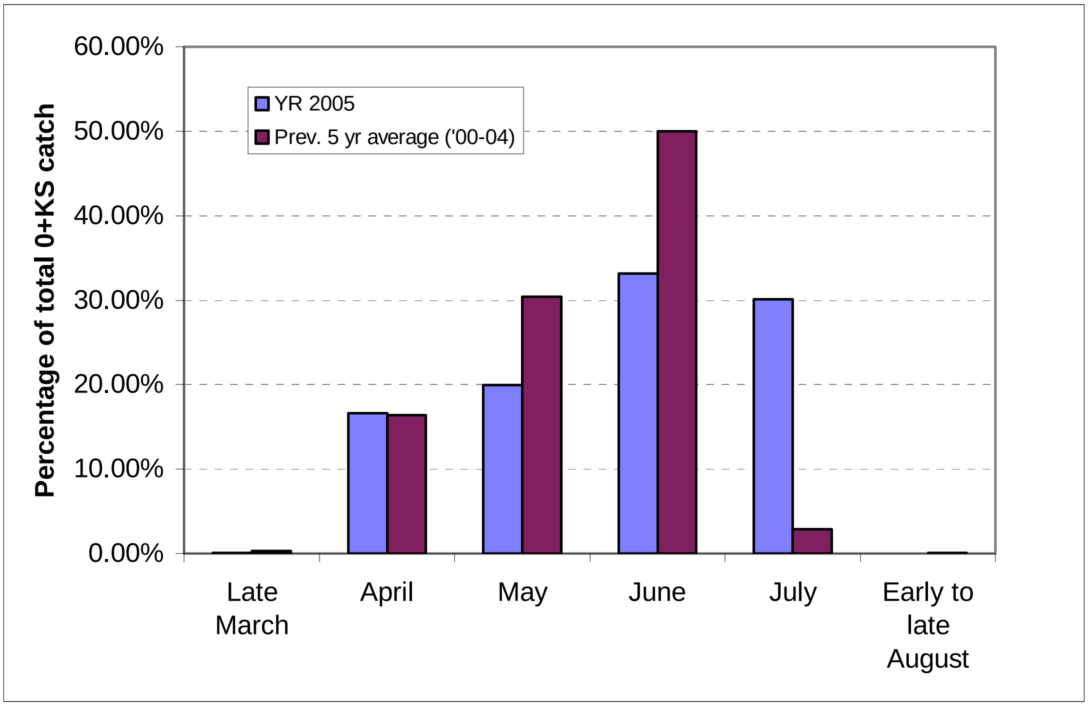

Figure 3. Comparison of the percentage of total 0+ Chinook salmon catch by month in YR 2005 with the previous five year average, upper Redwood Creek, Humboldt County, CA. Age/species abbreviation is the same as in Figure 2.

The correlation of 0+ Chinook salmon catches with study years showed a non-significant negative relationship (p = 0.56, r = 0.30, power = 0.08).

0+ Steelhead Trout

The pattern in monthly catches (as a percentage of total catch) for 0+ steelhead trout in YR 2005 was markedly different than for the previous five year average (Figure 4). The majority of catches in YR 2005 occurred in July (60%), compared to May and June (74%) for the previous five year average. In YR 2005, relatively few fish were captured in May and June (26%). The percentage of 0+ steelhead trout captured in July 2005 was nearly 3 times greater than the percentage caught in July for the previous five year average.

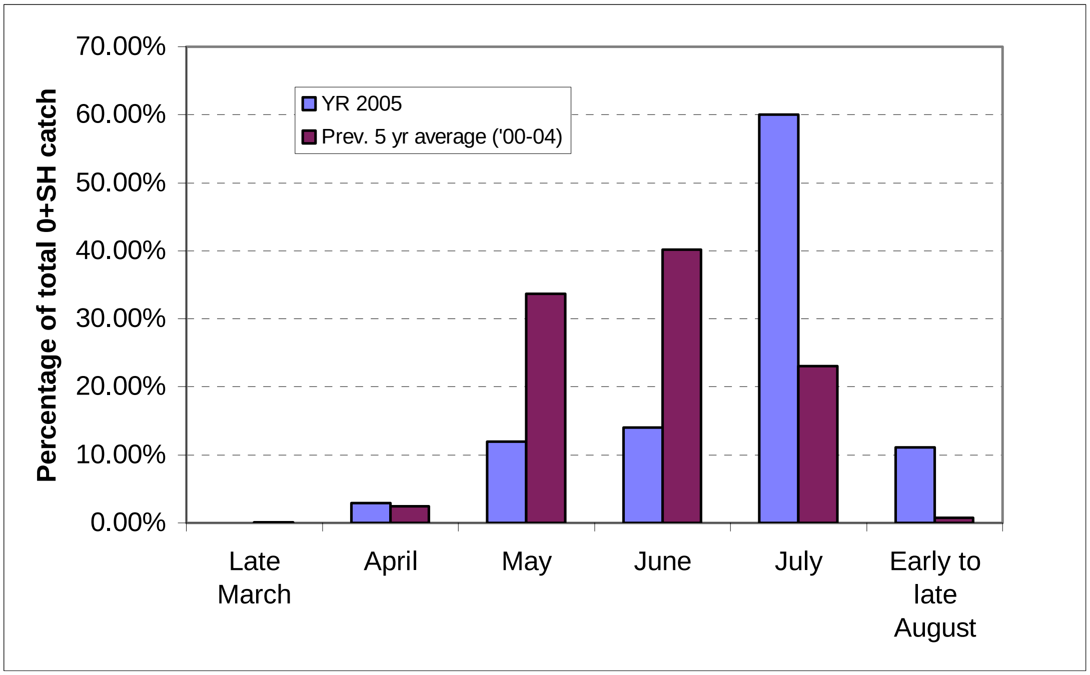

Figure 4. Comparison of the percentage of total 0+ steelhead trout catch by month in YR 2005 with the previous five year average, upper Redwood Creek, Humboldt County, CA. Age/species abbreviation is the same as in Figure 2.

The correlation of 0+ steelhead trout catches with study years showed a non-significant negative relationship ($p = 0.98$, $r = 0.20$, power = 0.05).

1+ Steelhead Trout

The majority of 1+ steelhead trout catches occurred in April and May for both YR 2005 and the previous five year average, and were equal in value (74%) on a percentage basis (Figure 5). In YR 2005, the greatest captures occurred in April, as compared to May for the previous five year average. In YR 2005, catches in May and June were reduced compared to the five year averaged values. On a percentage basis, few 1+ steelhead trout were captured in Late March and August.

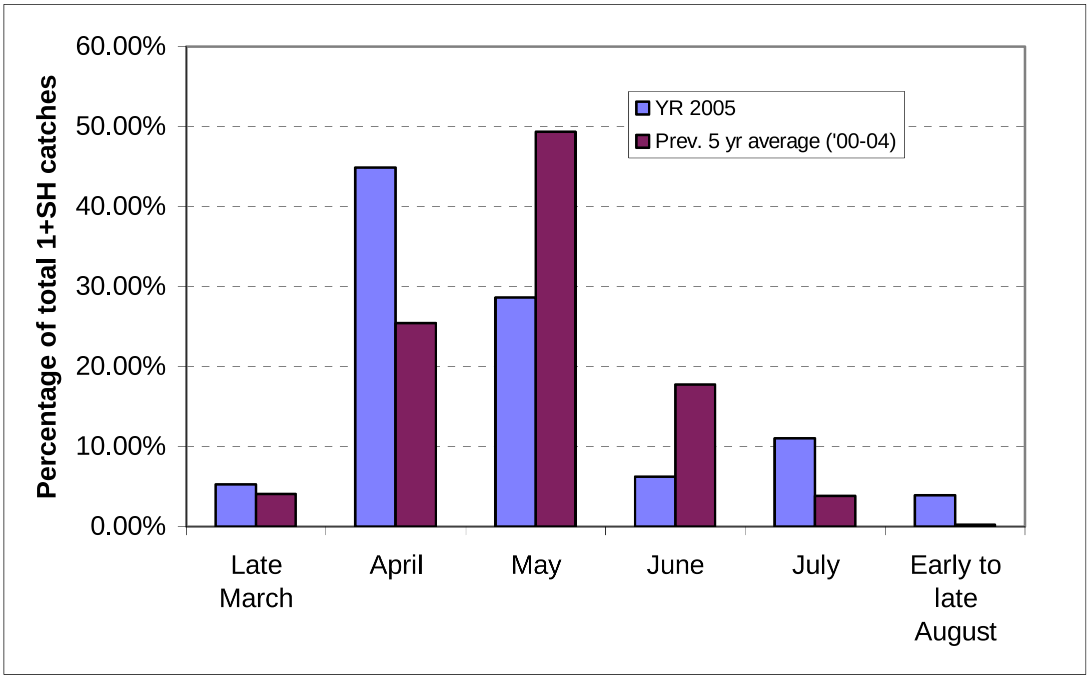

Figure 5. Comparison of the percentage of total 1+ steelhead trout catch by month in YR 2005 with the previous five year average, upper Redwood Creek, Humboldt County, CA. Age/species abbreviation is the same as in Figure 2.

The correlation of 1+ steelhead trout catches with study years showed a non-significant negative relationship ($p = 0.37$, $r = 0.45$, power = 0.12).

2+ Steelhead Trout

The majority of 2+ steelhead trout catches occurred in April and May for both YR 2005 (ie 70%) and the previous five year average (ie 69%) (Figure 6). Peak monthly catches in YR 2005 occurred in April and for the previous five year average occurred in May. More 2+ steelhead trout were captured in August, 2005 compared to the previous five year average for August.

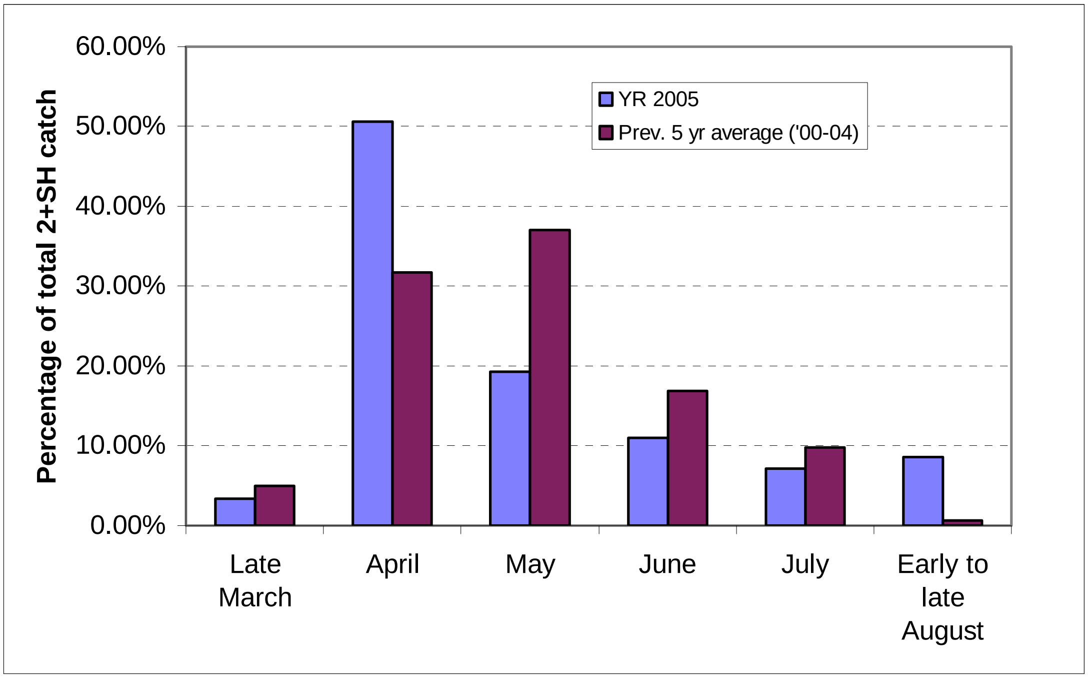

Figure 6. Comparison of the percentage of total 2+ steelhead trout catch by month in YR 2005 with the previous five year average, upper Redwood Creek, Humboldt County, CA. Age/species abbreviation is the same as in Figure 2.

The correlation of 2+ steelhead trout catches with study years showed a non-significant negative relationship (p = 0.69, r = 0.21, power = 0.06).

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

Linear regressions of average daily stream temperature (^{o}C), average daily discharge (cfs), or daily gage height (feet) on daily catches of all salmonids combined, 0+ Chinook salmon, 0+ steelhead trout, 1+ steelhead trout, and 2+ steelhead trout (except for average stream temperature and week number) violated regression assumptions (even with log(x+1) transformations), and results were not valid. Average daily stream temperature on 2+ steelhead trout daily catches (log (x+1) transformation) passed regression assumption tests, and a significant (yet weak) negative relationship was detected ($p < 0.001$, $R^2 = 0.18$, negative slope, power = 1.0). Trapping day on 2+ steelhead trout catches also showed a significant negative relationship (Correlation, $p = 0.000001$, $r = 0.48$, negative slope, power = 1.0).

Although statistical tests were not warranted for most 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 3) on daily catches. Slightly more 0+ Chinook salmon (56.6%) were captured during average daily (24 hr) stream temperatures of 7.1 – 14.3 ^{o}C compared to catches in stream temperatures ranging from 15.1 – 22.4 ^{o}C. The majority of 0+ steelhead trout catches (71.9%) occurred during average daily stream temperatures of 15.1 – 22.4 ^{o}C; and the majority of 1+ steelhead trout catches (84%) and 2+ steelhead trout catches (83%) occurred during average daily stream temperatures of 7.1 – 14.3 ^{o}C.

None of the peak catches of 0+ Chinook salmon occurred during peaks in the stream's gage height (although trap efficiencies for those weeks when storms occurred were sufficient). Most of the higher catches occurred during the descending limb of the hydrograph, however, on two occasions catches slightly increased during increases in gage height. 0+ steelhead trout followed a similar pattern to 0+ Chinook salmon; no peak catches occurred during peaks in the gage height, most catches occurred during the descending limb of the hydrograph, and on one occasion catches slightly increased during a small increase in gage height. 1+ steelhead trout catches decreased during peaks in the hydrograph (although trap efficiencies for those weeks when storms occurred were sufficient), and also on the descending limb of some of the peaks in the hydrograph; the peaks in 1+ steelhead catches occurred on the descending limb of other increases in gage height. Most of the 1+ steelhead trout were caught prior to June when storm events (and higher gage height readings) occurred compared to post June catches. 2+ steelhead trout followed a very similar pattern to 1+ steelhead trout.

The regressions of weekly gage height and average weekly discharge, and the correlation of trapping week number on catches of all salmonids by week or each species at age by week was not significant ($p > 0.05$, power = 0.05); however, a positive significant relationship was found for average weekly stream temperature on catches of all salmonids by week ($p < 0.05$) (Appendix 4). No significant relationships of independent variables with 0+ Chinook salmon catches were detected ($p > 0.05$). 0+ steelhead trout catches were negatively related to gage height and stream discharge, and positively related to stream temperature and week number ($p < 0.05$ for each test). 1+ steelhead trout and 2+ steelhead trout catches were each positively related to gage height and stream discharge, and negatively related to stream temperatures and week number ($p < 0.05$ for each test).

Trapping Efficiencies

0+ Chinook Salmon

We fin clipped and released 3,569 young-of-year Chinook salmon upstream of the trap site during 57 efficiency trials over the course of trapping in YR 2005. The average number used in our weekly trials (includes 2 - 5 efficiency trials) was 210, and ranged from 4 - 500 (per week).

Weekly trapping efficiencies in YR 2005 ranged from 6.2 - 75%, and averaged 32.8% (Table 6). Average weekly and seasonal (total number of recaptures/total number marked) trapping efficiencies in YR 2005 were less than efficiencies for the previous five year average (Table 6).

0+ Chinook salmon weekly trap efficiencies in YR 2005 significantly increased over time (Correlation, $p = 0.000001$, $r = 0.93$, positive slope, power = 1.0), and were negatively related to gage height (Regression, $p = 0.000004$, $R^2 = 0.77$, negative slope, power = 1.0) and stream discharge (Regression, $p = 0.0002$, $R^2 = 0.61$, negative slope, power = 0.99).

Table 6. 0+ Chinook salmon trapping efficiency in YR 2005 and the previous five year average, upper Redwood Creek, Humboldt County, CA.

	0+ Chinook salmon trap efficiency (percentage)		
	Weekly trapping efficiency		
Study Year	Range	Average	Seasonal
2005	6.2 - 75.0	32.8	33.0
2000-04	3.2 - 100.0	49.6	48.0

1+ Steelhead Trout

We fin clipped and released 1,940 1+ steelhead trout upstream of the trap site during 80 efficiency trials over the course of trapping in YR 2005. The average number used in our weekly trials (includes 2 - 5 efficiency trials) was 88, and ranged from 11 - 243 (per week).

Weekly trapping efficiencies in YR 2005 ranged from 9.2 – 36.4%, and averaged 23.4% (Table 7). Average weekly and seasonal (total number of recaptures/total number marked) trapping efficiencies in YR 2005 were less than efficiencies for the previous five year average (Table 7).

1+ steelhead trout weekly trap efficiencies in YR 2005 significantly increased over time (Correlation, p = 0.0005, r = 0.66, positive slope, power = 0.97), and were negatively related to gage height (Regression, p = 0.004, R^2 = 0.35, negative slope, power = 0.88) and stream discharge (Regression, p = 0.006, R^2 = 0.32, negative slope, power = 0.83).

1+ steelhead trout weekly trap efficiencies were not significantly different than 2+ steelhead trout weekly efficiencies (Kruskal-Wallis One-Way ANOVA on Ranks, p = 0.65).

Table 7. 1+ steelhead trout trapping efficiency in YR 2005 and the previous five year average, upper Redwood Creek, Humboldt County, CA.

	1+ Steelhead trout trap efficiency (percentage)		
	Weekly trapping efficiency		
Study Year	Range	Average	Seasonal
2005	9.2 - 36.4	23.4	21.1
2000-04	0.0 - 57.0	28.6	30.1

2+ Steelhead Trout

We fin clipped and released 371 2+ steelhead trout upstream of the trap site during 53 efficiency trials over the course of trapping in YR 2005. The average number used in our weekly trials (includes 2 - 5 efficiency trials) was 17, and ranged from 2 - 47 (per week).

Weekly trapping efficiencies in YR 2005 ranged from 0.0 – 50.0%, and averaged 26.2% (Table 8). Average weekly and seasonal (total number of recaptures/total number marked) trapping efficiencies in YR 2005 were greater than efficiencies for the previous five year average (Table 8).

2+ steelhead trout weekly trap efficiencies in YR 2005 significantly increased over time (Correlation, $p = 0.0007$, $r = 0.57$, positive slope, power = 0.82) and were negatively related to gage height (Regression, $p = 0.005$, $R^2 = 0.34$, negative slope, power = 0.85) and stream discharge (Regression, $p = 0.006$, $R^2 = 0.34$, negative slope, power = 0.84).

All of the fin clipped 2+ steelhead trout released upstream of the trap site were recovered in the 'correct' strata when recaptured.

Table 8. 2+ steelhead trout trapping efficiency in YR 2005 and the previous five year average, upper Redwood Creek, Humboldt County, CA.

	2+ Steelhead trout trap efficiency (percentage)		
	Weekly trapping efficiency		
Study Year	Range	Average	Seasonal
2005	0.0 - 50.0	26.2	23.5
2000-04	0.0 - 48.8	16.7	18.9

Population Estimates

0+ Chinook Salmon

The population estimate (or production) of 0+ Chinook salmon emigrating from upper Redwood Creek in YR 2005 equaled 39,614 with a 95% CI of 34,961 - 44,268. Population estimate error (or uncertainty) equaled ± 11.7%. Population emigration in YR 2005 was markedly lower than emigration in YR 2004 ($N = 629,847$) by 94% and the previous five year average ($N_{av5yr} = 390,926$) by 90%.

Correlation of time (study year) on yearly population estimates showed a non-significant negative relationship ($p = 0.49$, $r = 0.35$, power = 0.09) (Figure 7).

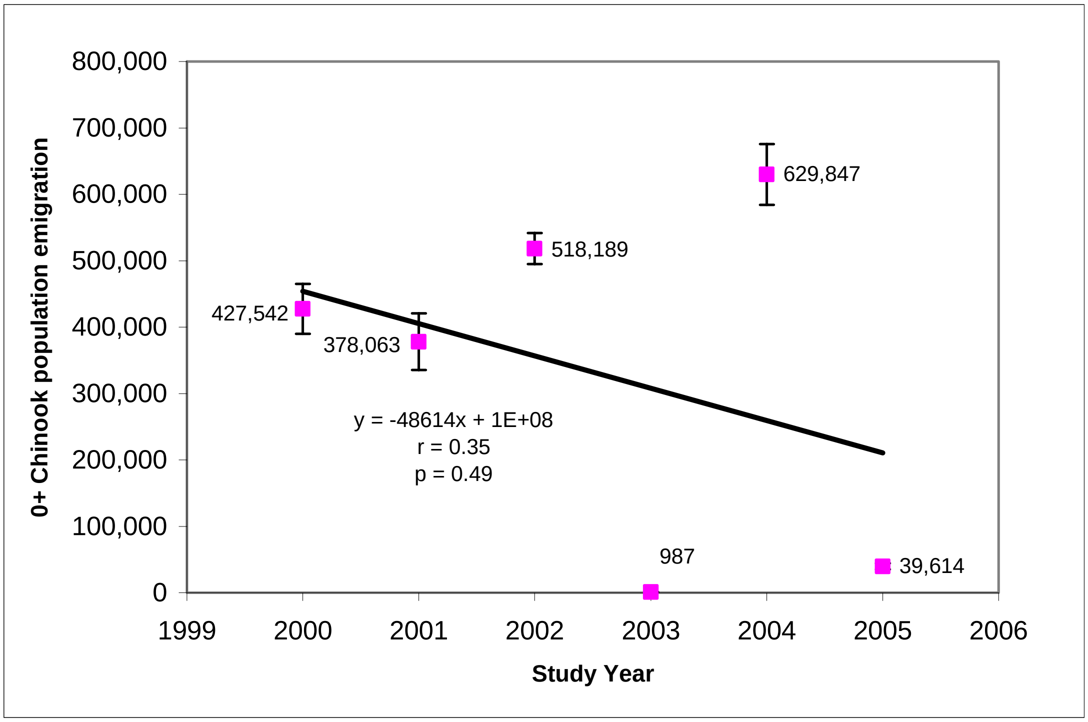

Figure 7. 0+ Chinook salmon population estimates (error bars are 95% confidence interval) in six consecutive years. Lack of 95% CI for YRS 2003 and 2005 is due to scale of Y axis. Numeric values next to box represent number of individuals. Line of best fit is a regression line, with corresponding equation,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

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 six study years ($p = 0.005$, $R^2 = 0.89$, slope is negative, and power = 0.98). The variation in peak stream flow (in this case, bedload mobilizing flow and non-bedload mobilizing flow) during the redd incubation period explained 89% 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 2005 was about 90% less than values for the previous five year average (Table 9).

Table 9. Estimated number of 0+ Chinook salmon per stream mile, stream kilometer, and watershed acreage upstream of the trap site, YRS 2000-2005.

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
Average:	10,566	6,570	6.01
2005	1,071	666	0.61

0+ Chinook salmon population emigration by month in YR 2005 was severely reduced compared to emigration by month for the previous five year average (Figure 8).

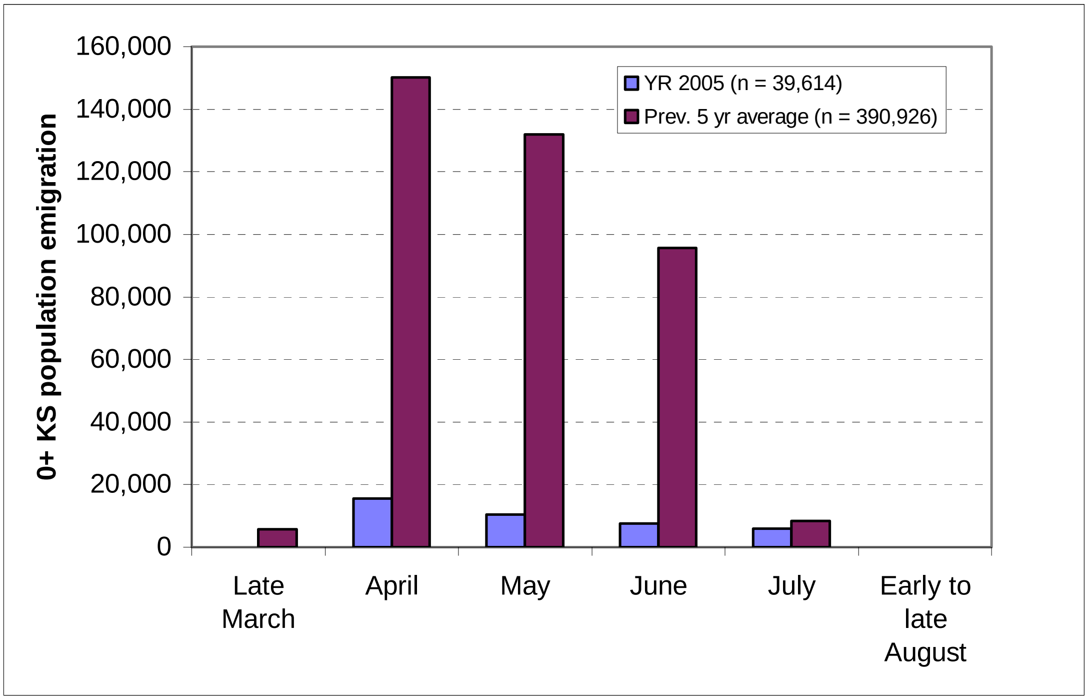

Figure 8. Comparison of 0+ Chinook salmon population emigration by month in YR 2005 with the previous five year average, upper Redwood Creek, Humboldt County, CA. Age/species abbreviation is the same as in Figure 2.

The majority of 0+ Chinook salmon population emigration occurred in April and May for both YR 2005 (66%) and the previous five year average (72%) (Figure 9). Emigration during April – June accounted for 85% of the population in YR 2005, and 96% for the previous five year average. Emigration in July 2005 was nearly seven times greater than emigration in July for the previous five year average.

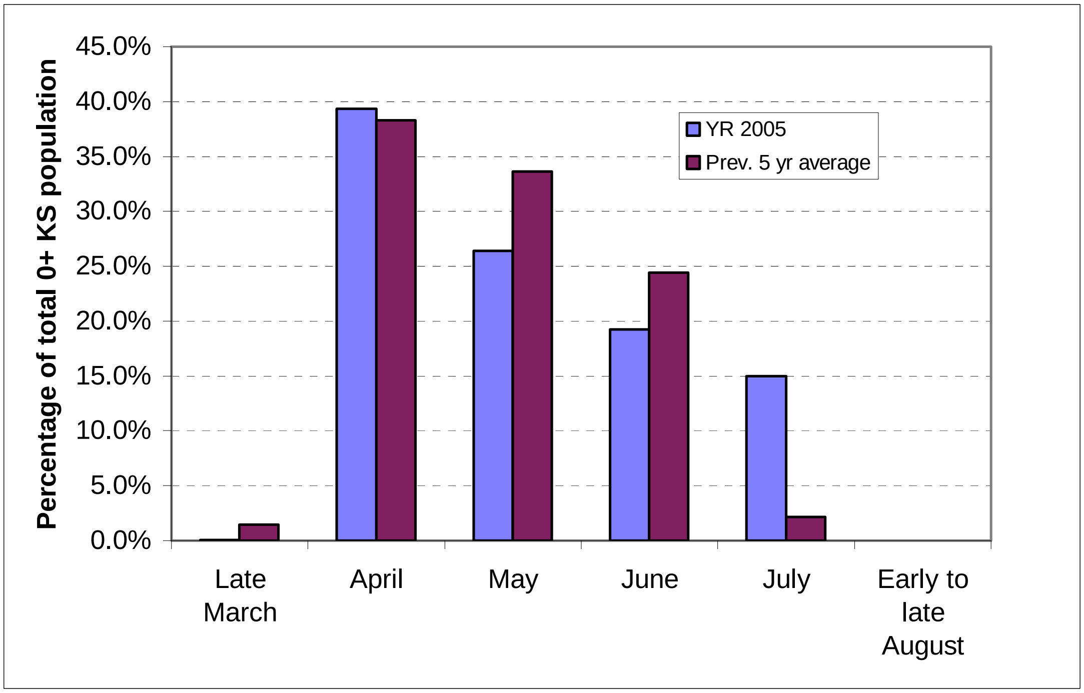

Figure 9. Comparison of the percentage of total 0+ Chinook salmon population emigration by month in YR 2005 with the previous five year average, upper Redwood Creek, Humboldt County, CA. Age/species abbreviation is the same as in Figure 2.

The peak in population emigration in YR 2005 occurred 4/23 - 4/29 (Table 10). Peak emigration occurred in late May/early June for YR 2000, May for YR 2001, June for YRS 2002 and 2003, and April for YR 2004 (Table 10).

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

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

The number and percentage of 0+ Chinook salmon migrants grouped into fry or fingerling categories varied among study years (Table 11). In YR 2005, 58% of the migrants were estimated as fry, and 42% were estimated as fingerlings. The previous five year average (N_{av5yr} = 390,926) consisted of 53% fry and 47% fingerlings. A statistically higher proportion of fry and a lesser proportion of fingerlings were present in YR 2005 compared to the previous five year average (Chi-square, $p = 0.000001$). The percentage of fry over study years was not influenced by emigrant population size, size of emigrants (FL, Wt), stream temperature, or stream discharge (Regression, $p > 0.10$ for all tests).

Table 11. Comparison of the production of 0+ Chinook salmon partitioned into fry and fingerling categories for 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)
5 yr ave.	209,020 (53)	181,906 (47)
YR 2005	22,957 (58)	16,657 (42)

0+ Chinook salmon fry and fingerling migrants showed differences in abundance and migration timing in YR 2005 compared to the previous five year average (Figure 10). For the previous five 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 in mid April, and gradually diminished to low values by early June; fingerling migration began in mid to late April, reached peaks in late May - June 10, and gradually decreased to low values by late July (Figure 10). In YR 2005, fry migration was low in the beginning of trapping (first three weeks), reached a peak value during late April through May 6th, and quickly decreased to low values by May 20th; fingerling migration began in early April in very low numbers (n = 3), reached a smaller peak May 28 - June 3 and a larger peak late June/early July; and descended to low values near the end of July (Figure 10).

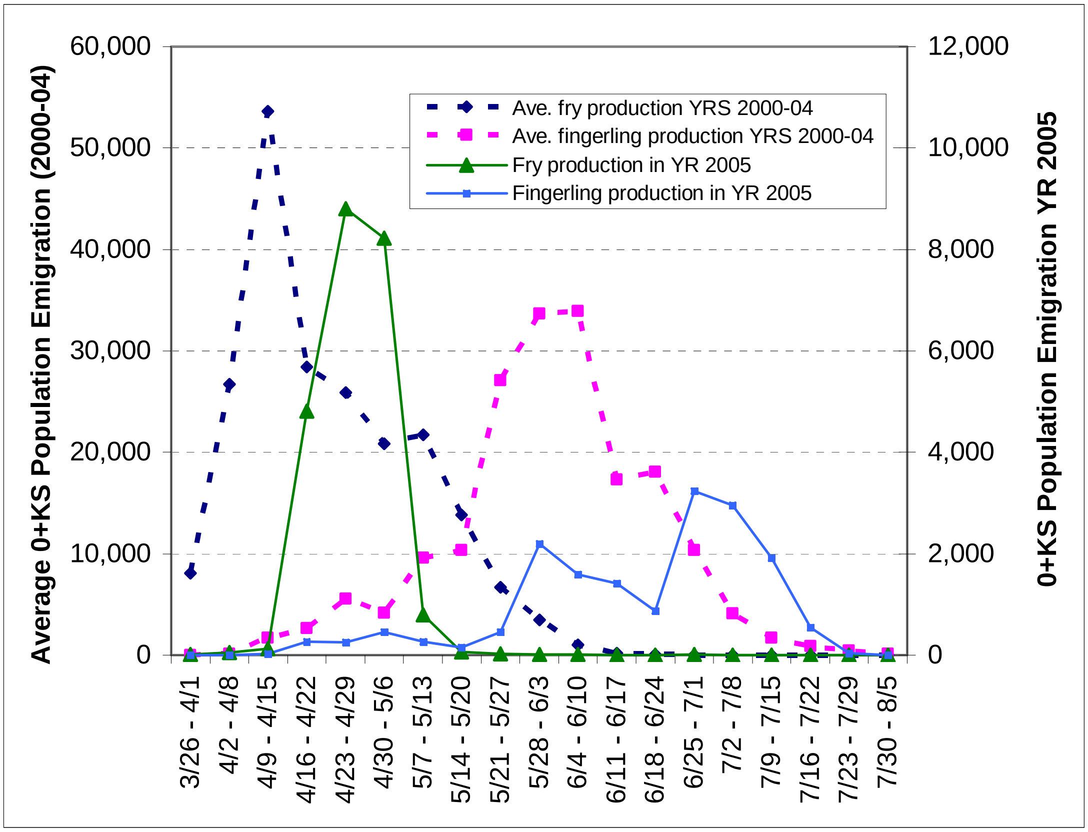

Figure 10. Comparison of estimated 0+ Chinook salmon fry and fingerling abundance and migration timing in YR 2005 (uses second "Y" axis) with previous five year average, upper Redwood Creek, Humboldt County, CA. Age/species abbreviation is the same as in Figure 2.

1+ Steelhead Trout

The population estimate (or production) of 1+ steelhead trout emigrating from upper Redwood Creek in YR 2005 equaled 26,176 with a 95% CI of 22,726 – 29,625. Population estimate error (or uncertainty) equaled ± 13.2%. Population emigration in YR 2005 was lower than emigration in YR 2004 (N = 41,434) by 37% and the previous five year average (N_{av5yr} = 43,762) by 40%.

Correlation of time (study year) on yearly population estimates showed a significant negative relationship (p = 0.07, r = 0.77, power = 0.46) (Figure 11).

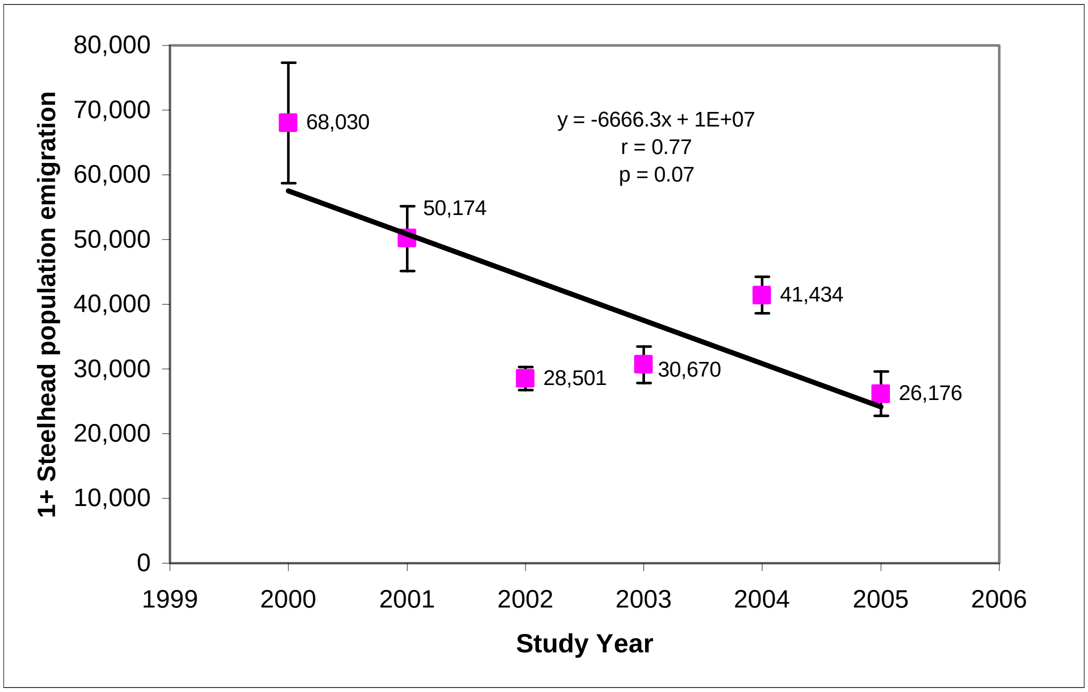

Figure 11. 1+ steelhead trout population estimates (error bars are 95% confidence interval) in six consecutive years. Numeric values next to box represent number of individuals. Line of best fit is a regression line, with corresponding equation, correlation value (r), and p value.

The number of 1+ steelhead trout (at population level) per mile, kilometer, and watershed acreage upstream of the trap site in YR 2005 was about 40% less than values for the previous five year average (Table 12). Highest values occurred in YR 2000 and lowest values occurred in YR 2005.

Table 12. Estimated number of 1+ steelhead trout per stream mile, stream kilometer, and watershed acreage upstream of the trap site, YRS 2000-05.

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
Average:	1,183	735	0.67
2005	707	440	0.40

1+ steelhead trout monthly population emigration peaked in April (N = 15,285 or 58% of total) in YR 2005 and May (N_{av} = 20,092 or 46% of total) for the previous five year average (Figure 12). In YR 2005 20,592 individuals (or 79% of total) emigrated in April and May, compared to 40,613 (or 92% of total) migrants that emigrated in April - June for the previous five year average. Emigration in May 2005 (N = 5,307) was about four times less than the previous five year average for May (N_{av} = 20,092; and emigration in June 2005 (N = 1,384) was about eight times less than the previous five year average for June (N_{av} = 10,793). Emigration in August 2005 (N = 721) was about 12 times higher than the five year average for August (N_{av} = 60).

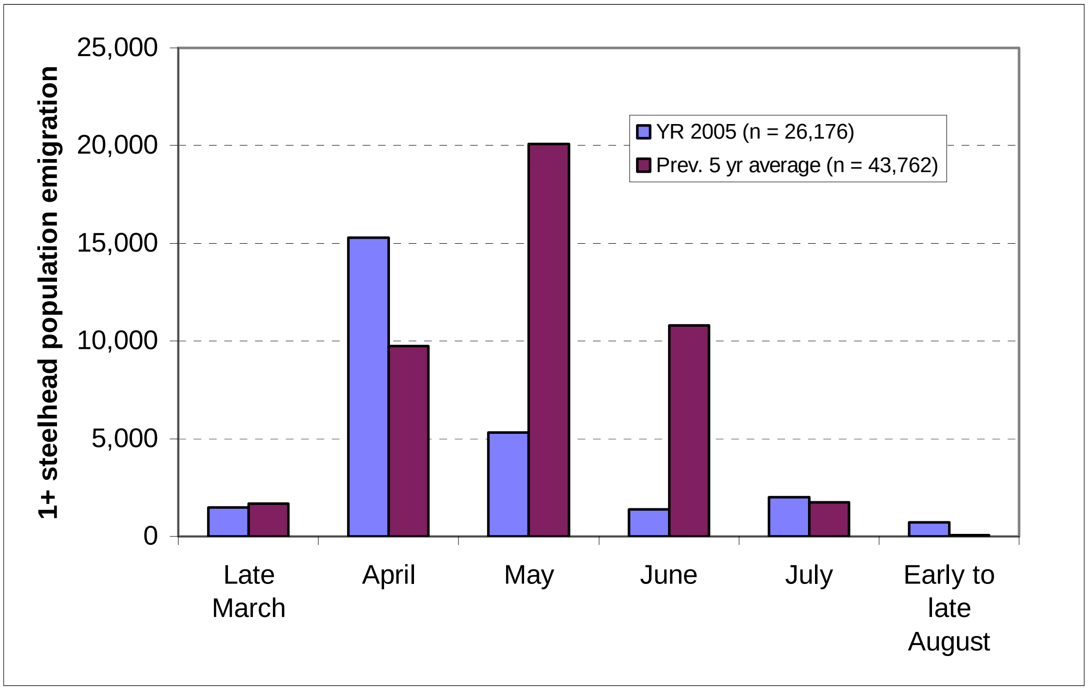

Figure 12. Comparison of 1+ steelhead trout population emigration by month in YR 2005 with the previous five year average, upper Redwood Creek, Humboldt County, CA.

The peak in 1+ steelhead trout weekly emigration in YR 2005 occurred at the same time as in YR 2001, and earlier than other study years (Table 13). Peaks occurred in April (YRS 2001 and 2005) and May (YRS 2000, 2002 - 2004).

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

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

2+ Steelhead Trout

Two weeks (or strata) had zero recaptures (primarily due to low sample sizes for marked fish) and the seasonal trap efficiency was inserted into those weeks.

The population estimate (or production) of 2+ steelhead trout emigrating from upper Redwood Creek in YR 2005 equaled 2,364 with a 95% CI of 1,933 - 2,796. Population estimate error (or uncertainty) equaled ± 18.2%. Population emigration in YR 2005 was lower than emigration in YR 2004 (N = 5,778) by 59% and the previous five year average (N_{av5yr} = 6,667) by 64%.

Correlation of time (study year) on yearly population estimates showed a non-significant negative relationship (p = 0.28, r = 0.52, power = 0.16) (Figure 13).

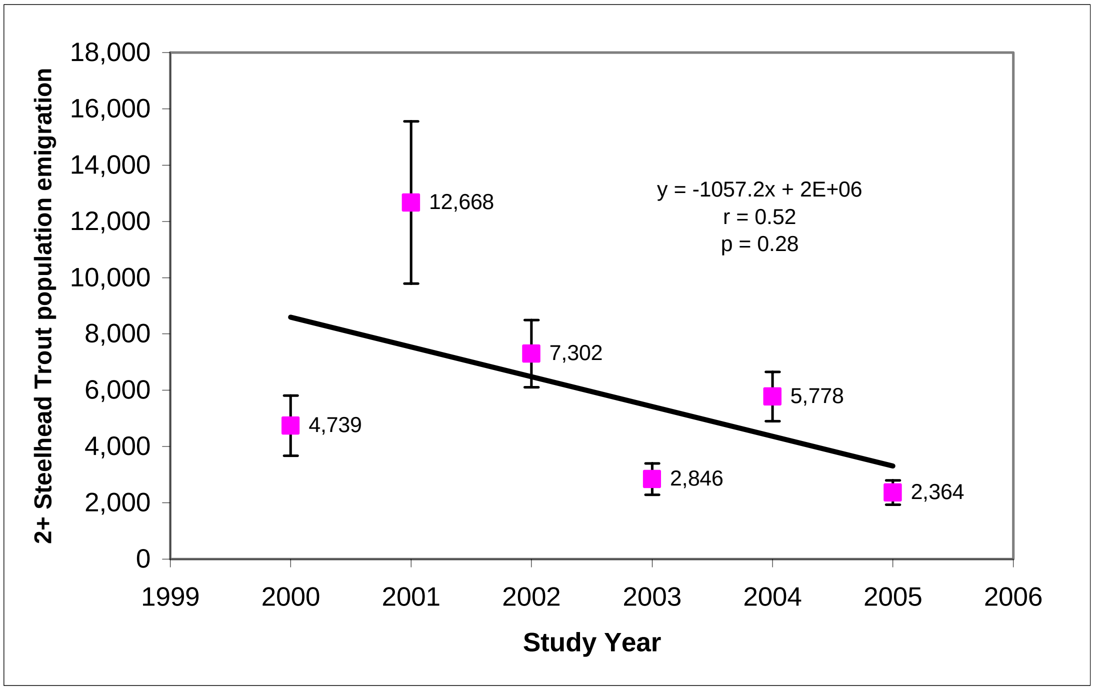

Figure 13. 2+ steelhead trout population emigration (error bars are 95% confidence interval) in six consecutive years. Numeric values next to box represent number of individuals. Line of best fit is a regression line with corresponding equation, correlation value (r), and p value.

The number of 2+ steelhead trout (at population level) per mile, kilometer, and watershed acreage upstream of the trap site in YR 2005 was 60 - 64% less than values for the previous five year average (Table 14). Highest values occurred in YR 2001 and lowest values occurred in YR 2005.

Table 14. Estimated number of 2+ steelhead trout per stream mile, stream kilometer, and watershed acreage upstream of the trap site, YRS 2000-2005.

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
Average:	180	112	0.10
2005	64	40	0.04

2+ steelhead trout monthly population emigration in YR 2005 was less than each month of the previous five year average except for August (Figure 14). The highest emigration in YR 2005 occurred in April (55.2% of total) compared to May (34% of total) for the previously averaged data. The percentage emigrating April - June in YR 2005 (84%) was similar to the previous five year average for those months (88%).

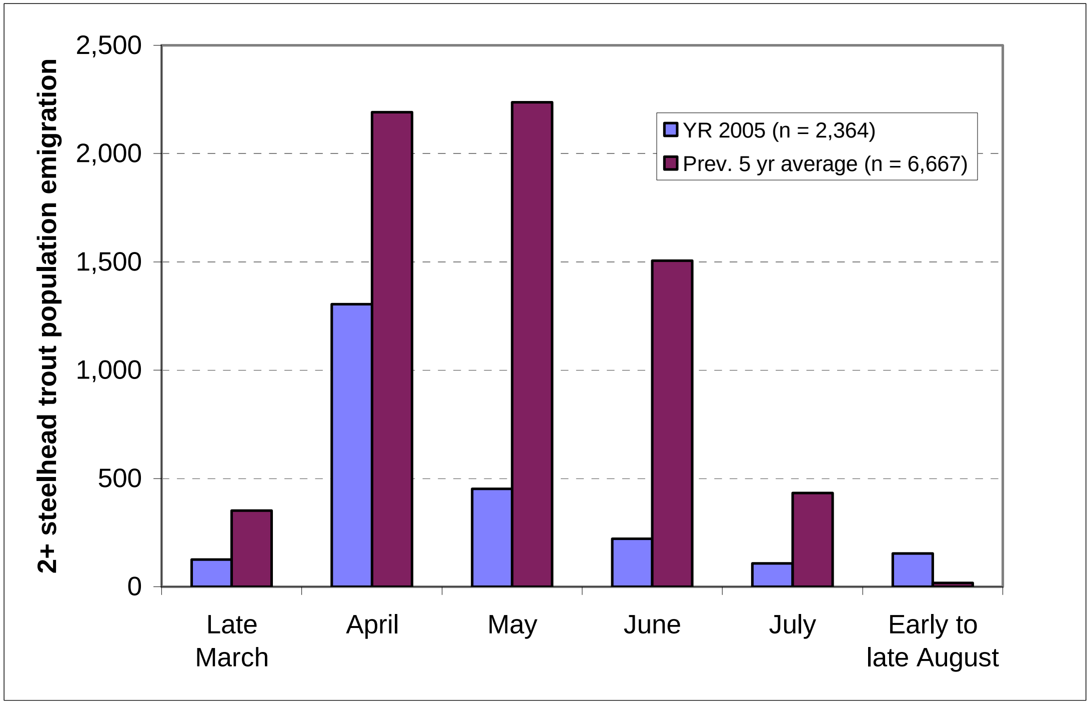

Figure 14. Comparison of 2+ steelhead trout population emigration by month in YR 2005 with the previous five year average, upper Redwood Creek, Humboldt County, CA.

Peaks in 2+ steelhead trout emigration occurred during April (YRS 2000, 2002 and 2005) or May (YRS 2001, 2003, and 2004) (Table 15).

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

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

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

0+ Chinook salmon weekly population emigration was positively related to the stream gage height and stream discharge ($p < 0.05$ for each test), and negatively related to stream temperature and week number ($p < 0.05$ for each test) (Appendix 5). Models with gage height or stream discharge each explained 30% of the variation in population emigration over time (Appendix 5).

1+ steelhead trout weekly population emigration was positively related to the stream gage height and stream discharge ($p < 0.05$ for both tests), and negatively related to stream temperature and week number ($p < 0.05$ for both tests) (Appendix 5). Models with gage height or stream discharge explained 37 and 32%, respectfully, of the variation in population emigration (Appendix 5). Stream temperature explained slightly more of the variation ($R^2 = 0.39$). The correlation of week number with emigration ($r = 0.72$, or $r^2 = 0.52$) determined that 52% of the variation in emigration can be associated with trapping week number.

2+ steelhead trout weekly population emigration was also positively related to the stream gage height and stream discharge ($p < 0.05$ for both tests), and negatively related to stream temperature and week number ($p < 0.05$ for both tests) (Appendix 5). Models with gage height or stream discharge explained 32 and 36%, respectfully, of the variation in population emigration (Appendix 5). Stream temperature explained slightly more of the variation ($R^2 = 0.44$; or 44%). The correlation of week number with emigration ($r = 0.73$, or $r^2 = 0.53$) determined that 53% of the variation (in emigration) can be associated with week number.

Age Composition of Juvenile Steelhead Trout

The following percentages represent maximum values for 1+ and 2+ steelhead trout because their population estimates were compared to catches of 0+ steelhead trout (ie the actual catches of 0+ steelhead trout are less than expected 0+ steelhead trout population out-migration). Far more 0+ steelhead trout migrated downstream than either 1+ or 2+ steelhead trout on a percentage basis (Table 16). In YR 2005, the ratio of 0+ steelhead trout to 1+ steelhead trout to 2+ steelhead trout equaled 18:11:1 compared to the previous five year average ratio of 15:7:1. The ratio of 1+ steelhead trout to 2+ steelhead trout was 11:1 in YR 2005, and 7:1 for the previous five year average.

Table 16. Comparison of 0+ steelhead trout, 1+ steelhead trout, and 2+ steelhead trout percent composition of total juvenile steelhead trout downstream migration in YR 2005 and the previous five 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
2005	59.3	37.3	3.4
Prev. 5 yr ave.	67.0	28.6	4.4
All years combined	66.4	29.3	4.3

* Uses actual catches instead of population estimate.

Fork Lengths and Weights

0+ Chinook Salmon

We measured (FL mm) 2,489 and weighed (g) 1,751 0+ Chinook salmon in YR 2005 (Table 17). Excluding YR 2003, average FL and Wt in YR 2005 was greater than the average for each previous study year, and the average of previous four study years (excludes YR 2003).

Average FL and Wt did not significantly change over study years 2000 - 2002, 2004 and 2005 (Correlation: FL, $p = 0.56$, $r = 0.36$, slope is positive, power = 0.08; Wt, $p = 0.37$, $r = 0.52$, power = 0.12). Linear regression detected a significant negative relationship of population estimate on average FL ($p = 0.03$, $R^2 = 0.83$, power = 0.72) and average Wt ($p = 0.02$, $R^2 = 0.88$, power = 0.86), which suggests a density-dependent relationship.

Table 17. 0+ Chinook salmon population estimates, and average fork length (mm) and weight (g) for study YRS 2000 - 2005, upper Redwood Creek, Humblodt County, CA.

	0+ Chinook Salmon						
		Fork Length (mm)			Weight (g)		
Study Year	(N)*	n	Ave.	SEM	n	Ave.	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
4 yr ave.**			52.7			1.77	
2005	39,614	2,489	60.4	0.3	1,751	3.09	0.05

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

Average weekly FL (mm) significantly increased over time (weeks) in YR 2005 and for the four year average (Correlation, $p = 0.000001$, $r = 0.99$, power = 1.0 for each test) (Figure 15). The increases in average FL over time show growth was taking place, and from 4/09/05 – 7/29/05 0+ Chinook salmon grew 0.41 mm/d.

Kruskal-Wallis One-Way ANOVA on Ranks showed that the median weekly FL in YR 2005 (60.2 mm) was not significantly different than the median weekly FL of the four year average (52.6 mm) ($p = 0.35$).

Average weekly Wt (g) significantly increased over time (weeks) in YR 2005 and for the four year average (Correlation, $p = 0.000001$, $r = 0.97$ and 0.98, power = 1.0) (Figure 16). The increases in average Wt over time show growth was taking place, and from 4/09/05 – 7/29/05 0+ Chinook salmon grew 0.05 g/d.

The average weekly Wt (g) (2.70 g) in YR 2005 was not significantly different than the average weekly Wt (1.77 g) for the previous four year average (excludes YR 2003) (ANOVA, $p > 0.05$, power = 0.40).

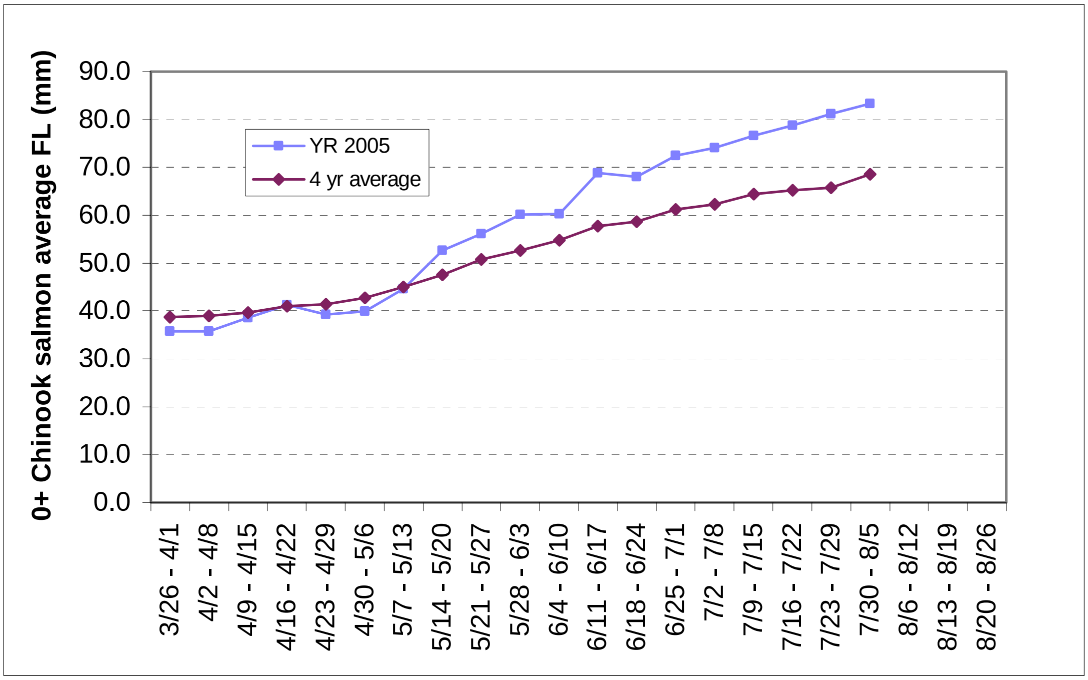

Figure 15. 0+ Chinook salmon average weekly fork lengths (mm) in YR 2005 and the average of four years, upper Redwood Creek, Humboldt County, CA.

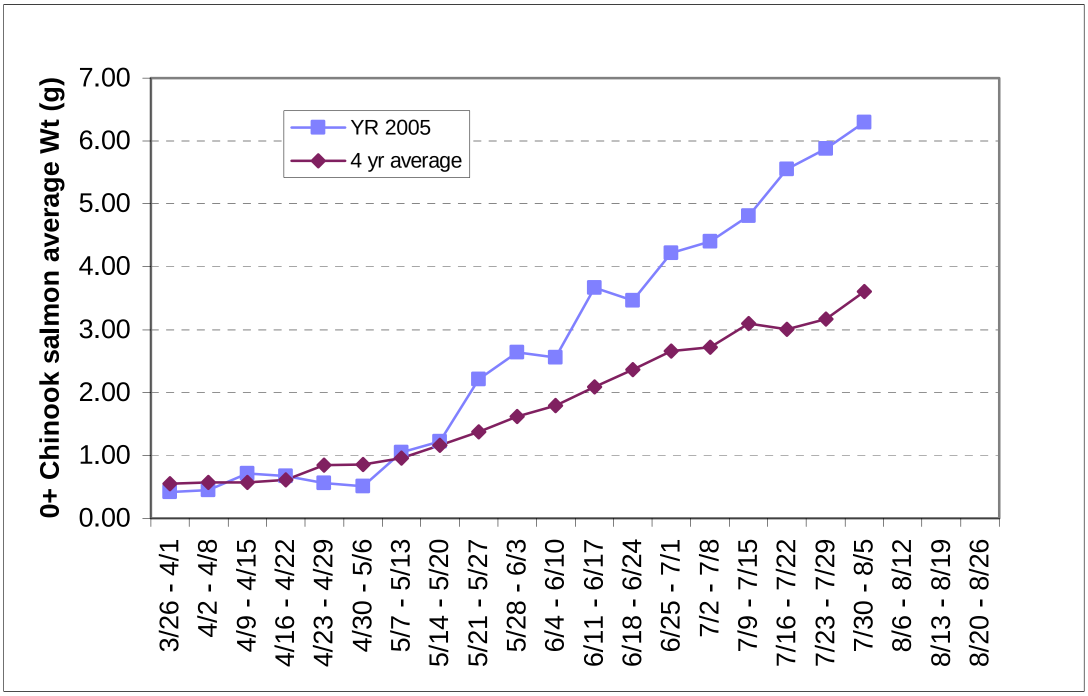

Figure 16. 0+ Chinook salmon average weekly weights (g) in YR 2005 and the average of four years, upper Redwood Creek, Humboldt County, CA.

0+ Steelhead Trout

We measured (FL mm) 3,661 0+ steelhead trout in YR 2005 (Table 18). Average FL in YR 2005 was greater than previous study years (Table 18).

Table 18. 0+ steelhead trout total catch and average fork length (mm) for study years 2000 - 2005, upper Redwood Creek, Humboldt County, CA.

	0+ Steelhead Trout						
		Fork Length (mm)			Weight (g)		
Study Year	(Catch)	n	Ave.	SEM	n	Ave.	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	-	-	-
5 yr ave.			38.9			-	
2005	41,671	3,661	42.3	0.2			

Average FL did not significantly change over the six study years (Correlation, $p = 0.90$, $r = 0.07$, slope is positive, power = 0.05). Linear regression detected a significant negative relationship of seasonal catch on average FL by season ($p = 0.002$, $R^2 = 0.93$, power = 1.0), which suggests a density-dependent relationship.

Average weekly FL (mm) significantly increased over time (weeks) in YR 2005 (Correlation, $p = 0.000001$, $r = 0.92$, power = 1.0) and for the previous five year average (Correlation, $p = 0.000001$, $r = 0.98$, power = 1.0) (Figure 17). The increases in average weekly FL over time show growth was taking place.

Kruskal-Wallis One-Way ANOVA on Ranks showed that the median weekly FL in YR 2005 (32.2 mm) was not significantly different than the median weekly FL of the five year average (35.4 mm) ($p = 0.53$).

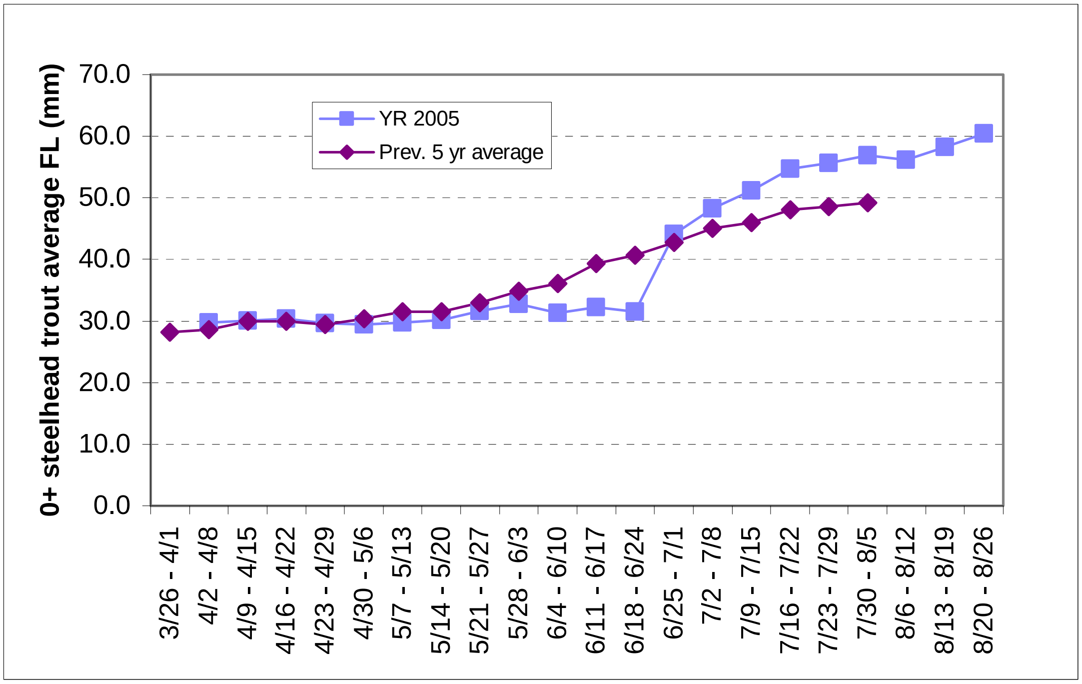

Figure 17. 0+ steelhead trout average weekly fork lengths (mm) in YR 2005 and the previous five year average, upper Redwood Creek, Humboldt County, CA.

1+ Steelhead Trout

We measured (FL mm) 2,473 and weighed (g) 1,592 1+ steelhead trout in YR 2005 (Table 19). Average FL and Wt in YR 2005 was nearly equal to the average of the previous five study years (Table 19).

Average FL and Wt did not significantly change over study years 2000 - 2005 (Correlation: FL, p = 0.12, r = 0.70, slope is negative, power = 0.33; Wt, p = 0.29, r = 0.52, slope is negative, power = 0.16). Linear regression detected a significant positive relationship of population estimate on average FL (p = 0.07, R^2 = 0.61, power = 0.48), and a non-significant positive relationship for average Wt (p = 0.29, R^2 = 0.27, power = 0.16).

Table 19. 1+ steelhead trout population estimates, and average fork length (mm) and weight (g) for study years 2000 - 2005, upper Redwood Creek, Humboldt County, CA.

	1+ Steelhead Trout						
		Fork Length (mm)			Weight (g)		
Study Year	(N)*	n	Ave.	SEM	n	Ave.	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
5 yr ave.			88.3			8.01	
2005	26,176	2,473	88.1	0.2	1,592	8.02	0.09

* "N" denotes emigrant population size; "n" denotes sample size for FL and Wt.

1+ steelhead trout average weekly FL (mm) did not significantly change over time (weeks) in YR 2005 (Correlation, $p = 0.13$, $r = 0.33$, slope is positive, power = 0.33). The average FL (mm) by week for the previous five year average positively changed over time (Correlation, $p = 0.008$, $r = 0.59$, slope is positive, power = 0.80) (Figure 18).

As expected, single factor ANOVA showed that the average weekly FL in YR 2005 (88.6 mm) was not significantly different than the average weekly FL for the previous five year average (88.4 mm) ($p = 0.92$).

1+ steelhead trout average weekly Wt (g) significantly decreased over time (weeks) in YR 2005 (Correlation, $p = 0.04$, $r = 0.44$, slope is negative, power = 0.56) and for the five year average, average Wt (g) significantly increased over time (Correlation, $p = 0.001$, $r = 0.68$, slope is positive, power = 0.95) (Figure 19).

Similar to FL comparisons, single factor ANOVA showed that the average weekly Wt in YR 2005 (8.24 g) was not significantly different than the average weekly Wt for the previous five year average (8.38 g) ($p = 0.75$, power = 0.06).

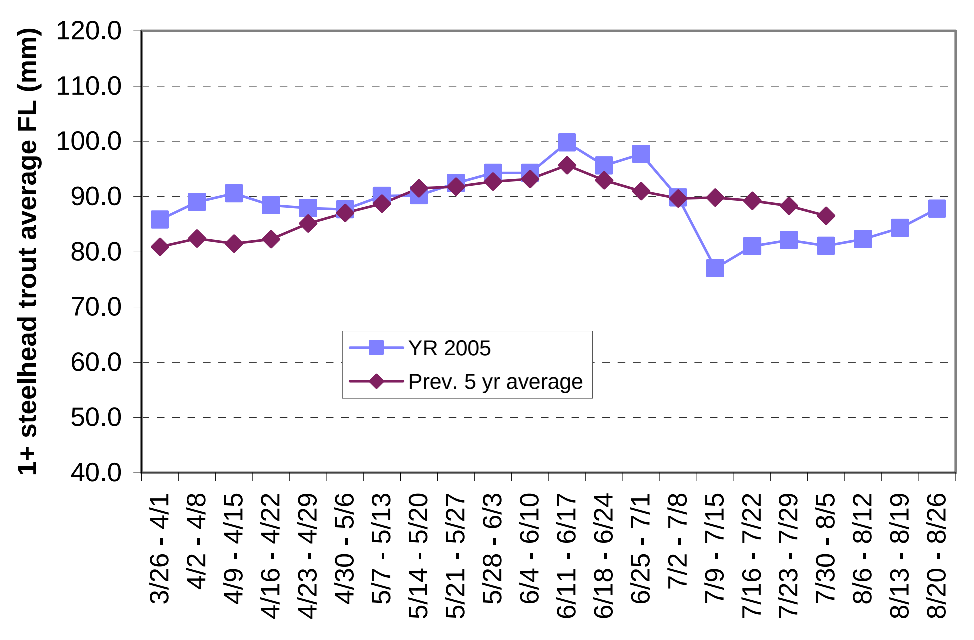

Figure 18. 1+ steelhead trout average weekly fork lengths (mm) in YR 2005 and the previous five year average, upper Redwood Creek, Humboldt County, CA.

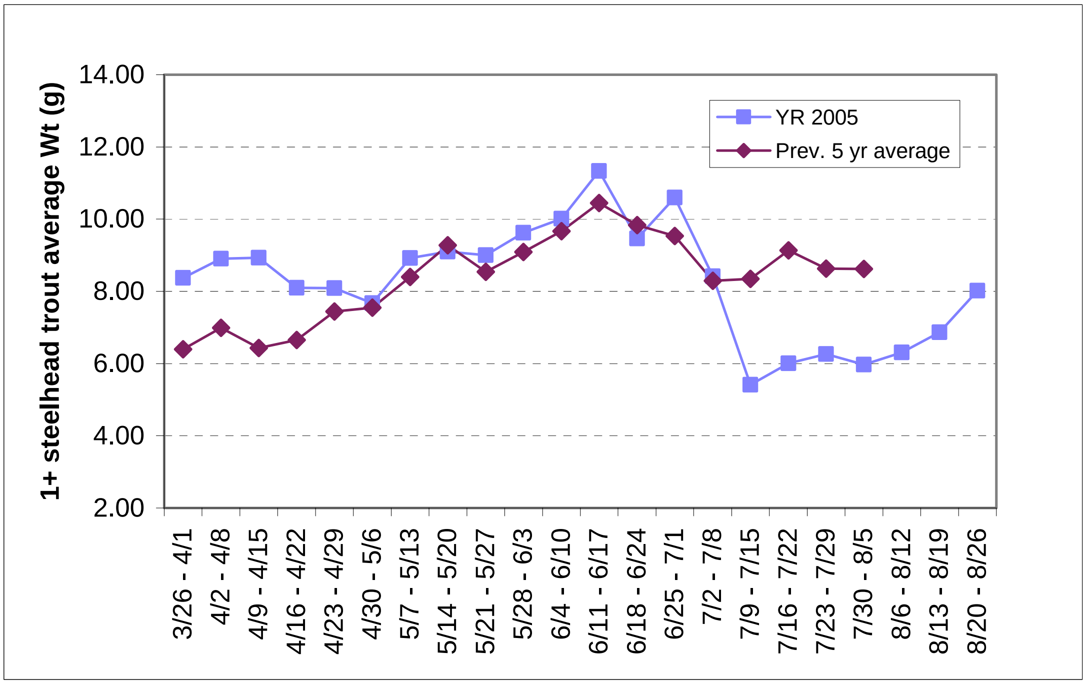

Figure 19. 1+ steelhead trout average weekly weights (g) in YR 2005 and the previous five year average, upper Redwood Creek, Humboldt County, CA.

2+ Steelhead Trout

We measured (FL mm) 594 and weighed (g) 592 2+ steelhead trout in YR 2005 (Table 20). Average FL and Wt in YR 2005 was nearly equal to the previous five year average (Table 20). Average FL and Wt over study years 2000 - 2005 did not significantly change (Correlation: FL, p = 0.15, slope is negative, r = 0.67, power = 0.28; Wt, p = 0.18, r = 0.63, power = 0.24). Linear regression detected a non-significant relationship of population estimate on average FL (p = 0.95, R^2 = 0.00, slope is positive, power = 0.05) and average Wt (p = 0.95, R^2 = 0.00, 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 - 2005, upper Redwood Creek, Humboldt County, CA.

	2+ Steelhead Trout						
		Fork Length (mm)			Weight (g)		
Study Year	(N)*	n	Ave.	SEM	n	Ave.	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
5 yr ave.			150.2			39.35	
2005	2,364	594	150.5	0.2	592	39.90	0.91

* "N" denotes emigrant population size; "n" denotes sample size for FL and Wt.

2+ steelhead trout average weekly FL (mm) did not significantly change over time (weeks) in YR 2005 (Correlation, p = 0.07, r = 0.39, slope is positive, power = 0.43). Average FL (mm) by week for the previous five year average significantly decreased over time (Correlation, p = 0.04, r = 0.49, slope is negative, power = 0.59) (Figure 20). Median weekly FL in YR 2005 (142.4 mm) was not significantly different than the median weekly FL for the previous five year average (150.0 mm) (Kruskal-Wallis One-Way ANOVA on Ranks, p = 0.07).

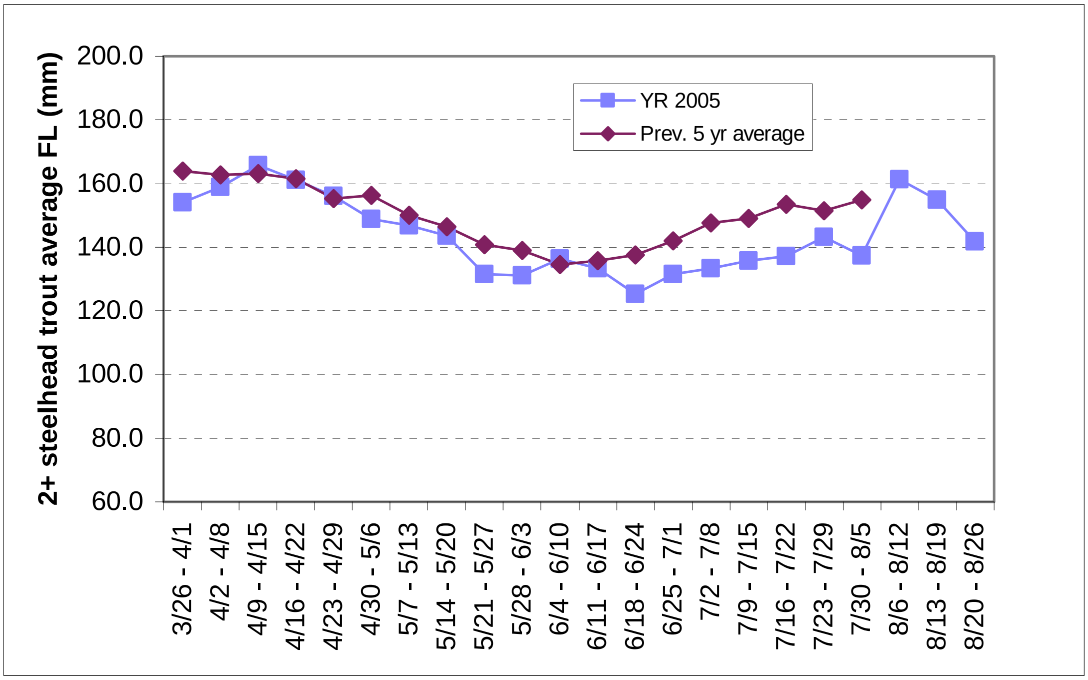

Figure 20. 2+ steelhead trout average weekly fork lengths (mm) in YR 2005 and the previous five year average, upper Redwood Creek, Humboldt County, CA.

2+ steelhead trout average weekly Wt (g) did not significantly change over time (weeks) in YR 2005 (Correlation, p = 0.09, r = 0.37, slope is negative, power = 0.39); and for the previous five year average, average Wt (g) significantly decreased over time (Correlation, p = 0.03, r = 0.50, slope is negative, power = 0.61) (Figure 21).

Single factor ANOVA determined that the average weekly Wt in YR 2005 (35.25 g) was not significantly different than the average weekly Wt for the previous five year average (38.97 g) (p = 0.15, power = 0.30).

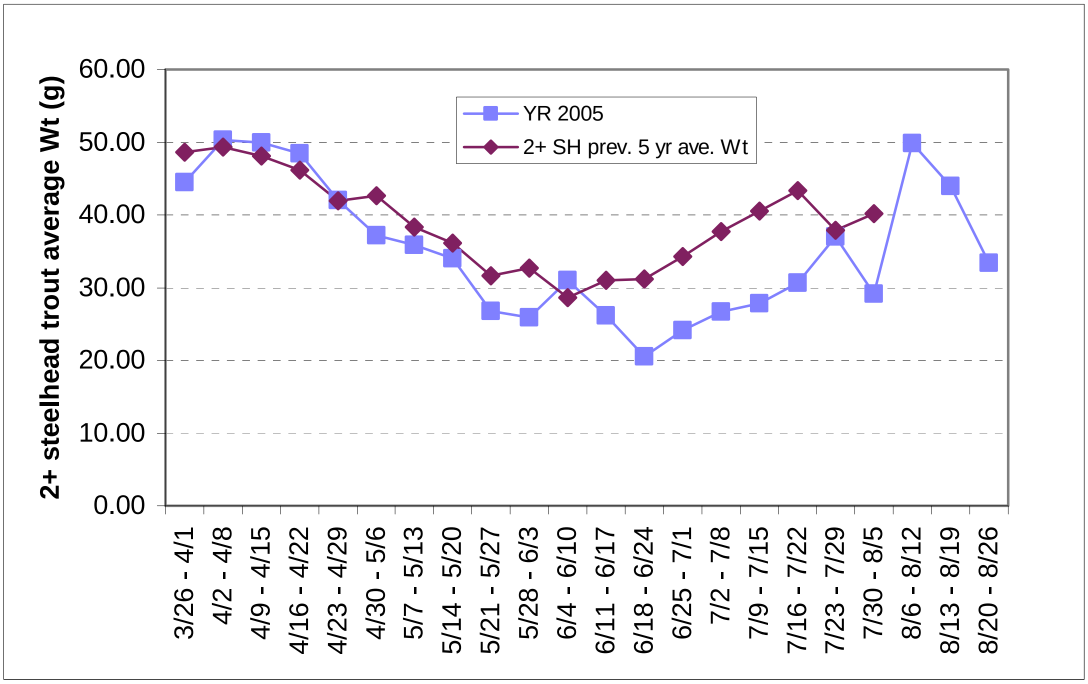

Figure 21. 2+ steelhead trout average weekly weights (g) in YR 2005 and the previous five year average, upper Redwood Creek, Humboldt County, CA.

Developmental Stages

1+ and 2+ Steelhead Trout

There was an obvious non-random distribution of parr, pre-smolt, and smolt designations (developmental stages) for 1+ and 2+ steelhead trout captured in YR 2005 and for the previous five year average (Table 21). Contingency tests (2x2) showed that there were significant differences in the proportions of pre-smolt and smolt designations for 1+ steelhead trout and 2+ steelhead trout in YR 2005 with the previous five year average (Chi-square, $p < 0.000001$; power = 1.00 for each test). For both tests (1+SH and 2+SH) there were comparatively more smolt designations in YR 2005. Using data by year (not given), the percentage of 1+ steelhead trout smolts in a given study year was not related to population size or size of fish (FL, Wt) (Regression, $p > 0.10$); however, smolt percentages were positively related to stream discharge (Regression, p = 0.06, $R^2 = 0.63$, power = 0.50, n = 6) and negatively related to stream temperature (Regression, p = 0.03, $R^2 = 0.82$, power = 0.70, n = 6). For 2+ steelhead trout, the percentage of smolts in a given year was inversely related to population size (Regression, p = 0.07, $R^2 = 0.59$, power = 0.45, n = 6), and inversely related to stream temperature (Regression, p = 0.09, $R^2 = 0.65$, power = 0.37, n = 6). No relationships were found with average fish size or average stream discharge ($p > 0.10$). The combined percentage of pre-smolts and smolts for 1+ steelhead trout and 2+ steelhead trout in YR 2005 and for the previous five year average was nearly 100% (Table 21).

Table 21. Developmental stages of captured 1+ and 2+ steelhead trout in YR 2005 and the previous five 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
2005	< 0.1	13.6	86.4	0.0	0.6	99.4
5 yr ave.*	4.4	70.2	25.4	0.1	28.6	71.3

* Study years 2000 – 2004.

Additional Experiments

Re-migration

We did not recapture any of the 1+ and 2+ steelhead trout marked with elastomer (n = 800) in YR 2004 in YR 2005. To date (including elastomer marked releases in YR 2001, n = 374), we have found no evidence of 1+ and 2+ steelhead trout re-migrating upstream of the trap site to be caught moving downstream the following year.

Travel Time and Growth

0+ Chinook Salmon

We recaptured 27 pit tagged 0+ Chinook salmon smolts released from the upper trap site at the lower trap (Sparkman 2006). Initial fork lengths of recaptured fish ranged from 70 - 90 mm and averaged 80 mm (Appendix 6). Time to travel the 29 miles between traps ranged from 1.5 - 19.5 d and averaged 7.5 d (median = 5.5 d). Travel time was not significantly related to FL or Wt at time 1 or time 2, stream temperature, or stream discharge (Regression, $p > 0.05$ for all tests, $n = 27$).

Travel rate ranged from 1.5 - 19.3 mi/d (2.4 – 31.1 km/d) and averaged 8.2 mi/d (13.2 km/d) (median = 5.3 mi/d or 8.5 km/d). Travel rate was weakly related to FL at time 1 (Regression, $p = 0.01$, $R^2 = 0.24$, slope is positive, power = 0.76, $n = 27$) and Wt at time 1 (Regression, $p = 0.006$, $R^2 = 0.27$, slope is positive, power = 0.83); no significant relationships were found with stream temperature, stream discharge or fish size at time 2 (Regression, $p > 0.05$ for each test).

Multiple fish released from the same release group were recaptured at the lower trap on the same day (n = 5 recaptures). In contrast, most fish that were released at the same time (as a group) were recaptured on varying dates, and travel time for recaptured individuals (n = 5) for the 7/21/05 release group ranged from 4.5 - 19.5 days (Appendix 6). The size of recaptured pit tagged 0+ Chinook salmon at time 2 (recapture day) was positively related to initial size at release (Regression, FL: $p = 0.000001$, $R^2 = 0.67$, power = 1.0; Wt: $p = 0.00001$, $R^2 = 0.62$, power = 1.0).

Fourteen (52%) of the 27 recaptured 0+ Chinook salmon showed positive growth in FL and Wt, five (18%) showed a decrease in Wt, and none of the recaptures showed a decrease in FL. Thirteen individuals (48%) showed no change in FL and eight individuals did not experience a change in Wt (30%) (Appendix 7). On average, the 0+ Chinook salmon experienced a positive percent change in size of 3.6% for FL and 9.6% for Wt (Appendix 8). The 0+ Chinook salmon showed, on average, positive growth in FL for absolute growth rate (Ave. = 0.22 mm/d), relative growth rate (Ave. = 0.003 mm/mm/d), and specific growth rate scaled [Ave. = 0.279 %(mm/d)] (Appendix 8). The 0+ Chinook salmon averaged an absolute growth rate in Wt of 0.00 g/d, a relative growth rate of 0.001 g/g/d and a specific growth rate scaled of 0.003 %(g/d) (Appendix 8).

The relationship of travel time on various FL and Wt growth indices was significant and positive (Appendix 9). Travel time explained more of the variation in growth than any other variable tested (Appendix 9 and Figure 22).

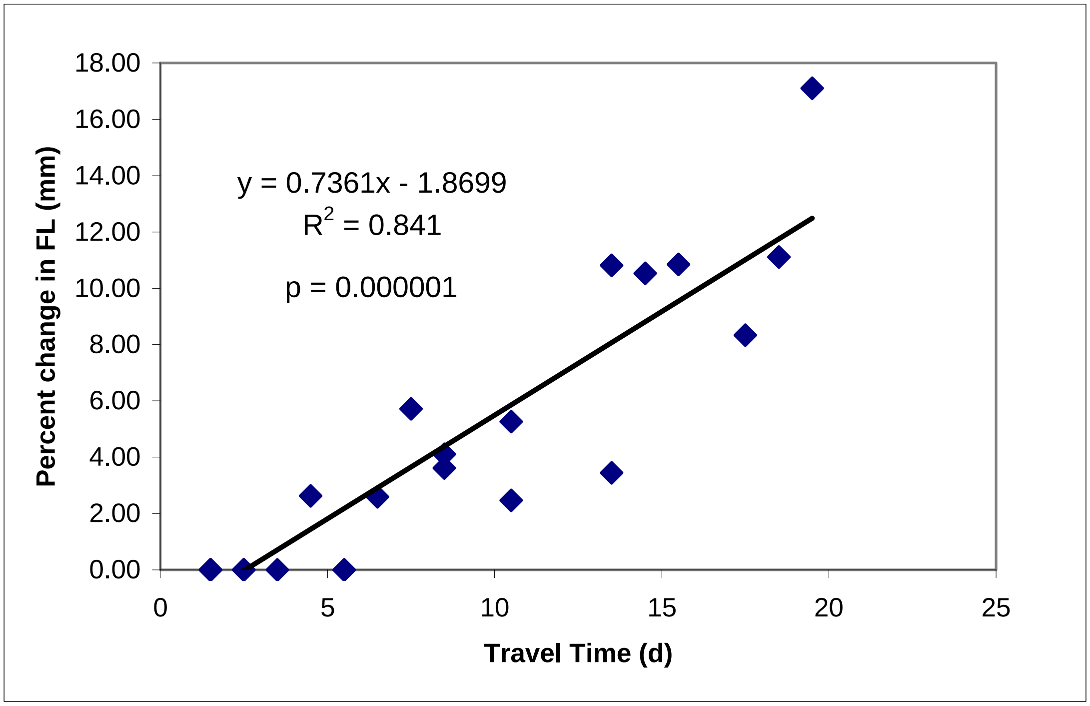

Figure 22. Linear regression of travel time (d) on percent change in FL (mm) for pit tagged 0+ Chinook salmon recaptured at the lower trap in Redwood Creek, Humboldt County, CA. 2005. Although 27 data points were used in the regression, only 18 are visible due to symbol overlap.

Separate growth statistics were determined for recaptured pit tagged 0+ Chinook salmon individuals showing either positive (n = 14) or negative growth (n = 5) (Table 22). On average, the pit tagged Chinook salmon absolute growth rate equaled 0.428 mm per day for FL, and 0.094 g per day for Wt (Table 22).

Table 22. Growth statistics for recaptured pit tagged 0+ Chinook salmon that showed positive (n = 14) or negative (n = 5) growth, Redwood Creek, Humboldt County, CA., 2005.

	Positive Growth							
	% Change in:		AGR*		SGRsc*		RGR*	
	FL	WT	FL	WT	FL	WT	FL	WT
Min.	2.47	4.20	0.190	0.020	0.232	0.312	0.002	0.003
Max.	17.11	46.04	0.670	0.270	0.810	3.177	0.009	0.033
Ave.	**7.04**	**20.75**	**0.428**	**0.094**	**0.538**	**1.546**	**0.006**	**0.017**
SD	4.46	16.03	0.142	0.063	0.182	0.744	0.002	0.009

	Negative Growth							
	% Change in:		AGR		SGRsc		RGR	
	FL	WT	FL	WT	FL	WT	FL	WT
Min.	-	-5.09	-	-0.190	-	-3.481	-	-0.034
Max.	-	-7.66	-	-0.390	-	-5.315	-	-0.051
Ave.	**-**	**-6.26**	**-**	**-0.286**	**-**	**-4.312**	**-**	**-0.042**
SD	-	0.95	-	0.076	-	0.677	-	0.006

* AGR = absolute growth rate (FL mm/d; Wt g/d), SGR = specific growth rate scaled [FL %(mm/d); Wt %(g/d)], RGR = relative growth rate (FL mm/mm/d; Wt g/g/d).

1+ and 2+ Steelhead Trout

We recaptured one 2+ steelhead trout marked with elastomer and a partial upper caudal fin clip, and three 1+ steelhead trout marked with elastomer in YR 2005 at the lower trap in YR 2005 (Table 23) (Sparkman 2006). The 2+ steelhead trout was not a re-migrating fish (1+SH) from YR 2004 because the partial fin clip was fresh, and showed no signs of regeneration. We also captured two pit tagged 1+ steelhead trout at the lower trap which were released at the upper trap (Table 23). Travel time for the single 2+ steelhead trout was 7 d, as compared to the average travel time for 1+ steelhead trout of 12 d (n = 5, SD = 13.3). The range in travel time for 1+ steelhead trout was 2 - 35 d, and the range in travel rate was 0.8 - 14.5 miles per day (Table 23).

One of the recaptured pit tagged steelhead trout showed growth during the 29 mile migration (initial size = 71 mm). This fish experienced a percent change in FL and Wt of 7.0 and 39.7%, an absolute growth rate of 0.43 mm/d and 0.11 g/d, a specific growth rate (scaled) of 0.257 %(mm/d) and 1.262 %(g/d), and a relative growth rate of 0.006 mm/mm/d and 0.035 g/g/d.

Table 23. Travel time (d) and travel rate (mi/d) results for 2+ steelhead trout and 1+ steelhead trout released at the upper trap site and recaptured at the lower trap (distance of 29 miles) in Redwood Creek, Humboldt County, CA., 2005.

Travel Time Experiments						
Age/species	Initial FL mm	Mark or Tag type	Date Released*	Date Recaptured**	Travel time (d)	Travel rate (mi/d)
2+ SH	-	Elastomer	5/28/05	6/04/05	7.0	4.1
	-					
1+ SH	-	Elastomer	4/28/05	4/30/05	2.0	14.5
1+ SH	-	Elastomer	4/28/05	6/02/05	35.0	0.8
1+ SH	-	Elastomer	5/05/05	5/15/05	10.0	2.9
1+ SH	89	Pit Tag	6/02/05	6/06/05	3.5	8.3
1+ SH	71	Pit Tag	7/14/05	7/26/05	11.5	2.5

* Released at upper trap (RM 33). Elastomer fish were released in the morning, pit tag fish were released at night.

** Recapture at lower trap (RM 4).

Delayed Mortality

0+ Chinook Salmon

A total of 28 delayed mortality experiments were conducted with 0+ Chinook salmon (n = 633) in YR 2005 (Appendix 10). The single fish that died during a partial fin clipping test occurred during a storm event and subsequent increase in stream discharge. A total of 555 0+ Chinook salmon were given pit tags (along with FL and Wt measurements, and a small partial upper caudal fin clip) and held for a 34 hour period prior to release. None of the pit tag fish died during the experiments.

1+ Steelhead Trout

A total of 31 delayed mortality experiments were conducted with 1+ steelhead trout (n = 379) in YR 2005 (Appendix 11). Aside from two immediate mortalities from injecting elastomer, no delayed mortalities attributable to fin clipping, pit tagging, or applying elastomer occurred over a 24 or 34 hour period (Appendix 11).

2+ Steelhead Trout

A total of 41 delayed mortality experiments were conducted with 2+ steelhead trout (n = 120) in YR 2005 (Appendix 12). No mortalities attributable to fin clipping, pit tagging, or applying elastomer occurred over a 24 or 34 hour period.

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 2005 ranged from 0.00 - 0.75%, and using all data, was 0.65% of the total captured and handled (Table 24). This level of trap mortality is very low, and considered negligible.

Juvenile salmonid trapping mortality in YR 2005 (0.65%) fell within the range for study years 2000 - 2004, and was slightly higher than the average for the previous five years by 0.20% (Table 25).

Table 24. Trapping mortality for juvenile salmonids captured in YR 2005, upper Redwood Creek, Humboldt County, CA.

	Trap Mortality in YR 2005		
Age/spp.	No. captured	No. of mortalities	Percent mortality
0+ Chinook	9,329	52	0.56
0+ Steelhead	41,671	312	0.75
1+ Steelhead	4,912	5	0.10
2+ Steelhead	628	1	0.16
Cutthroat trout	2	0	0.00
Overall:	56,542	368	0.65

Table 25. Comparison of trapping mortality of juvenile salmonids in six 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
Average (2000-04)			0.45

Stream Temperatures

The average daily (24 hr period) stream temperature from 3/26/05 – 8/26/05 was 14.56 ^{o}C (or 58.2 ^{o}F) (95% CI = 13.80 – 15.32 ^{o}C), with daily averages ranging from 7.10 – 22.40 ^{o}C (44.8 – 72.3 ^{o}F). In 2005, the average daily stream temperature exceeded 20 ^{o}C (68 F) for 40 d (26%) out of 154 d of record. The average daily stream temperature in YR 2005 from 3/26/05 – 8/05/05 (truncated to compare with other study years) was 13.54 ^{o}C (56.4 ^{o}F) (Table 26). Average stream temperature during the trapping period in YR 2005 was lower than other study years (Table 26).

The average stream temperature during the majority of the trapping period for YRS 2001 – 2005 was inversely related to the average discharge during the trapping period (Regression, $p = 0.03$, $R^2 = 0.82$, slope is negative, power = 0.71).

Average monthly stream temperatures during the majority of the trapping season (April – July) in YR 2005 ranged from 9.2 – 19.4 ^{o}C (48.6 – 66.9 ^{o}F) (Table 27). Highest stream temperatures occurred in the later part of the trapping season (June, July, early August) each study year. No significant difference in average monthly steam temperature (^{o}C) among study years was detected (ANOVA, $p = 0.93$, power = 0.08).

Table 26. Stream temperatures (^oC) (standard deviation in parentheses) during the trapping period in YR 2005 and previous four years, upper Redwood Creek, Humboldt County, CA.

	Stream Temperature					
	Celsius			Fahrenheit		
Study Year	Ave.	Min.	Max.	Ave.	Min.	Max.
2001	16.3 (4.4)	5.7	28.2	61.3 (7.9)	42.3	82.8
2002	15.8 (4.4)	6.7	27.5	60.4 (8.0)	44.1	81.5
2003	14.7 (5.3)	6.1	28.4	58.4 (9.5)	43.0	83.1
2004	15.8 (4.6)	6.7	28.8	60.5 (8.2)	44.1	83.8
4 Yr. Ave*	15.6 (4.7)	5.7	28.8	60.1 (8.5)	42.3	83.8
2005**	13.5 (4.3)	6.2	25.8	56.4 (7.8)	43.2	78.4

* YR 2000 excluded due to incomplete coverage during trapping period.
** Data truncated for comparison.

Table 27. Average stream temperature (^oC) by month (^oF in parentheses) in study years 2001 - 2005, upper Redwood Creek, Humboldt County, CA.

	Average stream temperature in Celsius (^oF in parentheses)				
Month	YR 2001	YR 2002	YR 2003	YR 2004	YR 2005
April	9.4 (48.9)	10.7 (51.3)	8.5 (47.3)	10.6 (51.1)	9.2 (48.6)
May	15.1 (59.2)	13.1 (55.6)	11.2 (52.2)	13.8 (56.8)	11.6 (52.9)
June	17.5 (63.5)	18.0 (64.4)	17.2 (63.0)	17.7 (63.9)	13.4 (56.1)
July	20.9 (69.6)	21.3 (70.3)	21.1 (70.0)	21.6 (70.9)	19.4 (66.9)

The MWAT during the trapping period in YR 2005 at the trap site was 21.9 °C (71.4 °F) and occurred on 8/05/05 (Table 28). MWMT in YR 2005 was 25.7 °C (78.3 °F) and also occurred on 8/05/05 (Table 28).

Table 28. Maximum weekly average temperature (MWAT) and maximum weekly maximum temperature (MWMT) for stream temperatures °C (°F in parentheses) at the trap site in upper Redwood Creek, Humboldt County, CA., study years 2001 – 2005.

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

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

The average stream temperature increased over the study period in YR 2005 (Correlation, p = 0.000001, r = 0.95, slope is positive, power = 1.0) (Figure 23).

Similar to past study years, average daily stream temperature in YR 2005 was significantly related to the stream gage height at the trapping site (Regression, p = 0.000001, R^2 = 0.83, slope is negative, power = 1.0).

The minimum stream temperature in YR 2005 (not truncated) was 6.25 °C (43.2 °F) and occurred on 4/14/05; the maximum stream temperature was 26.3 °C (79.3 °F) and occurred on 8/07/05 (Figure 23).

The previous four year average stream temperature also increased over time (Correlation, p = 0.00001, r = 0.98, slope is positive, power = 1.0) (Figure 24). Median daily stream temperature in YR 2005 (13.3 °C) was not significantly different than the median (16.0 °C) for the previous four year average (Kruskall-Wallis One Way ANOVA on Ranks, p = 0.15).

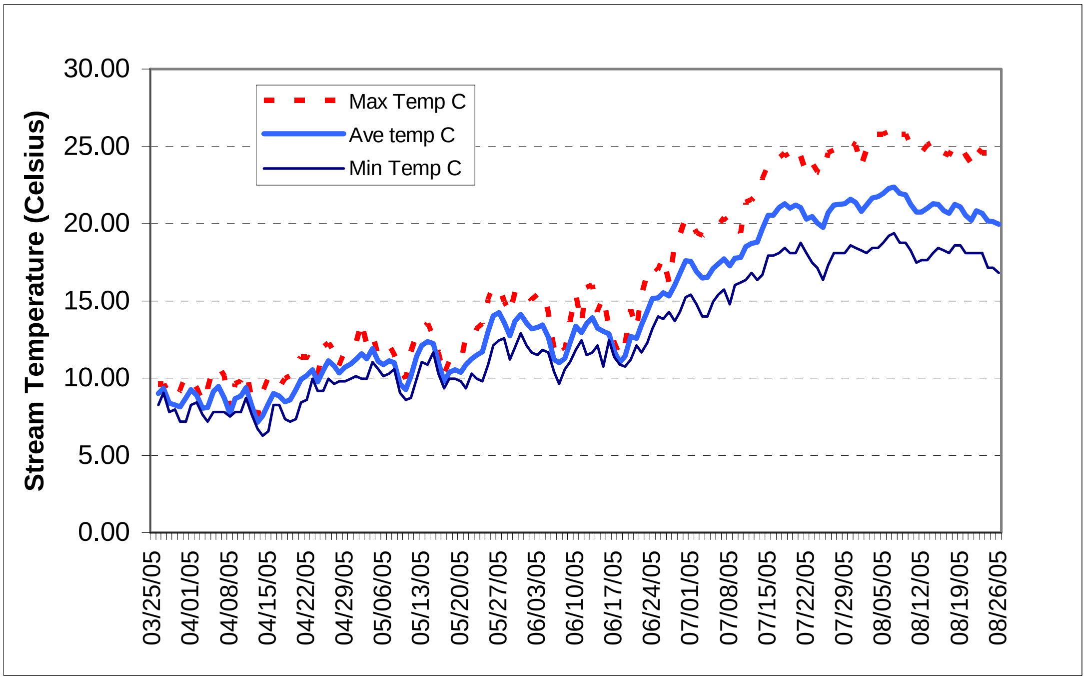

Figure 23. Average, minimum, and maximum stream temperatures (^{o}C) at trapping site, upper Redwood Creek, Humboldt County, CA., 2005.

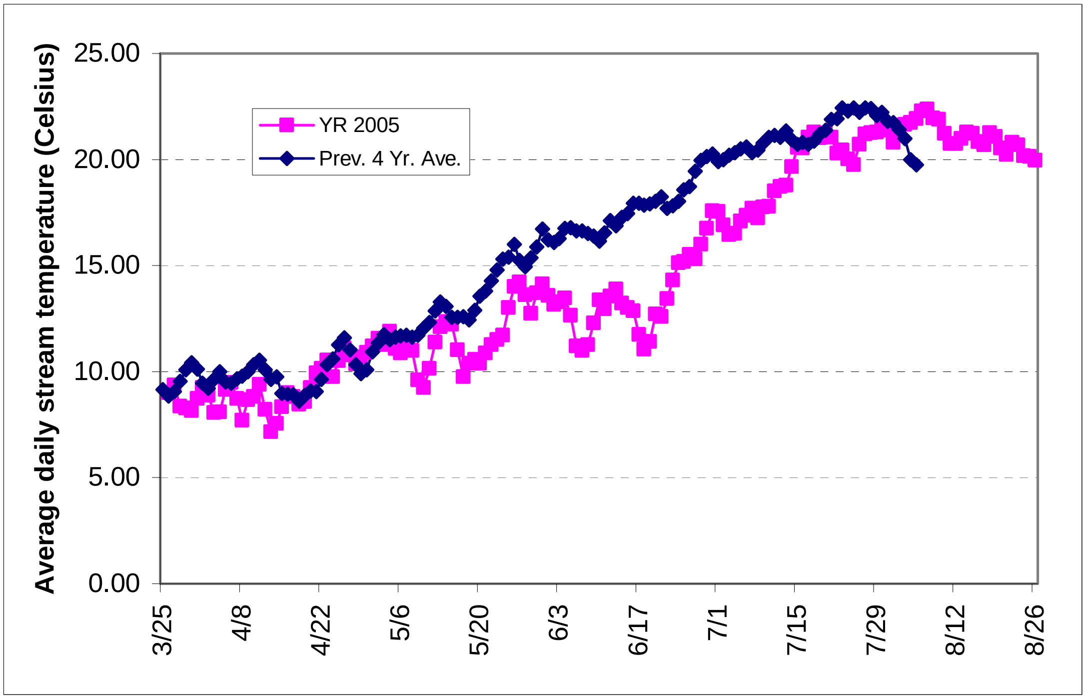

Figure 24. Comparison of the average daily stream temperature (^{o}C) in YR 2005 with the previous four year average, upper Redwood Creek, Humboldt County, CA.

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). 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 sixth consecutive year of trapping in upper Redwood Creek was a wet year, with average precipitation and stream flow during the trapping period greater than historic and recent averages. Precipitation during the trapping period (60.5 cm) was 2.3 times greater than the historic average, and 2.9 times greater than the previous five year average. In contrast with YR 2003 (also a wet year) when large amounts of rain fell in April, rainfall during the trapping period in YR 2005 fell in relatively large amounts during April, May, and June. In response, the average stream flow in which we operated the trap was about 2 times greater than the historic average, 2.4 times greater than the previous five year average, and slightly greater than the average for YR 2003. The increase in stream flow in YR 2005 led to cooler stream temperatures which in turn lowered the average stream temperature compared to other study years. High stream flow in YR 2005 also appeared to increase the summer base flow. The current six study years within which we have collected juvenile salmonid data encompass good variability in the stream environment, as evidenced by the range in physical variables (rainfall, stream flow, stream temperature).

Although conditions for trapping in YR 2005 were the most difficult of all prior seasons, we were able to operate the trap and run multiple efficiency trials over a range of trapping conditions to produce a reliable catch and population estimate for each species at age. The eight days we missed trapping were spread out over time with trappable days before and after a given event, which facilitated estimation techniques using linear regression. The estimates for catch and subsequent expansions to the population level, based on the missed trapping days, were negligible for each species at age; the greatest impact on a population estimate was estimated at 4.3%, and the adjusted point value easily fell within the 95% confidence interval of the un-adjusted point estimate. Thus, this season’s trapping resulted in very good estimates of wild Chinook salmon and steelhead trout emigration (production) from areas upstream of the trapping site.

0+ Chinook Salmon

0+ Chinook salmon (ocean-type) emigrating from upper Redwood Creek have dominated the trap’s catch for four out of six years. Low catches occurred in YRS 2003 and 2005, and the total catch in YR 2005 was 93% less than the average catch for the previous five years. 0+ Chinook salmon emigration at the population level was variable over the six consecutive years of study; the two lowest population estimates (YRS 2003 and 2005) followed years with the highest population estimate (YR 2002, N = 518,189; YR 2004, N = 629,847). The reduction in emigration in YR 2005 (90% reduction from previous five year average, 94% reduction of YR 2004 estimate) 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, 3) high bedload mobilizing flows in early December which scoured or jostled redd gravels, or 4) a combination of factors 1, 2, and 3.

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 from upper Redwood Creek. Since we currently do not count adults or have an index of adult escapement, I cannot say for certain that a major change in the spawning distribution did not occur, and was not reflected by low juvenile emigration from upper Redwood Creek in YR 2005. The emigrant population passing the rotary screw trap in lower Redwood Creek in YR 2005 (N = 127,350) does not give much supportive evidence because it too was greatly reduced (by 77%) compared to emigration in YR 2004 (Sparkman 2006). Data from the lower trap was able to show: 1) the severe decrease in 0+ Chinook salmon numbers was not limited to upper Redwood Creek, and included the entire Redwood Creek watershed upstream of where Prairie Creek enters Redwood Creek, and 2) production of 0+ Chinook salmon in YR 2005 was greater in areas downstream of the upper trap site. Unfortunately, peaks in stream flow measured in lower Redwood Creek in December 2004 were also high enough to mobilize the bedload and redd gravels (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 very low number of adults returning to areas upstream of the trap site would also result in a noticeable reduction in juvenile production. Unfortunately, stream flows during the months when adults returned in YRS 2002 and 2004 were high enough to obscure adult observations; and the high flows would also wash an unknown percentage of the carcasses downstream, thus giving the appearance that few fish returned to spawn in upper Redwood Creek. However, I cannot say for certain that few fish did or did not return to spawning areas upstream of the trap site in YRS 2002 and 2004 because we do not currently count adults.

At least some adult Chinook salmon were present in upper Redwood Creek in mid November 2004 because a female (with a male nearby) was observed in the initial act of redd construction. After the mouth of Redwood Creek opened to the ocean on October 23rd, adult fish were able to migrate upstream into upper Redwood Creek with the given stream flow (peak flow was 340 cfs). Returning adult salmon could not enter Redwood Creek from November 21 – 27 and November 29 – December 7 because the mouth was closed from the ocean (memo, Dave Anderson pers. com. 2005). Stream flows before, during, and after mouth closures in November appear to be great enough for adult fish to enter upper Redwood Creek (minimum flow was 16 cfs). Stream flows in upper Redwood Creek during most, if not all of December were also great enough for adult passage. The high flows observed after December 7, 2004 would have easily allowed adults to migrate far upstream in the watershed. The returning adult Chinook salmon in 2004 probably did not radically change their spawning distribution because flows during the migration and spawning period seem adequate for upstream passage.

Although we do not know how many adult Chinook salmon were present upstream of the trap site in the 2004/05 spawning season, we do know that for each severely reduced population estimate (YRS 2003 and 2005), high flows capable of mobilizing bedload and scouring or jostling redd gravels occurred when Chinook salmon redds were present. The idea of a negative relationship of high winter flows (> 4,500 cfs) on subsequent juvenile Chinook salmon production in upper Redwood Creek was first put forward as a hypothesis to explain the cohort crash in YR 2003 (Don Chapman pers. comm. 2003, Sparkman 2004a, study 2a5). 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, and Don Chapman pers. comm. 2003, Greene et al. 2005); and that estimates of mortality attributable to high flows and redd scour can reach 90% (Schuett-Hames et al. 2000). Greene et al. (2005) were able to show that the flood recurrence interval 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). In the 2005 five-year summary report, linear regression showed that 84% of the variation in the population size over study years 2000 – 2004 could be attributable to peak winter stream flow that can mobilize bedload (including redds) and jostle gravels (Sparkman 2005, study 2i4). One of the main caveats at the time was that we needed another high flow event after the Chinook salmon had deposited eggs in spawning redds. On December 8, 2004 the stream flow in upper Redwood Creek reached 6,350 cfs and stayed near this level for about three hours, thereby providing another high flow data point to test our hypothesis. This year, utilizing six data points, linear regression detected a significant negative relationship with bedload mobilizing flow and the subsequent production of 0+ Chinook salmon juveniles ($p = 0.005$, $R^2 = 0.89$, power = 0.98, $n = 6$). The variation in peak stream flow (in this case bedload mobilizing flows and non-bedload mobilizing flows) during the egg incubation period in redds explained 89% of the variation in the seasonal 0+ Chinook salmon population estimate over the six year period. These high, potentially damaging stream flows in upper Redwood Creek are not uncommon because the recurrence interval is estimated to be around 3.1 years (Randy Klein, pers. comm. 2003). There might be an upper threshold to discharges in upper Redwood Creek above which redd survival can be expected to be severely reduced; the highest flows occurring when eggs were in redds with good emigrant production the following spring/summer (YR 2004) equaled 4,400 cfs (occurred during December 2003).

An alternative explanation that the 0+ Chinook salmon simply remained upstream of the trap site in YR 2003 and YR 2005 is not likely because few juvenile Chinook salmon hold over for another year to out-migrate. 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 YR 2003 to be later captured as one-year-olds in YR 2004.

Percent emigration by month in YR 2005 was similar to the previous five year average, with April, May, and June accounting for the majority of out-migration. In contrast, emigration (on a percentage basis) in July 2005 was nearly seven times greater than July for the previous five year average. Weekly population emigration in YR 2005 was positively related (albeit weakly, $R^2 = 30\%$) to stream gage height and stream discharge; and negatively related to average stream temperature and week number. Thus, more 0+ Chinook salmon were emigrating earlier in the season when stream temperatures were lower and stream discharge was higher compared to later in the season. During periods of peak stream flow within which we trapped, we found that emigration substantially decreased. It is likely the 0+ Chinook salmon found refuge during these high stream flow events.

The 0+ Chinook salmon (ocean-type) migrants in upper Redwood Creek exhibit two different juvenile life histories (fry and fingerling) based on size and time of downstream migration. The fry are migrating shortly after emergence from spawning redds, and therefore are much smaller than the fingerlings which have reared in the stream for a longer period of time. In YR 2005, for example, the average FL for fry equaled 39.0 mm, compared to 68.8 mm for fingerlings. The emigration of 0+ Chinook salmon fry begins near the onset of trapping (in some years can be weeks later), peaks in mid April, and tapers off to very low values by early June. Factors that can influence the temporal component to fry 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. Fingerling migration in upper Redwood Creek begins in very low numbers in April, peaks in late May/early June, and tapers to low values by mid to late July. In YR 2005, fry emigration was severely reduced in number and the period of emigration was compressed compared with the previous five year average. Fingerling migration in YR 2005 was also severely reduced in number; however, the period of emigration was extended compared to the previous five year average.

Large numbers of Chinook salmon fry emigrate soon after redd emergence in upper Redwood Creek, with percentages ranging from 1 – 69% of the Chinook salmon emigrant population per study year. The percentage of juvenile Chinook salmon migrating as fry in YR 2005 (58% of total) was higher than the percentage migrating as fingerlings (42%); and statistically higher than the percentage migrating as fry for the previous five year average (53% of total emigration). Other streams 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.

The reasons why Chinook salmon fry migrate soon after emergence (or remain in the stream to grow into fingerlings) are elusive, difficult to prove, and generally unknown (Healey 1991). Healey (1991) covers the topic in much detail, and cites findings from authors who attributed (or speculated) fry dispersal to: 1) passive migration, 2) flow increases, 3) social interactions within species, 4) limits to rearing area (carrying capacity), 5) interactions with other species, and 6) genetics. In contrast, Healey (1991) also cites authors who reported no relationship between the number (or percentage) of fry and stream discharge, stream temperature, and rearing capacity. To summarize, Healey (1991) states that: 1) fry migration is a normal dispersal mechanism that helps re-distribute fry within the river, 2) estuaries can provide important rearing areas for fry, 3) fry are not ‘lost’ or surplus production, and 4) genotype may play an important role in fry migration.

Analysis was done on six years of data using linear regressions of average stream flow (surrogate for habitat space), average 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 existed). The mechanism for fry dispersal in upper Redwood Creek, based upon our data, appears to be largely genetic.

Passive migration probably does not play an important role in fry dispersal in upper Redwood Creek based upon our low trap catches during a range of high flow events, numerous mark/recapture trials, and a long migration period. The fry we use in our mark/recapture trials are released 250+ m upstream of the trap site, in fry habitat (very low velocity, stream margin area with overhanging trees and woody debris) that is about 20 m from the river’s current. Un-marked fry are occasionally observed in small numbers at the release site so there is plenty of space for the marked fry. The marked fry have to physically move about 20 m to the river current to migrate downstream, and most if not all of the recaptures (> 98%) are caught the next morning following release.

Therefore, if the marked fry were passively moving, they would have stayed in the low velocity fry habitat which would have delayed their migration. With ample space to rear and reside, the migrating fry also indicate that space was not a cue to migrate. With respect to space or habitat availability and fry movement, Prairie Creek offers another example. Prairie Creek is known as a relatively pristine stream, with old growth forests, cool stream temperatures and high degrees of habitat complexity; yet, each year, regardless of the number of adults (and egg deposition) and subsequent juvenile production, Chinook salmon fry are captured in traps every year as they migrate downstream (Roelofs and Klatte 1996; Roelofs and Sparkman 1999, Walt Duffy pers. com. 2005).

The long period of fry migration from upper Redwood Creek is evidenced by trap catches that extend from the beginning of trapping (late March) to early June. Thus if the fry were passively migrating we would probably not catch any at the upper trap well after the high flow events (usually in March and April). The fry leaving upper Redwood Creek are also moving far downstream because for two consecutive years the lower trap in Redwood Creek (RM 4) has captured fry with fresh partial upper caudal fin clips (efficiency trial fish from upper trap). The lower trap also catches fingerlings with regenerating fin clips and fingerlings with fresh fin clips; the fingerlings with regenerating fin clips indicate that they were fin clipped as fry, and this in turn shows that some fry are growing into fingerlings as they migrate downstream. Fishery crews sampling in the estuary during June and July also observe these fin clipped fish (both fry and fingerlings) from upper Redwood Creek (Dave Anderson pers. com. 2005), which corroborates Healey's (1991) and Allen and Hassler's (1986) assertion that estuaries are important places for fry to rear. The fry in upper Redwood Creek appear to be actively (volitionally) moving downstream. Fry dispersal is a normal component of diversity in the juvenile life history of ocean-type Chinook salmon found in upper Redwood Creek.

Healey (1991) also points out that fry are not surplus or lost production that will never augment future adult populations; therefore, fry should be part of a juvenile Chinook salmon emigrant population estimate. Chinook salmon fry in 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. 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 wild fry, with the exception of coded wire tags (1/2 tags) and otolith marking.

Although more fry emigrated in YR 2005 compared to fingerlings, the average FL and Wt in YR 2005 was greater than other study years; however, differences were not statistically significant. YR 2003 was not included in analysis because so few measurements were taken due to the cohort failure (N = 987, n = 573 for FL); and exclusion did not change any test conclusion. The larger average size in YR 2005 will most likely not compensate for the severe reduction in population emigration in YR 2005. One explanation for not compensating the low numbers with increased survival due to a larger average size (FL or Wt) for the 2005 cohort is found by looking at the percentage of migrants in the fry and fingerling categories each year. Although study years 2000 - 2002, and 2004 had an average FL or Wt less than in YR 2005, far more fingerlings were present in those years compared to YR 2005. The number of fingerlings emigrating in YR 2005 was so low compared to previous years (excluding YR 2003) that far fewer adults are expected to return, regardless of the average FL and Wt in YR 2005.

Linear regression detected a significant negative relationship of yearly population emigration on average FL or Wt which may indicate a density-dependent relationship; with higher emigration we see a decrease in the average FL or Wt. The overall percentage of fry or fingerlings in a given population estimate was not related to the average seasonal FL or Wt (Regression, $p > 0.67$ for both tests, $R^2 = 0.06$, n = 6, power = 0.06). The density-dependent relationship suggests that rearing space or carrying capacity (and food availability) upstream of the trap site is limiting the average size of Chinook salmon juveniles at higher population abundances. However, the current carrying capacity is expected to be much less than the carrying capacity of the past because Redwood Creek has changed over time, and is currently listed as sediment and temperature impaired. The juvenile Chinook salmon population abundance we have measured over the past six years has a high probability of being far less than abundance during pre-disturbance (or impairment) periods. If habitat is limiting the size of smolts at high abundances, successful watershed restoration in the upper basin should allow for the juvenile Chinook salmon to gain a larger size than currently observed, even if the emigrant population is relatively large.

Although a negative relationship of average size with population abundance was detected for 0+ Chinook salmon, the average weekly FL and Wt for any given year increased over the study period. Average weekly FL and Wt in YR 2005 followed a similar pattern over time; starting out low and relatively stable for the first 6 weeks, then increasing through the end of the study period. The rather sharp increase in FL and Wt by week in YR 2005 was attributable to the increasing percentage of fingerlings in the catch over time compared to fry (Regression: FL, $p = 0.00001$, $R^2 = 0.83$, slope is positive, power = 1.0; Wt, $p = 0.00001$, $R^2 = 0.71$, slope is positive, power = 1.0). Unwin (1985) reported a similar finding in his trapping studies in New Zealand. The relationships of weekly FL and Wt in YR 2005 with the previous four year average were numerically similar for the first 7- 8 weeks, thereafter average weekly FL's and Wt's in YR 2005 were greater than the four 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 for growth rate from 4/09/05 - 7/29/05 equaled 0.41 mm/d for FL and 0.05 g/d for Wt. A growth rate of 0.41 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 = 27) should be viewed as a maximum because the lower trap caught these fish sometime prior to when the crew checks and empties the livebox at 0900. For example, if a pit tagged fish was captured at 0200 and the crew emptied the trap's livebox at 0900, then travel time would be off by 7 hours. Travel time may also be positively biased if the juveniles resided in the stream during daylight hours and primarily migrated downstream at night (likely scenario). In contrast to travel time, travel rate should be viewed as a minimum for similar reasons; the individual's rate would be higher than what was observed if they were captured prior to checking the trap's livebox, and higher if they primarily migrated at night. Nevertheless, our experiments gave insight into individual juvenile Chinook salmon migration and growth between the two trap sites, which in turn may reflect stream habitat conditions, the salmon stock in Redwood Creek, or variable cohort behavior.

The travel time for 0+ Chinook salmon smolts to migrate 29 miles downstream ranged from 1.5 - 19.5 d, and averaged 7.5 d. On average, 0+ Chinook salmon moved downstream to the lower trap in fewer days than 2+ steelhead trout (n = 7, range = 2 to 35 d, ave. = 13 d) and 1+ steelhead trout (n = 9, range = 2 to 32 d, ave. = 15 d) in YR 2004 (Sparkman 2004b, study 2i3). The travel time for 0+ Chinook salmon fingerlings to reach the lower trap was not significantly related to: 1) the size of the migrant at time 1 or time 2, 2) stream temperature, or 3) stream discharge. The recapture of pit tagged 0+ Chinook salmon per release group in YR 2005 was variable. For one release group (6/30/05), five individuals were captured on the same day at the lower trap which suggests these fish traveled together as a group. In contrast, for five separate release groups, multiple recaptures from the same release group were captured on different days at the lower trap. For example, five individuals from the 7/21 release group were recaptured at the lower trap anywhere from 4.5 – 19.5 d after release from the upper trap; these fish did not travel as a group.

Travel rate ranged from 1.5 - 19.3 miles per day (2.4 – 31.1 km/d), and averaged 8.2 miles per day (13.2 km/d). Travel rate (mi/d) was weakly related to the size (FL or Wt) at time 1 (initial release), such that with a greater initial size we observed a higher travel rate. Similar to travel time, travel rate was not related to stream discharge, stream temperature, or fish size at time 2 ($p > 0.05$). Healey (1991) gives results from a study in the Rogue River, Oregon in which 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. The upper range in travel rate (31.1 km/d) for Chinook salmon fingerlings in Redwood Creek was higher than that observed in the upper Rogue River (24.0 km/d) (Healey 1991); and the average travel rate from upper Redwood Creek (13.2 km/d) was also higher than the average (1.6 km/d) put forward by Allen and Hassler (1986). 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 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 fingerlings, and in un-regulated river systems (upstream of estuaries).

In YR 2005, 52% of the 27 recaptured 0+ Chinook salmon fingerling smolts showed positive growth in FL and Wt, 18% showed a decrease in Wt, 48% showed no change in FL and 30% did not show a change in Wt. Absolute growth rate (FL) ranged from 0 - 0.67 mm/d, and averaged 0.22 mm/d. The average value (0.22 mm/d) is comparable to the group growth rate for Chinook salmon fingerlings in the Nitinat River (0.21 mm/d) and about 2/3 less than the group growth rate determined in the Cowichan River (0.62 mm/d), British Columbia (Healey 1991). The average value for recaptured pit tagged fingerlings (0.22 mm/d) in Redwood Creek was about 46% less than that calculated for fry and fingerlings in YR 2005 using the average weekly FL data (0.41 mm/d). However, the latter estimate is a group 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 Chinook salmon juveniles in Redwood Creek showing only positive growth ranged from 0.19 - 0.67 mm/d and averaged 0.428 mm/d, which is very close to the group estimate previously calculated (0.41 mm/d).

Eighteen percent (n = 5) of the recaptured pit tagged Chinook salmon lost weight (absolute growth rate in g/d) from time of release to time of recapture (range = -0.19 to -0.39 g/d, average = -0.29 g/d). Closer examination of data for these fish reveal that four out of the five were released as a group on 6/30 and recaptured 1.5 d later; the fifth fish also had a travel time of 1.5 d. With such a short travel time, it is conceivable that these fish might have had more food in their stomachs when released than when recaptured, which could explain the apparent weight loss (loss of 0.3 – 0.6 g per fish). Alternative explanations that could apply are: 1) these fish simply spent more time traveling downstream and less time foraging for food and feeding, thereby losing weight, or 2) crews at the upper or lower trap made measurement errors. The probability that the scale malfunctioned was slight because field crews calibrated the scale each day prior to use.

The growth (positive, negative, or zero) of the 27 recaptured pit tagged 0+ Chinook salmon was successfully modeled using linear regression. The best model for any growth index included travel time as the independent variable (p ranged from 0.002 – 0.000001, R^2 ranged from 0.32 – 0.84, slope is positive for all tests); no significant relationships were detected using stream discharge or stream temperature even though the range in values for each was fairly wide. Percent change in FL was positively related to travel time, and travel time explained 84% of the variation in growth; likewise, absolute growth rate (FL) was positively related to travel time, which explained 69% of the variation in growth. Thus, fish that took longer to reach the lower trap gained more length or weight than fish that traveled the distance in a shorter amount of time. 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. 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.

The final size of recaptured pit tagged Chinook salmon fingerlings was positively related to the size at initial release (FL; $p < 0.0001$, $R^2 = 0.67$, power =1.0). Sixty-seven percent of the variation in the final FL was explained by the initial FL. Larger fish released at the upper trap site were, on average, larger at recapture than smaller fish released at the trap site and subsequently recaptured; likewise, smaller fish at time 1 were, on average, usually the smaller fish at time 2. The importance of this relationship is that fish size at the upper trap (initial size) had a large impact on fish size at the lower trap (final size); the larger fish at the lower trap were more likely to have been the larger fish at the upper trap.

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 and 2005 zero were captured. Stream-type Chinook salmon are easily differentiated from ocean-type by size at time of downstream migration. For example, the average FL in May 2003 was 124 mm for 1+ Chinook salmon and 58 mm for 0+ Chinook juveniles. The total number of 1+ Chinook salmon juveniles captured over six study years equaled 68 individuals, or 0.01% of the total juvenile Chinook salmon catch. *A priori* I expected to catch 1+ Chinook salmon in YR 2005 because our highest emigration occurred in YR 2004; I thought at least some of the juvenile Chinook salmon would over-summer and residualize upstream of the trap site for a year prior to seaward migration. Maximum stream temperatures (eg. up to 28.7 ^{o}C or 83.7 ^{o}F) during late summer in YR 2004 may have inhibited or prevented 1+ Chinook salmon from rearing in upper Redwood Creek. However, the 1+ Chinook salmon captured in YRS 2001 and 2002 over-summered with stream temperatures reaching 27 - 28 ^{o}C (81 – 82 ^{o}F) at the trapping site. The lack of 1+ Chinook salmon catches at the upper trap in YR 2005 was in contrast to the capture of 11 individuals at the lower trap in YR 2005 (Sparkman 2006).

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 (Dave Anderson, pers. comm. 2004). For example, in 21 years of adult summer steelhead snorkel dives, adult spring Chinook salmon were only observed in one year (1988) and in very low numbers (< 7 individuals) (Dave Anderson, pers. comm. 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) may also prevent any adult spring-run Chinook salmon migration into upper Redwood Creek, or inhibit their ability to over-summer in pools. Thus, the 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 Conner et al. (2005) reported that fall Chinook salmon in the Snake River produced juveniles exhibiting an ocean-type or stream-type juvenile life history.

The 1+ Chinook salmon life history pattern may be important for increased ocean survival of Chinook salmon juveniles, and general species diversity (Don Chapman pers. comm. 2003, Sparkman 2005, study 2i4).

0+ Steelhead Trout

Considerable numbers of young-of-year steelhead trout migrate downstream from upper Redwood Creek during spring and summer months; over six consecutive study years we have captured 555,470 individuals. The total catch of 0+ steelhead trout migrating downstream in YR 2005 was the lowest of all trapping seasons. Trap catches in YR 2005 (n = 41,671) were markedly lower than catches in YR 2004 (n = 128,885) and the previous five year average (Ave. = 102,760). In each previous study year we also observed numerous 0+ steelhead trout in stream margin areas and in areas influenced by sub-gravel (seep) water. In contrast, we saw far fewer 0+ steelhead trout in margin areas and far less using thermal refugia areas in YR 2005.

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 2005). 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 age 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). A limitation with the view of habitat carrying capacity's affect on migration is that it fails to explain why juvenile fish emigrate at low densities or low population levels.

The decrease we observed in YR 2005 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) increase in carrying capacity of stream habitat upstream of trap site due to above average stream flow and cooler stream temperatures, 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 decrease we observed in YR 2005 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 2005 we did observe adult steelhead on redds upstream of the trap site, with the latest observation occurring in April. High flows on April 8, 2005 reached 2,430 cfs and may have impacted redd survival (scouring of redds, jostling of redd gravels); however, on March 26, 2003 we had flows up to 3,520 cfs and captured far more individuals (n = 102,954) in that trapping season compared to catches in YR 2005.

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 2005. 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 2006.

Young-of-year steelhead trout were caught in low numbers (n= 3) on the first day following trap deployment (March 26, 2005). Catches of less than 11 individuals per day occurred into the middle of April, and thereafter daily catches were generally greater than 40 per day until the end of August. The pattern of migration in YR 2005 was markedly different than other study years (including the wet year in 2003). For the previous five year average, catches by month increased until June (peak month) and then decreased to the end of the study period; May and June were the two most important months and accounted for 74% of the total catch. In contrast, catches by month in YR 2005 were low from late March through June, peaked in July, and then decreased in August; July was the most important month and accounted for 60% of total catch. Total catches in August (normally a time of reduced migration and catches) in YR 2005 were close in value to the number captured in May and June of YR 2005. On a percentage basis, far more 0+ steelhead trout were captured in August in YR 2005 than August for the previous five year average. During YR 2005, 0+ steelhead trout migration appeared to be skewed towards the end of the trapping period, instead of being predominately in the middle as shown by the previous five year average.

The average FL in YR 2005 was higher than other study years, and about 3 mm's greater than the average of the previous five years. The average FL did not significantly change over study years, thus the differences in FL among study years were slight. Average FL by year was negatively related to the total 0+ steelhead catch by year and indicates a density-dependent relationship; with higher catches we observed a lower average FL. Similar to Chinook salmon juveniles, the density-dependent relationship may indicate that rearing space (and food availability) upstream of the trap site is limiting the average size of 0+ steelhead trout migrants at higher abundances. Although a negative relationship of average size with total catch was detected, the average weekly FL for any given year increased during the study period. This increase in weekly size shows that growth occurred, and may indicate that habitat conditions and the availability of prey items were sufficient for growth. Average weekly FL in YR 2005 followed a similar pattern over time with the previous five year average for the first 10 weeks (3/26 – 6/3); thereafter, average FL in YR 2005 was less than the previous five year average from 6/4 – 6/24, and higher than the five year average from 7/2 through the end of the study. The rather sharp increase in FL by week in YR 2005 from 6/25 – 7/1 was probably influenced by the increasing percentage of parr in the catch compared to fry.

During periods of high stream temperatures (eg July and August) we frequently observe 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 (Sparkman and Willits, In progress). However, in YR 2005 we observed few 0+ steelhead in the groundwater refugia areas (maximum observation was 15 fish) compared to last year (maximum observation was 400 fish). Reasons for the decrease could be attributed to low 0+ steelhead trout emigration and cooler stream temperatures in YR 2005.

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 (we observe this as well in Redwood Creek). In streams that are temperature impaired (many 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 – 2004 ranged from 28,501 – 68,030 and averaged 43,762 individuals. Population emigration in YR 2005 was the lowest of all study years: 37% less than emigration in YR 2004 and 40% less than emigration for the previous five year average. Linear correlation detected a significant negative trend in 1+ steelhead trout population size over time ($p < 0.10$), which indicates that fewer 1+ steelhead trout were emigrating each year compared to previous years. Linear regression was used in the five year summary report to show that the number of 1+ steelhead trout in year (x+1) was inversely related to the number of 0+ steelhead trout emigrating the previous year (x) ($n = 4$). Based upon the regression model, the expected 1+ steelhead trout population size in YR 2005 was estimated to be 28,251 individuals or about 7.3% more than what was actually determined using mark/recapture techniques. The range of the 95% CI for the population estimate in YR 2005 (22,726 – 29,625) encompasses the regression estimated value. Thus, the regression model appears to accurately estimate 1+ steelhead trout emigrant population size with the given data.

Aside from being numerically less than previous study years, the pattern of population emigration in YR 2005 was markedly different than for the previous five year average. Monthly emigration in YR 2005 was skewed towards the beginning of the trapping period compared to being predominately in the middle as shown by the previous five year average. The most important month for 1+ steelhead trout emigration in YR 2005 was April, compared to May for the previous five year average. 1+ steelhead trout emigration in May and June 2005 was much less (by 78%) than May and June for the previous five year average. Emigration in late March and July were nearly equal among comparisons, and emigration in August 2005 was 12 times higher than emigration in August for the previous five year average. Weekly population emigration in YR 2005 was positively related to gage height (although weakly, $R^2 = 0.37$) and stream discharge, and negatively related to average stream temperature and week number. Thus, more 1+ steelhead trout emigrated earlier in the trapping season when stream discharge was higher and stream temperature was lower compared to later in the season. Similar to 0+ Chinook salmon, 1+ steelhead trout emigration during peaks in stream flow appeared to substantially decrease; it is likely the 1+ steelhead trout found refugia during these high flow events.

The average size of 1+ steelhead trout in YR 2005 (FL = 88.1 mm, Wt = 8.01 g) was greater than the averages for YRS 2002 – 2004 and less than the averages for YRS 2000 and 2001; however, differences were not statistically significant. The FL of 1+ steelhead trout over the six study years was positively related to the population size; with a higher population, we observed a greater FL. This is in contrast to the normal viewpoint of density-dependent relationships in which higher fish densities result in smaller fish sizes. The regression indicates that if stream conditions are favorable for survival, they are also favorable for growth. The weekly FL in YR 2005 did not significantly change over time which differed from the significant positive increase over time for the previous five year average. The general trend over time (weeks) for both lines was similar in that both reached highest values near the middle of June, with decreases in average FL in the following weeks. However, in YR 2005 average FL's starting July 16 - 22 began to slowly increase until the end of the season, compared with the five year average where average FL's decreased to the end of the season. The weekly Wt in YR 2005 significantly decreased over time which contrasts the significant positive increase in Wt over time for the previous five year average. The decrease in fish size over time in YR 2005 is not unusual because larger smolts frequently migrate earlier in the emigration period compared to smaller smolts (Quinn 2005).

Information in the literature indicates that steelhead smolting at age 1 is not uncommon, particularly in streams that are south of British Columbia (Quinn 2005, Busby et al. 1996). The percentage of 1+ steelhead trout migrants showing smolt characteristics in YR 2005 (86%) was much greater than for YR 2004 (41% were smolts) and the previous five year average (25% were smolts). 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 three 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; thus for the data tested (n = 6), abundance and fish size did not have any influence on the seasonal percentage of smolt designations. However, stream flows and stream temperatures during the study period influenced the percentage of 1+ steelhead trout showing smolt characteristics. Using an alpha of 0.10 due to low sample sizes, regression detected a significant positive relationship of stream flow and the percentage of smolts ($p = 0.06$, $R^2 = 0.63$, power = 0.50, $n = 6$) over the six study years; with higher flows in a given study year, we observed more 1+ steelhead trout as smolts. The relationship between average stream temperature and the percentage of smolts was significantly negative (Regression, $p = 0.03$, $R^2 = 0.82$, power = 0.70, $n = 5$); thus, with colder stream temperatures more of the 1+ steelhead trout migrants were in a smolt stage.

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 and elastomer marked fish released from the upper trap site in both years of operation. The recapture of pit tagged 1+ steelhead trout in lower Redwood Creek in YR 2005 also indicates emigration from the upper basin. 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 (Dave Anderson, pers. comm. 2004). We have not observed re-migration of 1+ steelhead trout into upper Redwood Creek based upon elastomer marked releases in YR 2001 (n = 374) and YR 2004 (n = 577). These tests confirmed that the elastomer marked 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 > 90% for the first 16 months.

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 2000-2004 ranged from 4:1 to 14:1 and averaged 7:1; in YR 2005 the ratio was 11:1. 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; 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. 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, 2004b, study 2i3), warrants further investigation.

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.

2+ steelhead trout population emigration from upper Redwood Creek from YRS 2000 – 2004 ranged from 2,846 – 12,668, and averaged 6,667 individuals. Similar to 1+ steelhead trout, the 2+ steelhead trout emigrant population in YR 2005 was the lowest of all study years; 59% less than emigration in YR 2004 and 64% less than emigration for the previous five year average. The pattern or trend in population size over the six study years was negative, yet non-significant.

The pattern of population emigration in YR 2005 was markedly different than other study years. Similar to 1+ steelhead trout, 2+ steelhead trout emigration by month in YR 2005 was skewed towards the beginning of the trapping period compared to being predominately in the middle as shown by the previous five year average. The most important month for 2+ steelhead trout emigration in YR 2005 was April, compared to April and May for the previous five year average. Emigration in April – July in YR 2005 was much less than those months for the previous five year average, with reductions per month ranging from 40 – 85%. The greatest reduction in emigration in YR 2005 occurred in May (85% reduction). 2+ steelhead trout population emigration in August 2005 was considerably higher (by a factor of eight) than emigration in August for the previous five year average. Weekly population emigration in YR 2005 was positively related to gage height (although weakly, $R^2 = 0.32$) and stream discharge, and negatively related to average stream temperature and week number. Thus, more 2+ steelhead trout emigrated earlier in the trapping season when stream discharge was higher and stream temperatures were lower compared to later in the season. Similar to 0+ Chinook salmon and 1+ steelhead trout, 2+ steelhead trout emigration during peaks in stream flow appeared to substantially decrease; it is likely the 2+ steelhead trout found refugia during these high flow events.

The average size of 2+ steelhead trout in YR 2005 (FL = 150.5 mm, Wt = 39.90 g) was greater than the averages for YRS 2002 – 2004 and less than the averages for YRS 2000 and 2001; however, differences were not statistically significant. Unlike 1+ steelhead trout, the FL (and Wt) of 2+ steelhead trout over the six study years was not related to emigrant population size. The weekly FL in YR 2005 did not significantly change over time which differed from the significant negative decrease in FL by week for the previous five year average. The general FL trend over time (weeks) for both lines showed some similarity in that both reached highest values near the beginning of trapping, with decreases in average FL in the following weeks until the middle of June; thereafter FL’s increased to the end of the study. The relationship of Wt in YR 2005 with time (year and week) followed the same general pattern as FL. Both median weekly FL and average weekly Wt in YR 2005 were not significantly different than the previous five year average. Thus, the size of 2+ steelhead smolts in YR 2005 was not markedly different than the previous five year average. The decrease in average FL and Wt by week during study year 2005 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 2005 (99.4%) was greater than YR 2004 (84%) and the previous five year average (75%). The number of parr designations was very low each year (6 yr average = 0.08%, ranged from 0.0 – 0.2% each year), and indicates that very few 2+ steelhead trout emigrate in a stream-resident form. The regression of 2+ steelhead trout population size on the percentage of 2+ steelhead trout showing smolt characteristics each year was significantly negative; thus, with a decreasing population size there was a higher percentage of smolts in the population. Average fish size (FL, Wt) by year or average stream discharge during each trapping period had no influence on the percentage of 2+ steelhead trout showing smolt characteristics (unlike 1+ steelhead trout). The relationship between average stream temperature during the trapping period and the percentage of smolts was significantly negative (Regression, $p = 0.09$, $R^2 = 0.65$, power = 0.37, $n = 5$); thus, with colder stream temperatures more of the 2+ steelhead trout migrants were in a smolt stage. Quinn (2005) reported that stream temperatures play an important role in smoltification.

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 site in both years of operation. 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 (Dave Anderson, pers. comm. 2004). We have not observed re-migration of 2+ steelhead trout into upper Redwood Creek based upon elastomer marked releases in YR 2001 (n = 8) and YR 2004 (n = 223). These tests confirmed that the elastomer marked fish 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 five years of study (0.4% of 2+ steelhead trout population) provides more evidence that the 2+ steelhead trout are migrating to the ocean, and not just re-distributing in the stream to 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 relate to future adults (and watershed conditions) is hard to dismiss or invalidate.

With respect to younger juvenile stages (0+ and 1+), the 2+ steelhead smolt is the best candidate for assessing steelhead status, trends, and abundance when information on adult steelhead is unavailable or un-attainable. 2+ steelhead trout have overcome the numerous components of stream survival that younger steelhead (0+ and 1+) have not yet completely faced (over-summer, over-winter, etc), and 2+ steelhead smolts are also the most direct recruit to adult steelhead populations. 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.

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 present and reproducing, albeit in low numbers.

Coho Salmon

We have not seen any juvenile coho salmon in six consecutive study years. We look at every individual fish we catch; thus, it seems highly probable that the trapping effort would catch some juveniles if they were present above the trap site. Additionally, juvenile coho salmon (eg parr and smolts) are fairly easy to identify from juvenile steelhead trout and Chinook salmon. Therefore, the trap data shows that coho salmon are not successfully returning to spawn upstream of the trap site. Historic records of coho salmon in areas above the trap site, though anecdotal, do warrant mentioning. Bill Chezum (long time resident in Redwood Valley, 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, 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. The last reported sighting of juvenile coho salmon upstream of the trap site occurred in 1997 (Tom Weseloh, pers. comm. 2003).

Even if the historic run of coho salmon from upper Redwood Creek is extirpated, I am surprised that we have not seen juvenile coho salmon because a few adults should at least stray into upper Redwood Creek from a tributary or mainstem area downstream of the trap site. Madej et al. (2005, draft) report that stream temperatures upstream of the trap site are probably too high for successful juvenile coho salmon rearing. Stream temperature data collected at the trap site supports their findings, however, adult coho salmon that could stray or migrate into upper Redwood Creek would not face these high stream temperatures. The lack of coho salmon in upper Redwood Creek is worthy of additional study.

Cutthroat Trout

A low number of cutthroat trout were captured in all six study years (< 9 individuals each year, total = 24), and only two individuals were captured in YR 2005. 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. 2003).

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 six 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 all data equaled 3,366:1. 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 six years that could have been hybrid juveniles. Thus, out of 74,063 1+ and 2+ steelhead trout catches, only 0.00005% 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

The average stream temperature in a given trapping period ranged from 13.5 to 16.3 ^{o}C (56.4 to 61.3 ^{o}F), with the lowest values occurring in the wettest water years (WY 2003 and 2005), and the highest occurring in the driest water year (WY 2001). Stream temperatures each study year were inversely related to stream discharge during the trapping period, thus with higher flows we observed cooler stream temperatures. Daily stream gage height (a surrogate for daily discharge) was also inversely related to daily stream temperatures; with a higher gage height (due to higher flows) we observed decreases in daily stream temperature. Conversely, stream temperatures increased with decreasing stream (or water) depth. The large influence of discharge (or gage height) on stream temperature in upper Redwood Creek was evidenced by a relatively high R^2 of 0.82, which indicates that 82% of the variation in stream temperature can be explained by the variation in stream discharge or gage height. Of course there are other variables that can also affect stream temperature that were not tested (e.g. riparian canopy cover over the stream, air temperature, and streambed sediments, among others). Variation due to temperature gage placement was minimized by placing the probes in the same place each year.

Stream temperatures in YR 2005 followed the same general trend as previous study years; temperatures were lowest in April and gradually increased to maximum values in July. Daily stream temperatures during the trapping period in YR 2005 and the previous four year average followed the same general trend of increasing over the course of the study and decreasing at the end of the study. Although there was some variation in average monthly and daily stream temperatures in YR 2005 with the previous four year average, differences were not significant.

Stream temperatures measured at the trap site appear to influence the degree of smolting for 1+ steelhead trout and 2+ steelhead trout; with colder temperatures, more of the juvenile steelhead emigrants were classified as smolts. Quinn (2005) reports that both photo period and steam temperature play important roles in smoltification by providing an external stimulus for the endocrine system, which drives the internal physiological changes necessary for smoltification. Stream temperatures also appeared to influence the migration of juvenile salmonids from upper Redwood Cr in YR 2005. The migration of 0+ Chinook salmon, 1+ steelhead trout, and 2+ steelhead trout populations was inversely related to stream temperatures; however, catches of 0+ steelhead trout were positively related to stream temperatures. Migration prior to times of increasingly higher stream temperatures could be a favorable life history strategy because high stream temperatures can cause stress and mortality, among other negative outcomes. The increase in migration of 0+ steelhead trout with increasing stream temperatures may, in part, indicate that rearing space or habitat conditions were not very favorable. In general, emigration prior to times when streams or sections of streams reach high or maximum temperatures (July/August) can be viewed as an advantageous life history strategy, and one that juvenile salmonids in upper Redwood Creek appear to employ.

CONCLUSIONS

The migration of juvenile salmonids from upper Redwood Creek in YR 2005 was the lowest of the six current study years. 0+ Chinook salmon experienced the greatest reduction (90%) in population size, which could be attributable to high winter flows which either scoured or jostled redd gravels in early December. 1+ steelhead trout population emigration in YR 2005 was reduced by 40%, 2+ steelhead trout emigration was reduced by 64%, and the catches of 0+ steelhead trout in YR 2005 was 59% less than the average catch in previous study years. All juvenile salmonids showed a negative preliminary trend over the six years of study; however, statistical significance was only found for 1+ steelhead trout. The number of 1+ steelhead trout in a given year was inversely related to the catches of 0+ steelhead trout the previous year. The predicted number of 1+ steelhead trout in YR 2005 was 7% more than the mark/recapture estimate for YR 2005. The pattern of population migration for 0+ Chinook salmon, 1+ steelhead trout, and 2+ steelhead trout in YR 2005 was skewed towards the beginning of the trapping season, with peak emigration occurring in April for each species at age. This pattern was similar to the pattern of the previous five year average for 0+ Chinook salmon and dissimilar to the migration pattern for 1+ and 2+ steelhead trout, which is normally in the middle of the trapping period.

The population of 0+ Chinook salmon emigrants in YR 2005 consisted of both fry and fingerlings, with more fry emigrating than fingerlings. No relationships between the percentage of fry and population size, stream temperature, or stream discharge were detected. The percentage of fry in a given study year did not influence the average emigrant size by year, however, the percentage of fry in a given week influenced the average size by week in YR 2005. The size of emigrating juvenile Chinook salmon and 0+ steelhead trout in YR 2005 was greater than previous study years; the size of 1+ and 2+ steelhead trout in YR 2005 was greater than YRS 2002-2004, and less than YRS 2000 and 2001. A density-dependent relationship of emigrant numbers and size was detected for 0+ Chinook salmon and 0+ steelhead trout over the six years of study; with higher numbers emigrating, the average size of the emigrants decreased. A positive relationship between emigrant numbers and size was detected for 1+ steelhead trout. This may indicate that stream conditions favorable for survival were also favorable for growth. No such relationships were detected for 2+ steelhead trout.

Twenty-seven pit tagged 0+ Chinook salmon fingerlings from upper Redwood Creek were recaptured 29 miles downstream at the second trap in lower Redwood Creek. Travel time ranged from 1.5 – 19.5 d, and averaged 7.5 d. Travel rate ranged from 1.5 – 19.3 mi/d, and averaged 8.2 mi/d. The recapture of pit tagged 0+ Chinook salmon per release group was variable. Individuals from the same release group were recaptured on the same day and in contrast, multiple recaptures from the same release group could be on different days. The greatest range in travel time for multiple recaptures from a single release group was 15 days. Fifty-two percent of the downstream migrating pit tagged 0+ Chinook salmon showed growth (FL, Wt), 18% showed a decrease in Wt, 48% showed no change in FL, and 30% showed no change in Wt. Growth was positively related to travel time and negatively related to travel rate. Thus, fish that took longer to reach the lower trap gained more FL and Wt than fish that traveled the distance in less amount of time. The final size of recaptured pit tagged 0+ Chinook salmon was positively related to the initial size at tagging. The importance of this relationship is that fish size at the upper trap (initial size) had a large impact on fish size at the lower trap (final size); larger fish recaptured at the lower trap were more likely to have been the larger fish released at the upper trap.

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, and Northern California Steelhead 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. Collect base line data for future comparisons.

2. 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.

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

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

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

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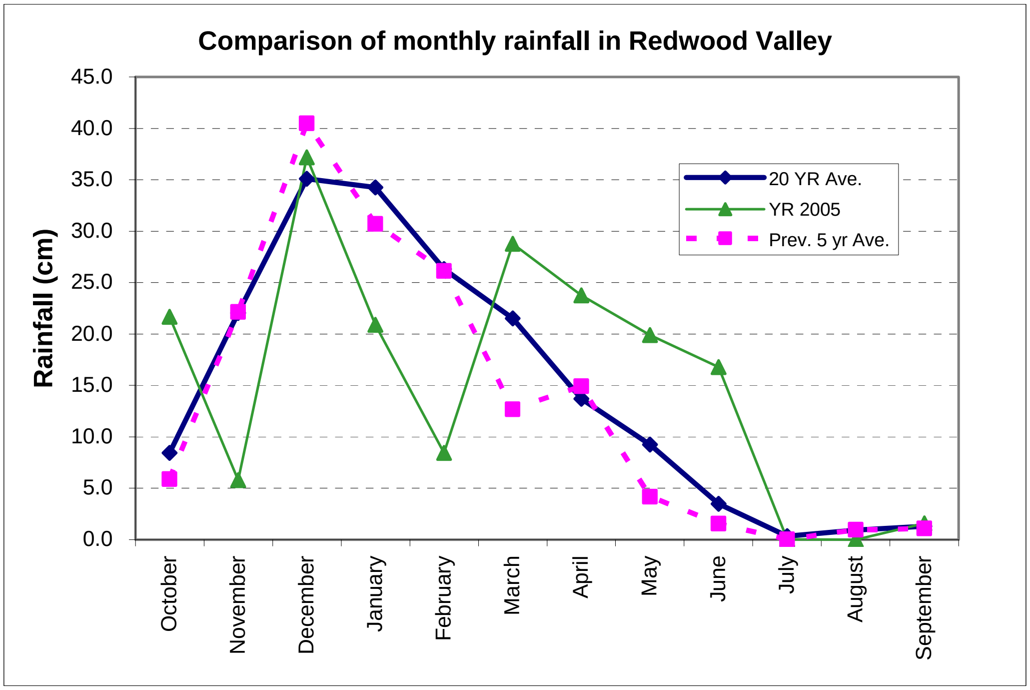
APPENDICES

Appendix 1. Comparison of 20 year average annual rainfall with average of previous five water years (2000 - 2004) and water year 2005 at Hinz family residence, Redwood Valley, Redwood Creek, Humboldt County, California.

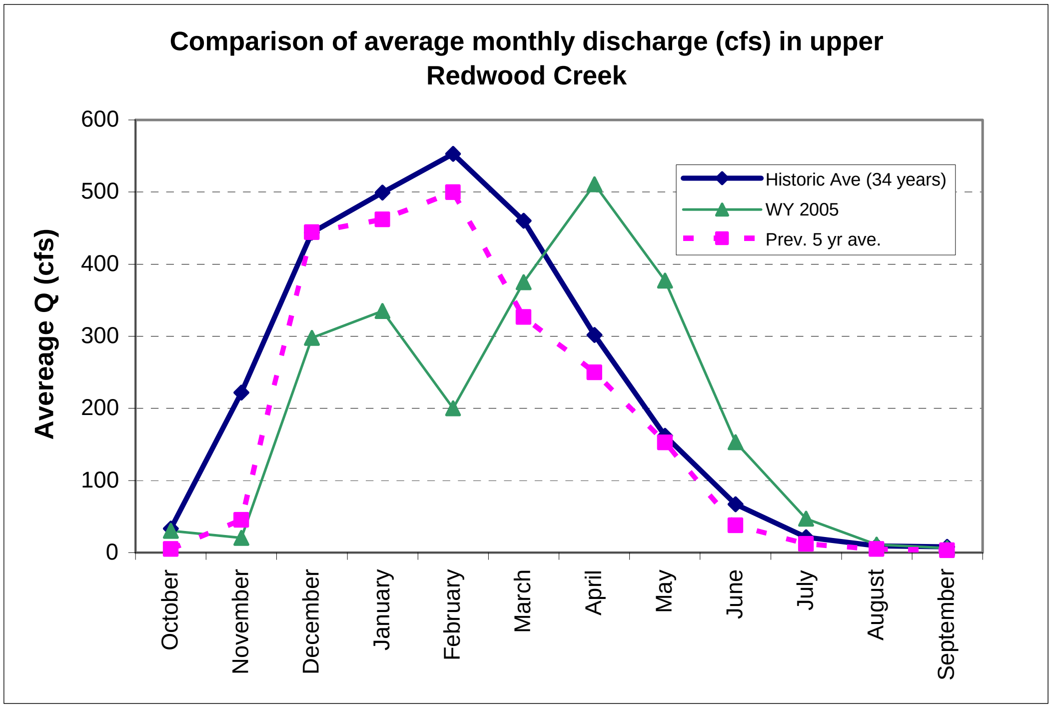
	Annual Rainfall* (centimeters)		
Month	Historic Average	Average of previous 5 study years (2000-04)	Water Year 2005
Oct.	8.4	5.9	21.7
Nov.	22.0	22.1	5.8
Dec.	35.1	40.5	37.2
Jan.	34.2	30.7	20.9
Feb.	26.3	26.1	8.4
Mar.	21.5	12.7	28.8
Apr.	13.7	14.9	23.8
May	9.2	4.2	19.9
June	3.5	1.6	16.8
July	0.3	0.0	0.0
Aug.	0.9	1.0	0.0
Sept.	1.3	1.1	1.6
Total:	176.6	160.8	184.9

* Data courtesy of Redwood National Park, Vicki Ozaki pers. comm. 2005.

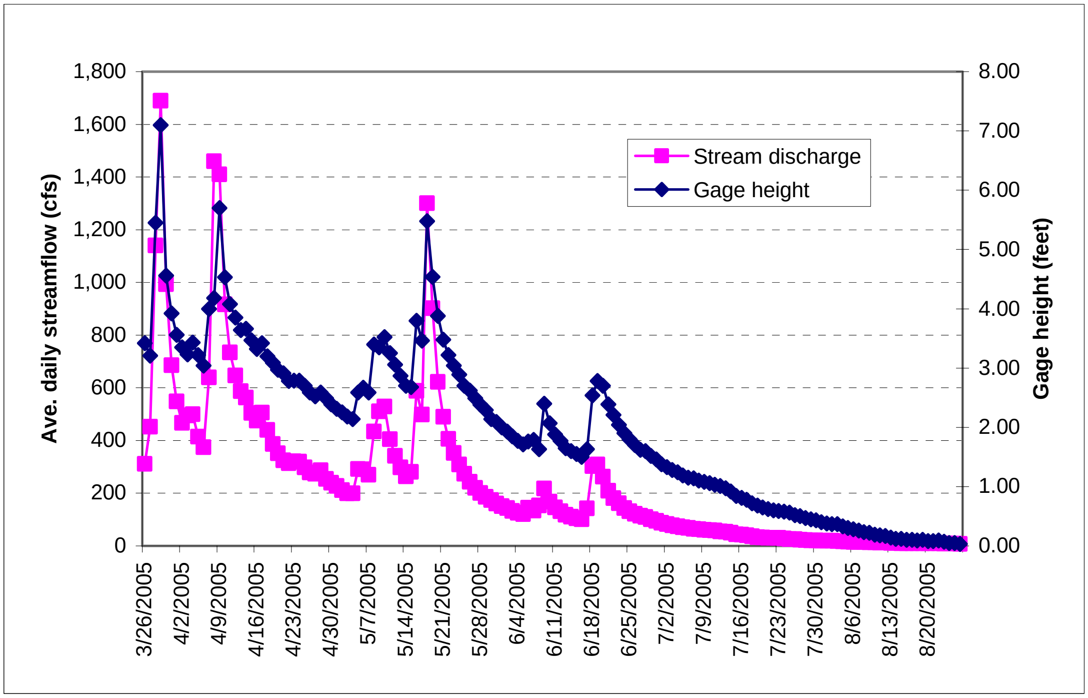


Appendix 2. Comparison of 34 year average monthly discharge (cfs) with average of previous five water years and water year 2005, O'Kane gaging station, upper Redwood Creek, Humboldt County, CA. (USGS 2005).

	Annual Discharge (cfs)		
Month	Historic Average	Average of previous 5 study years (2000-04)	Water Year 2005
Oct.	33	5	30
Nov.	222	45	20
Dec.	444	444	298
Jan.	499	462	335
Feb.	553	500	200
Mar.	460	327	375
Apr.	302	250	511
May	162	153	377
June	67	38	153
July	21	12	47
Aug.	9	5	11
Sept.	8	3	6
Ave:	232	187	197



Appendix 3. Graphical representation of daily stream gage height (feet) at trap site and average daily stream flow (cfs) at O'Kane gaging station (USGS 2005), upper Redwood Creek, Humboldt County, CA.



Appendix 4. Regression and correlation results for tests of average weekly gage height (ft), stream discharge (cfs), stream temperature (^oC), and time (week number) on catches of all species combined and for each species at age, and regression results of trapping efficiencies on 0+ Chinook salmon, 1+ steelhead trout, and 2+ steelhead trout catches, upper Redwood Creek, Humboldt County, CA., 2005

Weekly Values		Regression Results			
Y variable (Catches)	X variable	p value	R^2 or r*	Slope Sign	Power of test
All spp.**	Gage height	0.23	0.07	Negative	0.22
All spp.**	Discharge**	0.22	0.07	Negative	0.22
All spp.	Temperature	0.02	0.23	Positive	0.65
All spp.**	Week number*	0.21	0.08	Positive	0.24
0+ KS	Gage height	0.77	0.00	Negative	0.06
0+ KS	Discharge	0.22	0.07	Negative	0.22
0+ KS	Temperature	0.71	0.00	Negative	0.06
0+ KS**	Week number**	0.42	0.17*	Negative	0.12
0+ KS	Trap efficiency	0.92	0.00	Positive	0.05
0+ SH**	Gage height	0.0008	0.43	Negative	0.96
0+ SH**	Discharge	0.00002	0.60	Negative	1.00
0+ SH**	Temperature	0.002	0.38	Positive	0.92
0+SH**	Week number*	0.002	0.62	Positive	0.93
1+ SH**	Gage height	0.006	0.32	Positive	0.83
1+ SH**	Discharge	0.01	0.27	Positive	0.74
1+ SH**	Temperature	0.004	0.35	Negative	0.88
1+ SH**	Week number*	0.00007	0.74	Negative	1.00
1+ SH**	Trap efficiency	0.002	0.39	Negative	0.92
2+ SH	Gage height	0.009	0.29	Positive	0.78
2+ SH**	Discharge	0.008	0.30	Positive	0.80
2+ SH	Temperature	0.001	0.41	Negative	0.94
2+ SH	Week number*	0.0002	0.70	Negative	0.99
2+ SH	Trap efficiency	0.11	0.12	Negative	0.34

* R^2 is for physical variables (temperature, etc.), “r” is for trapping week number.
** Log (x+1) transformation.

Appendix 5. Regression and correlation results for tests of average weekly gage height (ft), stream discharge (cfs), and stream temperature (^oC) on weekly population emigration of 0+ Chinook salmon, 1+ steelhead trout, and 2+ steelhead trout in YR 2005.

Weekly Values		Regression Results			
Y variable (Population)	X variable	p value	R^2 or r*	Slope Sign	Power of test
0+ KS**	Gage height**	0.008	0.30	Positive	0.80
0+ KS**	Discharge**	0.008	0.30	Positive	0.80
0+ KS**	Temperature	0.02	0.25	Negative	0.69
0+ KS**	Week number*	0.02	0.48	Negative	0.64
1+ SH**	Gage height	0.003	0.37	Positive	0.90
1+ SH**	Discharge	0.006	0.32	Positive	0.83
1+ SH	Temperature	0.002	0.39	Negative	0.92
1+ SH**	Week number*	0.0002	0.72	Negative	0.99
2+ SH	Gage height	0.006	0.32	Positive	0.84
2+ SH**	Discharge	0.003	0.36	Positive	0.90
2+ SH	Temperature	0.0007	0.44	Negative	0.97
2+ SH	Week number*	0.0001	0.73	Negative	0.99

* R^2 is for physical variables (temperature, etc.), “r” is for trapping week number.
** Log (x+1) transformation.

Appendix 6. Travel time (d) and travel rate (mi per day) for 0+ Chinook salmon released at upper trap site and recaptured at lower trap (distance of 29 miles) in Redwood Creek, Humboldt County, CA., 2005.

Travel Time Experiments

Age/species	Initial FL mm	Mark or Tag type	Date Released*	Date Recaptured**	Travel time (d)	Travel rate (mi d^{-1})
0+ KS	76	Pit Tag	6/03/05	6/14/05	10.5	2.8
0+ KS	77	Pit Tag	6/08/05	6/15/05	6.5	4.5
0+ KS	87	Pit Tag	6/09/05	6/12/05	2.5	11.6
0+ KS	79	Pit Tag	6/09/05	6/15/05	5.5	5.3
0+ KS	70	Pit Tag	6/09/05	6/17/05	7.5	3.9
0+ KS	83	Pit Tag	6/15/05	6/24/05	8.5	3.4
0+ KS	84	Pit Tag	6/15/05	7/03/05	17.5	1.7
0+ KS	83	Pit Tag	6/16/05	7/02/05	15.5	1.9
0+ KS	81	Pit Tag	6/24/05	6/26/05	1.5	19.3
0+ KS	85	Pit Tag	6/24/05	6/27/05	2.5	11.6
0+ KS	87	Pit Tag	6/30/05	7/02/05	1.5	19.3
0+ KS	85	Pit Tag	6/30/05	7/02/05	1.5	19.3
0+ KS	87	Pit Tag	6/30/05	7/02/05	1.5	19.3
0+ KS	90	Pit Tag	6/30/05	7/02/05	1.5	19.3
0+ KS	84	Pit Tag	6/30/05	7/02/05	1.5	19.3
0+ KS	72	Pit Tag	7/01/05	7/04/05	2.5	11.6
0+ KS	74	Pit Tag	7/07/05	7/10/05	2.5	11.6
0+ KS	76	Pit Tag	7/08/05	7/23/05	14.5	2.0
0+ KS	73	Pit Tag	7/14/05	7/18/05	3.5	8.3
0+ KS	72	Pit Tag	7/15/05	8/03/05	18.5	1.6
0+ KS	76	Pit Tag	7/21/05	7/26/05	4.5	6.4
0+ KS	73	Pit Tag	7/21/05	7/30/05	8.5	3.4
0+ KS	81	Pit Tag	7/21/05	8/01/05	10.5	2.8
0+ KS	74	Pit Tag	7/21/05	8/04/05	13.5	2.1
0+ KS	76	Pit Tag	7/21/05	8/10/05	19.5	1.5
0+ KS	85	Pit Tag	7/28/05	8/03/05	5.5	5.3
0+ KS	87	Pit Tag	7/28/05	8/10/05	13.5	2.1
Ave:	80 (SD =5.9)				7.5 (SD = 5.9)	8.2 (SD = 6.9)

* Released at upper trap site (RM33) at night (2100).

** Recaptured at lower trap (RM4).

Appendix 7. Growth of recaptured pit tagged 0+ Chinook salmon (n = 27) migrating from upper trap to the lower trap (distance of 29 mi.) in Redwood Creek, Humboldt County, CA., 2005.

	Initial Size		Size at Recapture		Period of	% Change in:		AGR**		SGRsc**		RGR**	
Age/spp	FL (mm)	Wt (g)	FL (mm)	Wt (g)*	growth (d)	FL (mm)	Wt (g)	mm/d	g/d	% (mm/d)	% (g/d)	mm/mm/d	mm/mm/d
0+ KS	87	7.6	88	7.51	2.5	0.00	0.00	0.00	0.00	0.000	0.000	0.000	0.000
0+ KS	76	4.8	80	5.41	10.5	5.26	12.71	0.38	0.06	0.489	1.139	0.005	0.012
0+ KS	77	5.1	79	5.41	6.5	2.60	6.08	0.31	0.05	0.394	0.908	0.004	0.009
0+ KS	79	5.0	79	5.21	5.5	0.00	4.20	0.00	0.04	0.000	0.748	0.000	0.008
0+ KS	70	4.1	74	4.41	7.5	5.71	7.56	0.53	0.04	0.741	0.972	0.008	0.010
0+ KS	83	6.4	86	7.01	8.5	3.61	9.53	0.35	0.07	0.418	1.071	0.004	0.011
0+ KS	81	5.7	82	5.41	1.5	0.00	-5.09	0.00	-0.19	0.000	-3.481	0.000	-0.034
0+ KS	85	6.8	86	6.71	2.5	0.00	0.00	0.00	0.00	0.000	0.000	0.000	0.000
0+ KS	87	7.5	87	7.01	1.5	0.00	-6.53	0.00	-0.33	0.000	-4.504	0.000	-0.044
0+ KS	83	6.2	92	8.61	15.5	10.84	38.87	0.58	0.16	0.664	2.119	0.007	0.025
0+ KS	85	6.7	86	6.31	1.5	0.00	-5.82	0.00	-0.26	0.000	-3.998	0.000	-0.039
0+ KS	87	7.7	87	7.11	1.5	0.00	-7.66	0.00	-0.39	0.000	-5.315	0.000	-0.051
0+ KS	90	8.4	90	8.81	1.5	0.00	4.88	0.00	0.27	0.000	3.177	0.000	0.033
0+ KS	84	6.3	84	5.91	1.5	0.00	-6.19	0.00	-0.26	0.000	-4.260	0.000	-0.041
0+ KS	84	6.4	91	8.31	17.5	8.33	29.84	0.40	0.11	0.457	1.492	0.005	0.017
0+ KS	72	4.0	73	4.01	2.5	0.00	0.00	0.00	0.00	0.000	0.000	0.000	0.000
0+ KS	74	4.4	74	4.41	2.5	0.00	0.00	0.00	0.00	0.000	0.000	0.000	0.000
0+ KS	73	4.0	74	3.91	3.5	0.00	0.00	0.00	0.00	0.000	0.000	0.000	0.000
0+ KS	76	4.9	84	6.61	14.5	10.53	34.90	0.55	0.12	0.690	2.064	0.007	0.024
0+ KS	76	5.0	78	4.91	4.5	2.63	0.00	0.44	0.00	0.577	0.000	0.006	0.000
0+ KS	73	4.1	76	4.71	8.5	4.11	14.88	0.35	0.07	0.474	1.632	0.005	0.018
0+ KS	81	5.8	83	5.91	10.5	2.47	0.00	0.19	0.00	0.232	0.000	0.002	0.000
0+ KS	85	6.3	85	6.21	5.5	0.00	0.00	0.00	0.00	0.000	0.000	0.000	0.000
0+ KS	72	3.9	80	5.61	18.5	11.11	43.85	0.43	0.09	0.570	1.965	0.006	0.024
0+ KS	74	4.6	82	6.11	13.5	10.81	32.83	0.59	0.11	0.760	2.103	0.008	0.024
0+ KS	87	7.2	90	7.51	13.5	3.45	4.31	0.22	0.02	0.251	0.312	0.003	0.003
0+ KS	76	4.8	89	7.01	19.5	17.11	46.04	0.67	0.11	0.810	1.942	0.009	0.024
Ave.	**80**	**5.7**	**83**	**6.15**	**7.5**	**3.65**	**9.60**	**0.22**	**0.00**	**0.279**	**0.003**	**0.003**	**0.001**

* Final weight equals weight of fish at recapture minus pit tag weight (0.09g).

** AGR = absolute growth rate, SGRsc = specific growth rate scaled, RGR = relative growth rate.

Appendix 8. Descriptive statistics of size at time 1 (T1) and time 2 (T2), 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 = 27) at the lower trap in Redwood Creek, Humboldt County, CA., YR 2005.

	Descriptive Statistics			
Variable	Min.	Max.	Ave. (median)	SD**
Size at T1				
FL mm	70	90	79.9 (81.0)	5.9
Wt g	3.9	8.4	5.69 (5.70)	1.32
Size at T2				
FL mm	73	92	82.9 (84.0)	5.7
Wt g	3.9	8.8	6.15 (6.11)	1.35
% change in				
FL mm	0.00	17.11	3.65 (2.47)	4.77
Wt g	- 7.66	46.04	9.60 (4.20)	16.50
AGR*				
FL mm	0.00	0.67	0.22 (0.19)	0.240
Wt g	- 0.39	0.27	0.00 (0.02)	0.153
RGR*				
FL mm	0.000	0.009	0.003 (0.002)	0.003
Wt g	- 0.051	0.033	0.001 (0.003)	0.023
SGR*				
FL mm	0.000	0.810	0.279 (0.232)	0.302
Wt g	- 5.315	3.177	0.003 (0.312)	2.282

* AGR = absolute growth rate (FL, mm/d; Wt g/d), RGR = relative growth rate (FL, mm/mm/d; Wt, g/g/d), SGR = specific growth rate scaled, [FL, %(mm/d); Wt %(g/d)].

** SD = standard deviation of mean.

Appendix 9. Results of linear regressions using travel time (d), travel rate (mi/d), average water temperature (^{o}C), and average stream discharge (cfs) on various growth indices for pit tagged 0+ Chinook salmon recaptured at the lower trap in Redwood Creek, Humboldt County, CA., YR 2005.

Variables		Regression Output (Results)			
Dependent (Y)	Independent (X)	p value	R2	Slope Sign	Power of test
% Change FL	Travel Time	0.000001	0.84	Positive	1.00
% Change FL	Travel Rate*	0.000001	0.64	Negative	1.00
% Change FL	Water Temp	0.32	0.04	Positive	0.16
% Change FL	Stream discharge	0.44	0.02	Negative	0.12
% Change Wt	Travel Time	0.000001	0.82	Positive	1.00
% Change Wt	Travel Rate	0.00007	0.47	Negative	1.00
% Change Wt	Water Temperature	0.41	0.03	Positive	0.12
% Change Wt	Stream discharge	0.62	0.01	Negative	0.08
AGR** FL	Travel Time	0.000001	0.69	Positive	1.00
AGR** FL	Travel Rate	0.000004	0.58	Negative	1.00
AGR** FL	Water Temperature	0.67	0.01	Positive	0.07
AGR** FL	Stream discharge	0.70	0.01	Negative	0.07
AGR** Wt	Travel Time	0.002	0.32	Positive	0.91
AGR** Wt	Travel Rate	Test assumptions not met, test not reliable.			
AGR** Wt	Water Temperature	Test assumptions not met, test not reliable.			
AGR** Wt	Stream discharge	Test assumptions not met, test not reliable.			
SGRsc** FL	Travel Time*	0.000001	0.68	Positive	1.00
SGRsc** FL	Travel Rate	0.000006	0.56	Negative	1.00
SGRsc** FL	Water Temperature	Test assumptions not met, test not reliable.			
SGRsc** FL	Stream discharge	Test assumptions not met, test not reliable.			
SGRsc** Wt	Travel Time	0.005	0.39	Positive	0.97
SGRsc** Wt	Travel Rate	Test assumptions not met, test not reliable.			
SGRsc** Wt	Water Temperature	Test assumptions not met, test not reliable.			
SGRsc** Wt	Stream discharge*	0.37	0.03	Negative	0.14
RGR** FL	Travel Time*	0.000001	0.68	Positive	1.00
RGR** FL	Travel Rate	0.000008	0.56	Negative	1.00
RGR** FL	Water Temperature	Test assumptions not met, test not reliable.			
RGR** FL	Stream discharge	Test assumptions not met, test not reliable.			
RGR** Wt	Travel Time	0.002	0.43	Positive	0.99
RGR** Wt	Travel Rate	Test assumptions not met, test not reliable.			
RGR** Wt	Water Temp	0.83	0.00	Positive	0.05
RGR** Wt	Stream discharge	0.72	0.00	Negative	0.06

* Denotes Log (x+1) transformation to approximate linearity.

** AGR = absolute growth rate (FL mm/d; Wt g/d), RGR = relative growth rate (FL mm/mm/d; Wt g/g/d), SGR = specific growth rate scaled, [FL %(mm/d); Wt %(g/d)].

Appendix 10. 0+ Chinook salmon delayed mortality experiments, upper Redwood Creek, Humboldt County, CA., 2005.

				Fin Clipping (24 hr)		Pit Tagging (34 hr)	
Age / spp.	Date	(n)	Ave. Water Temp (C)	Morts./total	Percent Mortality	Morts./total	Percent Mortality
0+KS	4/16 - 4/17	4	9.0	0/4	0.00		
0+KS	4/19 - 4/20	6	9.3	0/6	0.00		
0+KS	5/20 - 5/21	6	10.8	0/6	0.00		
0+KS	5/23 - 5/24	9	11.9	0/9	0.00		
0+KS	6/02 - 6/03	18	13.6			0/18	0.00
0+KS	6/07 - 6/08	26	11.4			0/26	0.00
0+KS	6/08 - 6/09	32	13.4			0/32	0.00
0+KS	6/09 - 6/10	6	13.2			0/6	0.00
0+KS	6/14 - 6/15	52	13.1			0/52	0.00
0+KS	6/15 - 6/16	40	13.4			0/40	0.00
0+KS	6/16 - 6/17	50	12.2			0/50	0.00
0+KS	6/18 - 6/19	50	11.3	1/50*	2.00		
0+KS	6/22 - 6/23	23	14.4			0/23	0.00
0+KS	6/23 - 6/24	32	15.3			0/32	0.00
0+KS	6/28 - 6/29	22	17.0			0/22	0.00
0+KS	6/29 - 6/30	30	17.8			0/30	0.00
0+KS	6/30 - 7/01	30	18.1			0/30	0.00
0+KS	7/06 - 7/07	30	18.0			0/30	0.00
0+KS	7/07 - 7/08	20	17.8			0/20	0.00
0+KS	7/13 - 7/14	30	19.9			0/30	0.00
0+KS	7/14 - 7/15	30	20.9			0/30	0.00
0+KS	7/19 - 7/20	22	21.7			0/21	0.00
0+KS	7/20 - 7/21	30	21.8			0/30	0.00
0+KS	7/21 - 7/22	18	21.1			0/18	0.00
0+KS	7/27 - 7/28	10	21.9			0/10	0.00
0+KS	7/28 - 7/29	4	21.9			0/4	0.00
0+KS	7/29 – 7/30	1	22.1	0/1	0.00		
0+KS	7/31 – 8/01	2	21.6	0/2	0.00		

* Unexpected storm event occurred during this trial.

Appendix 11. 1+ Steelhead trout delayed mortality experiments, upper Redwood Creek, Humboldt County, CA., 2005.

				Fin Clipping (24 hr)		Pit Tagging (34 hr)		Elastomer (24 hr)	
Age/ Spp.	Date	(n)	Average Water Temp (^{o}C)	Morts./ Total	Percent Mortality	Morts./ Total	Percent Mortality	Morts./ Total	Percent Mortality
1+SH	4/20-4/21	25	10.0	0/25	0.00				
1+SH	4/27-4/28	50	10.8					0/50	0.00
1+SH	5/04-5/05	48*	11.7					0/48	0.00
1+SH	5/20-5/21	1	10.8	0/1	0.00				
1+SH	5/26-5/27	27	14.2					0/27	0.00
1+SH	5/27-5/28	21	14.2					0/21	0.00
1+SH	6/01-6/02	34	13.6			0/34	0.00		
1+SH	6/08-6/09	10	13.4			0/10	0.00		
1+SH	6/09-6/10	4	13.2			0/4	0.00		
1+SH	6/11-6/12	3	13.4	0/3	0.00				
1+SH	6/15-6/16	14	13.4			0/14	0.00		
1+SH	6/16-6/17	8	12.2			0/8	0.00		
1+SH	6/18-6/19	10	11.3	0/10	0.00				
1+SH	6/20-6/21	3	13.0	0/3	0.00				
1+SH	6/22-6/23	2	14.4			0/2	0.00		
1+SH	6/23-6/24	1	15.3			0/1	0.00		
1+SH	6/24-6/25	3	15.6	0/3	0.00				
1+SH	6/26-6/27	4	15.8	0/4	0.00				
1+SH	6/27-6/28	4	15.9	0/4	0.00				
1+SH	6/29-6/30	7	17.8			0/7	0.00		
1+SH	6/30-7/01	6	18.1			0/6	0.00		
1+SH	7/06-7/07	12	18.0			0/12	0.00		
1+SH	7/07-7/08	18	17.8			0/18	0.00		
1+SH	7/13-7/14	19	19.9			0/19	0.00		
1+SH	7/14-7/15	12	20.9			0/12	0.00		
1+SH	7/18-7/19	8	21.7	0/8	0.00				
1+SH	8/05-8/06	5	22.8	0/5	0.00				
1+SH	8/08-8/09	10	22.0	0/10	0.00				
1+SH	8/12-8/13	4	21.3	0/4	0.00				
1+SH	8/19-8/20	5	21.3	0/5	0.00				
1+SH	8/22-8/23	1	21.3	0/1	0.00				

* Sample size was originally 50, two fish died immediately (w/in 5 minutes after injection).

Appendix 12. 2+ Steelhead trout delayed mortality experiments, upper Redwood Creek, Humboldt County, CA., 2005.

				Fin Clipping (24 hr)		Pit Tagging (34 hr)		Elastomer (24 hr)	
Age/ Spp.	Date	(n)	Average Water Temp (^{o}C)	Morts./ Total	Percent Mortality	Morts./ Total	Percent Mortality	Morts./ Total	Percent Mortality
2+SH	4/20-4/21	10	10.0	0/10	0.00				
2+SH	4/27-4/28	22	10.8					0/22	0.00
2+SH	5/04-5/05	7	11.7					0/7	0.00
2+SH	5/22-5/23	1	11.6	0/1	0.00				
2+SH	5/26-5/27	4	14.2					0/4	0.00
2+SH	5/27-5/28	4	14.2					0/4	0.00
2+SH	6/01-6/02	4	13.6			0/4	0.00		
2+SH	6/02-6/03	9	13.6			0/9	0.00		
2+SH	6/04-6/05	1	13.3			0/1	0.00		
2+SH	6/07-6/08	4	11.4			0/4	0.00		
2+SH	6/08-6/09	3	13.4			0/3	0.00		
2+SH	6/09-6/10	1	13.2			0/1	0.00		
2+SH	6/10-6/11	1	13.5	0/1	0.00				
2+SH	6/13-6/14	1	14.0			0/1	0.00		
2+SH	6/15-6/16	3	13.4			0/3	0.00		
2+SH	6/16-6/17	4	12.2			0/4	0.00		
2+SH	6/17-6/18	1	11.3	0/1	0.00				
2+SH	6/20-6/21	1	13.0	0/1	0.00				
2+SH	6/22-6/23	1	14.4			0/1	0.00		
2+SH	6/23-6/24	2	15.3			0/2	0.00		
2+SH	6/24-6/25	2	15.6	0/2	0.00				
2+SH	6/27-6/28	1	15.9	0/1	0.00				
2+SH	6/29-6/30	4	17.8			0/4	0.00		
2+SH	6/30-7/01	1	18.1			0/1	0.00		
2+SH	7/04-7/05	1	17.4	0/1	0.00				
2+SH	7/06-7/07	1	18.0			0/1	0.00		
2+SH	7/07-7/08	4	17.8			0/4	0.00		
2+SH	7/08-7/09	1	18.1	0/1	0.00				
2+SH	7/13-7/14	1	19.9	0/1	0.00				
2+SH	7/14-7/15	1	20.9			0/1	0.00		
2+SH	7/17-7/18	2	21.8	0/2	0.00				
2+SH	7/22-7/23	1	20.9	0/1	0.00				
2+SH	7/26-7/27	1	21.8	0/1	0.00				
2+SH	7/29-7/30	2	22.1	0/2	0.00				
2+SH	8/05-8/06	1	22.8	0/1	0.00				
2+SH	8/08-8/09	2	22.0	0/2	0.00				
2+SH	8/11-8/12	4	21.2	0/4	0.00				
2+SH	8/18-8/19	2	21.6			0/2	0.00		
2+SH	8/19-8/20	2	21.3	0/2	0.00				
2+SH	8/20-8/21	1	20.8	0/1	0.00				
2+SH	8/22-8/23	1	21.3	0/1	0.00				