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2006 ANNUAL REPORT

UPPER REDWOOD CREEK
JUVENILE SALMONID (SMOLT) DOWNSTREAM MIGRATION STUDY
2000 - 2006 Seasons
PROJECT 2a5

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DEDICATION

This report is dedicated to the memory of Patrick Garrison, a fellow CDFG Fisheries Biologist, fisherman, colleague, and most importantly, friend.

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ABSTRACT

Juvenile anadromous salmonid trapping was conducted for the seventh 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 135 nights out of 140 nights possible, and captured 4,830 0+ Chinook salmon, zero 1+ Chinook salmon, 48,759 0+ steelhead trout, 3,201 1+ steelhead trout, 400 2+ steelhead trout, 3 cutthroat trout, zero 0+ pink salmon, and zero juvenile coho salmon. Catches in YR 2006 were markedly less than previous study years, with the greatest reduction (96%) occurring for 0+ Chinook salmon. Average weekly trapping efficiency was 20% for 0+ Chinook salmon, 14% for 1+ steelhead trout, and 17% for 2+ steelhead trout. Trapping efficiency of 0+ Chinook salmon was inversely related to stream discharge and stream gage height. The total 0+ Chinook salmon population estimate with 95% confidence intervals in YR 2006 equaled 26,093 (23,009 – 29,178), and was 34% less than emigration in YR 2005 and 92% less than emigration for the previous six year average. The large decrease in YR 2006 may be attributable to: 1) high bedload mobilizing flows during egg incubation in spawning redds, which could account for 91% of the variation in emigration over the seven 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 26,248 (22,728 – 29,767), and was slightly higher than emigration in YR 2005 and 36% less than emigration for the previous six year average. 2+ steelhead trout population emigration equaled 1,866 (1,423 – 2,309) and was 21% less than emigration in YR 2005 and 69% less than emigration for the previous six 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-eight pit tagged 0+ Chinook salmon smolts released at the upper trap site were recaptured 29 miles downstream at the second trap in lower Redwood Creek. Travel time ranged from 2.5 – 20.5 d and averaged 8.0 d; and travel rate ranged from 1.4 – 11.6 mi/d and averaged 5.5 mi/d. On average, 0+ Chinook salmon migrated 29 miles downstream faster than 1+ and 2+ steelhead trout did in YRS 2004-06. Sixteen (57%) of the 28 recaptured 0+ Chinook salmon showed positive growth in FL and seventeen (61%) showed positive growth in Wt. Twelve fish showed no change in FL, and 11 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 – 12.8 and averaged 3.9. 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. 2007. Upper Redwood Creek juvenile salmonid (smolt) downstream migration study, study year 2006. CDFG AFRAMP, 2006 Annual Report 2a5: 131 p.

INTRODUCTION

This report presents results of the seventh 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 – 2006 have been a cooperative effort between the California Department of Fish and Game Anadromous Fisheries Resource Assessment and Monitoring Program (AFRAMP) (formerly Steelhead Research and Monitoring Program) and RCLA. In addition, the Fisheries Restoration Grant Program has assisted in funding this study from YR 2005 to the present. 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 (both live and carcass) and redds (eg spawning surveys) unreliable and unlikely for long term monitoring. Scientific studies which focus on salmonids in tributaries to Redwood Creek are less affected by these processes, however, the tributaries are less likely to adequately represent or account for the majority of the salmonid populations in Redwood Creek because the majority of adult salmon and steelhead spawn in the mainstem. A possible exception is the Prairie Creek watershed which probably accounts for a considerable amount of the coho salmon production in Redwood Creek. Tributaries to Redwood Creek are often steep, with limited anadromy (RNP 1997, Brown 1988). Additionally, some of the tributaries can dry up prior to late summer, which cause the juvenile fish to migrate into the mainstem Redwood Creek.

Determining and tracking smolt numbers over time is an acceptable, useful, and quantifiable measure of salmonid populations which many agencies (both state and federal), universities, consultants, tribal entities, and timber companies perform each year. Juvenile salmonid out-migration can be used to assess: 1) the number of parents that produced the cohort (Schmidt et al. 1996, Roper and Scarnecchia 1999, Ward 2000, Sharma and Hilborn 2001, Ward et al. 2002, Bill Chesney pers. comm. 2005), 2) redd gravel conditions (Cederholm et al. 1981, Holtby and Healey 1986, Hartman and

Scrivener 1990), 3) in-stream habitat quality and watershed health (Tripp and Poulan 1986, Hartman and Scrivener 1990, Hicks et al. 1991, Bradford et al. 2000, Sharma and Hilborn 2001, Ward et al. 2002), 4) restoration activities (Everest et al. 1987 *in* Hicks et al. 1991, Slaney et al. 1986, Tripp 1986, McCubbing and Ward 1997, Solazzi et al. 2000, Cleary 2001, Ward et al 2002, McCubbing 2002, Ward et al. 2003, Roni et al. 2006), 5) over-winter survival (Scrivener and Brown 1993 *in* McCubbing and Ward 1997, Quinn and Peterson 1996, Solazzi et al. 2000, McCubbing 2002, Ward et al. 2002, Giannico and Hinch 2003), and 6) future recruitment to adult populations (Holtby and Healey 1986, Nickelson 1986, Ward and Slaney 1988, Ward et al. 1989, Unwin 1997, Ward 2000).

This paper will present the results of trapping in study year 2006 with comparisons to the average of the previous six study years (YRS 2000 - 2005) and YR 2005.

Site Description

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

Geology

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

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

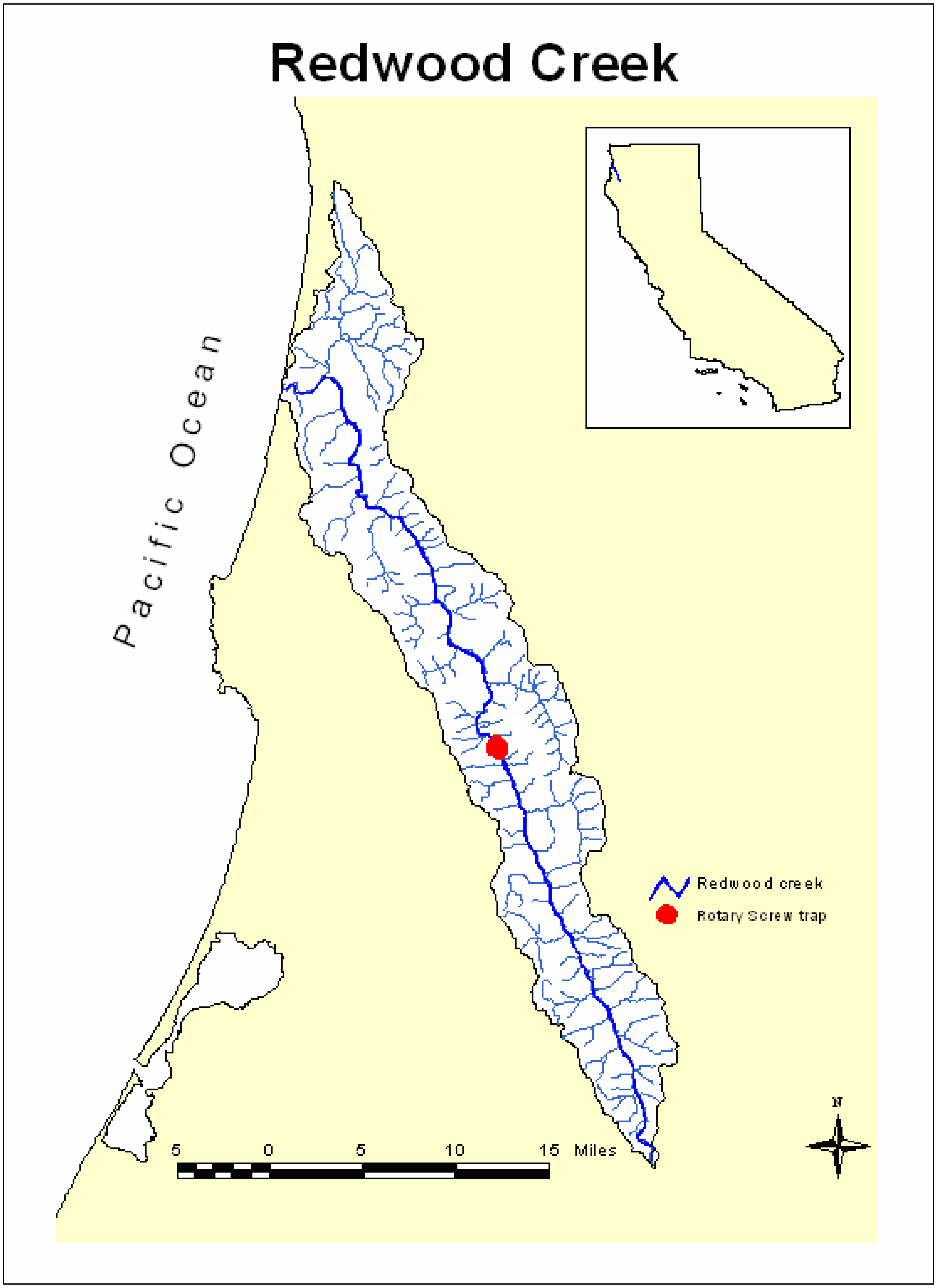

Figure 1. Redwood Creek watershed with rotary screw trap location (RM 33) in Redwood Valley, Humboldt County, CA., (scale is slightly inaccurate due to reproduction process; Charlotte Peters pers. comm. 2001).

Climate and Annual Precipitation

The climate of Redwood Creek basin varies dependent upon location within the watershed and season. Coastal areas have a moderate climate due to proximity to the ocean, and differ from inland areas (i.e. upper Redwood Creek) which experience higher and lower temperatures. Summers are typically cool and moist on the coast, and hot and dry inland. Ambient air temperatures in Redwood Valley often exceed 32 ^{o}C (or 90 ^{o}F) during summer months. Upper Redwood Creek experiences cold temperatures during the winter, and snowfall is common. In study year 2006, snowfall occurred as late as April. Rainfall in upper Redwood Creek is influenced by orographic effects, and can fall in considerable amounts.

A weather station (Davis Vantage Pro Weather Station) is located at the Hinz family residence in Redwood Valley, about 5.25 mi downstream of the trap site. Rainfall records cover the period from 1986 to the present to total 21 years (Redwood National Park, in house data, 2006; Vicki Ozaki pers. comm. 2006). Annual precipitation (by WY) ranged from 90 cm (35.4 in.) to 250 cm (98.4 in.), and averaged 180.4 cm (71.0 in.). Most (96%) 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 2006 (250 cm) was the highest on record, and about 70 cm (27 in.) greater than the 21 year average (Appendix 1).

The 21 year average monthly rainfall during the majority of the trapping season (April – July) totaled 26.6 cm (10.5 in.) (Table 1). Total monthly rainfall during this period of trapping in YR 2006 (23.6 cm or 9.3 in.) was about 11% less than the historic average and 14% less than the average of the previous six study years. Rainfall in April 2006 accounted for 64% of the total rainfall during the majority of the trapping period (Table 1).

Table 1. Comparison of 21 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 6 study years (2000-05)	YR2006
Apr.	13.8	16.4	15.2
May	9.1	6.8	5.8
June	3.4	4.1	2.5
July	0.3	0.0	0.1
Total:	26.6	27.3	23.6

* Data courtesy of Redwood National Park, Vicki Ozaki pers. comm. (2006).

Stream Discharge

A USGS/CDWR gaging station (Blue Lake O'Kane, #11481500) is located about 8.4 miles upstream of the trap site on Redwood Creek. Stream flow records cover the periods of 1953 – 1958, 1972 – 1993, and 1997 – 2006 to total 35 years (Chris O'Neil pers. comm. 2006, USGS 2006). 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 2006). However, in WY 2006, average monthly flow peaked in December. Low flows in WY 2006 occurred in October and July - September. Using all years' data, mean monthly discharge in upper Redwood Creek was 235 cfs (6.7 m^3/sec), and ranged from 8 - 558 cfs (USGS 2006). Average monthly discharge in WY 2006 equaled 351 cfs (9.9 m^3/sec) and was greater than the historic and previous six year average (188 cfs) (Appendix 2, USGS 2006).

The 35 year average monthly discharge during the majority of the trapping season (April - July) equaled 139 cfs (3.9 m^3/sec) (Table 2). Average monthly discharge from April – July, 2006 (188 cfs) was higher than the historic average and the average of the previous six study years by a factor of 1.35 (Table 2, data from USGS 2006).

Table 2. Comparison of 35 year average monthly discharge, average monthly discharge for the previous six years, and monthly discharge in upper Redwood Creek (O'Kane station) during the majority of the trapping period (USGS 2006).

	Average Discharge (cfs)		
Month	Historic	Previous 6 study years (2000-05)	YR2006
Apr.	307	291	491
May	163	189	191
June	67	57	55
July	21	18	14
Ave:	139	139	188

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 and to a much larger degree in YR 2006, large amounts of small gravels/sands were deposited at the trap site and areas downstream of the trap site. These deposits at the trap site were up to 2.5 ft deep.

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

Federal ESA Species Status

Chinook (King) salmon (*Oncorhynchus tshawytscha*), coho (Silver) salmon (*O. kisutch*), steelhead trout (*O. mykiss*), and cutthroat trout (*O. clarki clarki*) are known to inhabit Redwood Creek. This study also shows that pink salmon (*O. gorbuscha*) are present in Redwood Creek. Chinook salmon (KS) of Redwood Creek belong to the California Coastal Chinook Salmon Evolutionarily Significant Unit (ESU), and are listed as "threatened" under the Federal Endangered Species Act (Federal Register 1999a). The definition of threatened as used by National Oceanic and Atmospheric Administration (NOAA) and the National Marine Fisheries Service (NMFS) is "likely to become endangered in the foreseeable future throughout all or a significant portion of their range"

(NOAA 1999). Coho salmon (CO) belong to the Southern Oregon / Northern California Coasts ESU and were classified as "threatened" (Federal Register 1997) prior to the Chinook salmon listing. Steelhead trout (SH) fall within the Northern California Steelhead ESU, and are also listed as a "threatened" species (Federal Register 2000). Coastal cutthroat trout (CT) of Redwood Creek fall within the Southern Oregon / California Coasts Coastal Cutthroat Trout ESU, and were determined "not warranted" for ESA listing (Federal Register 1999b). Despite ESU listings of Redwood Creek anadromous salmonid populations, relatively little data exists concerning abundance and population sizes, particularly for juvenile (and adult) life history stages. Historically, the most prolific species in Redwood Creek was most likely the fall/early winter-run Chinook salmon.

Purpose

The purpose of this project is to describe juvenile salmonid downstream migration in upper Redwood Creek, and to determine smolt population sizes for wild 0+ (young-of-year) Chinook salmon (Ocean-type), 1+ (between 1 and 2 years old) steelhead trout, 2+ (2 years old and greater) steelhead trout, 1+ coho salmon, and cutthroat trout. The long term goal is to monitor the status and trends of out-migrating juvenile salmonid smolts in Redwood Creek in relation to watershed conditions and restoration activities in the basin; and to provide data needed for Viable Salmonid Population (VSP) Analysis. An additional goal is to document the presence or absence of juvenile coho salmon and 1+ Chinook salmon (Stream-type). Specific study objectives were as follows:

1) Determine the species composition and temporal pattern of downstream migrating juvenile salmonids, and enumerate species out-migration.
2) Determine population estimates for downstream migrating 1+ steelhead trout, 2+ steelhead trout, 0+ Chinook salmon, 1+ coho salmon, and cutthroat trout.
3) Record fork length (mm) and weight (g) of captured fish.
4) Investigate 0+ Chinook salmon, 1+ steelhead trout, and 2+ steelhead trout travel time and growth as they migrate from the upper trap to the lower trap (or estuary) using passive integrated transponder tags (Pit Tags).
5) Collect and handle fish in a manner that minimizes mortality and potential stress.
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, 2006 at the same location as in previous study years (i.e. downstream of a moderately high gradient riffle). However, during the winter storms in December 2005 and January 2006, large amounts of sands and small gravels were deposited (estimated at 2^+ feet) at the trap site such that the channel gradient decreased, and changed the habitat unit from a moderately high gradient riffle to a run.

The rotary screw trap was modified by using the larger pontoons normally equipped with the 8 foot cone so that a larger livebox could be used. The debris wheel of the E.G. solutions livebox was cut out, and aluminum was added to the livebox to increase the length nearly two-fold (L 218.4 cm x W 121.9 cm x H 55.9 cm). A framed perforated steel plate 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 25 through July 15 except when stream flows and debris loads were too high to trap safely. 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 stream in order to raise the cone above the water surface. 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 April 2006 (similar to YR 2003 and 2005) 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 highest flows (in April) to make sure that we were not 'missing' fish (few fish were caught). During one high flow event on April 2-3, 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 four hours so that we could access the livebox. Very few fish were captured (< 10 individuals). 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 reduced stream flows, rock type weirs and weir panels were used with the rotary screw to: 1) keep the trap's cone revolutions relatively high, and 2) maintain good trap efficiencies by directing the fish into the cone area. The weir panels were set to fall down under any unexpected, high stream flows. Plastic drop cloths were used to cover the weirs in June and early July to further increase flow into the cone area.

Beyond July 15, stream flows were too low to operate the rotary screw trap, and a fyke net was deployed on July 15 about 20 m upstream of the screw trap's position. Normally by mid to late July we remove the rotary screw trap and install a pipe trap to finish the study. However, due to the decrease in channel gradient, a fyke net was deployed instead of the pipe trap. Weir panels were placed immediately upstream of the fyke net to funnel all migrating fish into the net and livebox. On July 27 – 28, I temporarily stopped trapping because high stream temperatures (eg 28^{+} C or 82^{+} F) from July 24 – July 28 were killing juvenile steelhead trout in the stream. The fyke net was re-deployed on the evening of July 28, and operated until the end of the season on August 12. The trapping season in YR 2006 was extended compared to previous trapping years because juvenile salmonids were outmigrating beyond August 5, which is normally when out-migration has tapered off considerably. Trapping was discontinued when the catch distribution reached zero, or when relatively few individuals were caught in consecutive days.

The YR 2006 trapping season can be characterized as working in and out of high flow events in April; and for the remaining months maintaining the trap placement and configuration (via weir panels) to increase trap efficiencies and cone revolutions. Stream flow conditions in 2006 were not as problematic as YRS 2003 and YRS 2005, with exception to lethal stream temperatures observed during late July.

Biometric Data Collection

Fishery technicians carefully removed debris (e.g. alder cones, leaves, sticks, detritus, varying amounts of filamentous green algae, etc) from within the livebox nearly every night of trapping to reduce trap mortalities the following morning. The trap's livebox was emptied at 09:00 every morning by 2 - 4 technicians. Young of year fish were removed first and processed before 1+ and 2+ fish to decrease predation or injury to the smaller fish. Captured fish (0+ fish first, then 1+ and older) were placed into 5 gal. buckets and carried to the processing station. At the station, fish were placed into a 23.5 gal. ice chest modified to safely hold juvenile fish. The ice chest was adapted to continually receive fresh water from the stream using a 3,700 gph submersible bilge pump. The bilge pump connected to a flexible line (ID 4 cm or 1.6 in.) that connected to a manifold with four ports. "Y" type hose adapters were connected to each port. Garden hoses connected to the hose adapters, with one line feeding the ice chest, and four lines feeding recovery buckets for processed fish. Additional garden hoses were connected to the hose adaptors to quickly fill buckets if needed. Plumbing inside the ice chest consisted of two PVC pipes: one that served to dissipate stream water into the ice chest, and the other to drain excess water. Water lines to the recovery buckets were elevated above the recovery buckets so that the fresh water would also provide increased aeration. The system worked very well, did not require additional battery operated aerators, and decreased total fish processing time.

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

Fork Lengths/Weights

Fish were anesthetized with MS-222 prior to data collection in 2 gal. dishpans. Biometric data collection included 30 measurements of fork length (mm) and wet weight (g) for random samples of 0+ Chinook salmon (0+ KS), 1+ Chinook salmon (1+ KS), 1+ and greater cutthroat trout (CT), 1+ steelhead trout (1+ SH), and 2+ and greater steelhead trout (2+ SH). 0+ steelhead trout were only measured for fork length. A 350 mm measuring board ($\pm$ 1 mm) and an Ohaus Scout ll digital scale ($\pm$ 0.1 g) were used in the study. Fork lengths were taken every day of trap operation, and fork length frequencies of 0+ and older steelhead trout and Chinook salmon were used to determine age-length relationships at various times throughout the trapping period. Scales were occasionally read to verify age class cutoffs. 0+ Chinook salmon and 1+ steelhead trout weights were taken 2 - 5 times per week, and 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 and non-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 six times a week for 0+ Chinook salmon and 1+ steelhead trout, and two to five times a week for 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).

Small partial fin clips were used to identify trap efficiency trial fish by squaring the round edge (or tip) of a given fin (caudal, pectoral) with scissors. Fish used in efficiency trials were given partial fin clips while under anesthesia (MS-222), and recovered in 5 g buckets which received fresh stream water (via the plumbing system). Clips for 2+ steelhead trout were stratified by week such that marked fish of one group (or week) would not be included in the following week(s) calculations (no out of strata captures occurred in YR 2004, 2005, and 2006). I did not stratify clips for 0+ Chinook and 1+ steelhead trout because four years of data (when I did stratify clips) showed that nearly all of the recaptures (99.4%) occurred in the correct strata. Clip types for 1+ and 2+ steelhead were kept on different time schedules to aid in identifying the correct age group of the recaptured fish; if there was any doubt or question, we would re-measure the fish, and count it for the appropriate age group. 0+ Chinook salmon and 1+ steelhead trout were given upper caudal fin clips, and 2+ steelhead trout were given upper or lower caudal fin clips. Once recovered from anesthesia, the fish were placed in mesh cages in the stream for at least 1 - 2 hrs to test for short term delayed mortality (Carlson et al. 1998). Fin clipped 0+ Chinook salmon were released in fry habitat 260 m upstream of the trap, and clipped 1+ and 2+ steelhead were released into a pool 160 m upstream of the trap. Fin clipped 0+ Chinook salmon 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 2005, we marked and released 37 2+ steelhead trout and 146 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 2005 re-migrated back upstream of the upper trap to be caught in YR 2006 as two or three year old fish (we did this in YRS 2001-02, and YRS 2004-05 as well). Every 1+ and 2+ steelhead trout captured in YR 2006 was examined for elastomer marks. Mark retention was assumed to be nearly 90% within 16 months (Fitzgerald et al. 2004).

In YR 2005 we also pit tagged and released 46 2+ steelhead trout, 147 1+ steelhead trout, and 555 0+ Chinook salmon. Similar to the elastomer, these marks served to show if any of these juvenile fish re-migrated upstream of the trap site to be later re-captured migrating downstream in YR 2006. Each 2+ steelhead trout captured at the upper trap was scanned for pit tags, as were the largest juvenile Chinook salmon smolts (potential 1+ smolts).

Travel Time and Growth

We did not use plastic elastomer in YR 2006 to investigate travel time because individual fish cannot be uniquely identified when elastomer marks are used for batches of fish, and the mark is rather difficult to apply for fish under 85 mm (FL). Pit tags (passive integrated transponder tags) offer the ability of individual recognition by using numbers unique to each tag (and marked fish). In YR 2006 (and 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 2007b) or estuary (David Anderson, pers. comm. 2006). We found pit tagging to be easier and faster than applying elastomer. Pit tags used in the study were 11.5 mm long x 2 mm wide, and weighed 0.09 g (ALLFLEX USA, Inc., PO BOX 612266, Dallas/Ft Worth Airport, Texas). Pit tags were applied to randomly selected 1+ steelhead trout (n = 246), 2+ steelhead trout (n = 38) and 0+ Chinook salmon smolts (FL $\geq$ 68 mm, n = 121) using techniques shown by Seth Ricker in YR 2005 (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 10 - 58 hrs to test for delayed mortality; however, most pit tagged juveniles were held for a 34 hr period. 0+ Chinook salmon were kept separately from 1+ and 2+ steelhead trout. All pit tagged fish were released at night downstream of the trap site at the normal downstream release site. Field crews at the upper trap, lower trap, and estuary had hand held pit tag readers (ALLFLEX USA, Inc., PO BOX 612266, Dallas/Ft Worth Airport, Texas) so that they could scan and identify pit tag fish; and perform necessary fork length and weight measurements. I assumed pit tags did not affect feeding or migration based upon findings by Newby et al. (2007).

New to this study year, we partially fin clipped 0+ steelhead trout (FL = 40 - 55 mm) at the upper trap (7/19/06, n = 50) to see if any would be recaptured at the lower trap (distance of 29 miles).

Delayed Mortality

We conducted several delayed mortality tests for captured 0+ Chinook salmon (n = 22 tests), 0+ steelhead trout (n = 4 tests), 1+ steelhead trout (n = 24 tests), and 2+ steelhead trout (n = 17 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 154 for 0+ Chinook salmon, 58 for 1+ steelhead trout, and 25 for 2+ steelhead trout. The duration of each fin clip test was 24 hrs for 0+ Chinook salmon, 24 or 48 hrs for 1+ steelhead trout, and 24 hrs for 2+ steelhead trout.

Handling tests were for fish that were anesthetized and measured for FL, or FL and WT. Total sample size was 12 for 0+ Chinook salmon, 139 for 0+ steelhead trout, 110 for 1+ steelhead trout, and 9 for 2+ steelhead trout. The duration of each test was 24 hrs, except for a six hr test with 0+ steelhead trout on 7/25/06 to investigate mortality associated with high stream temperatures in the afternoon.

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 121 for 0+ Chinook salmon, 246 for 1+ steelhead trout, and 38 for 2+ steelhead trout. The duration of each test ranged from 10 – 58 hrs, with 34 hrs being most common.

Pit Tag Retention

We re-scanned a portion of the pit tagged 0+ Chinook salmon prior to release to assess pit tag retention over a 24 hr (6/19/06, n = 17) and 48 hr (6/22/06, n = 21) period. We also re-scanned 13 2+ steelhead trout for retention over a 34 hr period on April 14, 2006.

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 26 – August 12, 2006. 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 2006), 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. = 14.9 ^oC), therefore only data from one probe is reported. The probes were placed into a PVC cylinder with holes to ensure adequate ventilation and to prevent influences from direct sunlight; and attached to the rotary screw trap via 1/8" diameter wire rope. Probes were set to record stream temperatures (^oC) every 60 minutes and recorded about 3,384 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 - 2006 were determined following methods described by Madej et al. (2006). MWAT is defined as the maximum value of a 7-day moving average of daily average stream temperatures, and MWMT is the maximum value of a 7-day moving average of daily maximum stream temperatures (Madej et al. 2006).

Statistical Analyses

Numbers Cruncher Statistical System software (NCSS 97) (Hintze 1998) was used for linear correlation, regression/ANOVA output, single factor ANOVA, chi-square, and descriptive statistics.

Linear regression was used to estimate the catch for each species at age for days when the trap was not fishing by using data before and after the missed day(s) catch. The estimated catch (except for 0+ steelhead) was then added to the known catch in a given stratum and applied to the population model for that stratum (Roper and Scarnecchia 1999).

Linear regression and correlation (for temporal component) were used to test for influences of average daily stream temperature, average daily discharge (O'Kane gage, USGS 2005), stream gage height (at trapping site) and trapping day (temporal variable) on daily catches of all juvenile salmonids combined and for each species at age. Regression and correlation models did not include any combination of the independent variables (eg average temperature, average daily discharge, gage height, and trapping day) in a given model or test because they were highly correlated with one-another (Correlation, $p = 0.000001$, r ranged from 0.84 – 0.95). Regression and correlation were also used to test for influences of stream temperature, stream discharge and stream gage height averaged by week, and trapping week number on the weekly catches of all species combined, and for each species at age; weekly trapping efficiencies for 0+ Chinook salmon, 1+ steelhead trout, and 2+ steelhead trout were also regressed on weekly catches for a given species at age.

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

Linear correlation was used to determine if weekly trapping efficiencies for 0+ Chinook salmon, 1+ steelhead trout, and 2+ steelhead trout changed over time (weeks). Regression was used to test for influences of physical variables (average weekly gage height and average weekly stream discharge) on weekly trapping efficiencies for a given species at age. One week (stratum) for 2+ steelhead trout trap efficiency was omitted in the analysis because only two marked fish were released with zero subsequent recaptures; 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 ($p < 0.001$, $r = 0.95$).

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 seven years of study. Linear regression was used to test the relationship of peak winter flows during egg incubation in spawning redds on the subsequent population size of 0+ Chinook salmon by coding high, bedload mobilizing flows as 1 (for population estimates in YRS 2003, 2005, and 2006) and non-bedload mobilizing flows as 0 (for population estimates in YRS 2000 - 2002, 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 emigrant population in YR 2006 occurred 12/30/05 (peak cfs = 6,420, duration of nine hours) and 12/31/05 (peak cfs = 6,030, duration of two hours) (USGS 2006).

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

Descriptive statistics were used to characterize the mean FL (mm) and Wt (g) of each species at age on a study year and weekly basis. Linear correlation was used to test if average FL and Wt by season (study year) changed over time (study year). Regression was used to test for influences of a species total catch (0+SH) or population estimate (0+KS, 1+SH, 2+SH) on average FL and Wt per season for the current seven 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.

I determined a ' rough' estimate of growth rate in FL and Wt for 0+ Chinook salmon in YR 2006 generally following methods by Bendock (1995). I used the first weekly average in FL and Wt with a sample size $\geq$ 25 (week 3/26 - 4/01) and the last weekly average in the season (6/25 - 7/01) with a sample size $\geq$ 25. The first average was subtracted from the last average, and divided by the number of days from the first day after the first weekly average to the last day of the last weekly average. For the example above, the number of days used in the growth calculation equaled 91. The resultant growth rate is not an individual growth rate, but more of a 'group' growth rate. The calculated values were then compared to values put forth by Healey (1991) and Bendock (1995) for juvenile Chinook salmon in other streams. The growth rate for 0+ steelhead trout was also determined using this method.

Linear correlation was also used to test if the average weekly FL and Wt of each species at age (excluding 0+ steelhead weight) increased over the study period in YR 2006 and for the previous five year average for Chinook salmon, and previous six year average for 1+ and older steelhead trout. The lack of data in any given week was due to: 1) differences in trap deployment time among study years, 2) no catches occurred, or 3) sample size was too low to generate a reliable average. Single factor ANOVA (or non-parametric equivalent, Kruskal-Wallis One-Way ANOVA on Ranks) was used to test for significant variation among weekly FLs and Wts in YR 2006 with the five year average for 0+ Chinook salmon (excludes YR 2003), and six year average for 0+ (excludes Wt), 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 2006 with the previous six year average. Parr stage was not included in the tests because in YR 2006 none of the 1+ or 2+ steelhead trout were classified as parr (NCSS 97). Chi-square was also used to test if the percentages of Chinook salmon fry and fingerlings in YR 2006 differed from the previous six year average. The percentage of fry and fingerlings in YR

2006 was also tested for randomness by assuming that a random occurrence of the two designations would be 50/50 or 1:1.

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

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

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

Numerous growth indices (Percent Change in Growth, Absolute Growth Rate, Specific Growth Rate scaled, and Relative Growth Rate) were calculated to ensure comparisons of our data with data reported in the literature. Equations for growth indices are found in Busacker et al. (1990). Absolute growth rate is expressed as mm per day for FL or g per day for Wt. Specific growth rate (mm/d) is expressed as a scaled number (by multiplying specific growth by 100). Thus, if the specific growth rate scaled equaled 0.741% (mm per day), the un-scaled value would equal 0.00741 mm per day. Relative growth rate is a growth rate that is relative to the initial size of the fish, and units for FL are in mm/mm/d and for Wt, g/g/d. Therefore, if the relative growth rate equaled 0.003 mm/mm/d, then we would say that the fish grew 0.003 mm per mm of fish per day.

Travel time, travel rate, and growth for recaptured pit tagged 0+ Chinook salmon (n = 28) and 1+ steelhead trout (n = 6) smolts in YR 2006 were modeled using linear regression. Two additional 0+ Chinook salmon pit tag recaptures were not used in analysis because the fish were under stress with fungus visible on their backs and caudal fins; due to the rarity of this occurrence, these two fish were excluded from analysis. Removal of the two outliers did not change any test results. Travel and growth parameters for 2+ steelhead trout could not be modeled due to zero recaptures. Travel time and travel rate for recaptures in the Redwood Creek estuary (0+ Chinook, n = 7; 1+ steelhead, n = 4) could not be determined because estuary sampling did not occur every day. However, various growth indices were calculated, and tested for relationships with the period of growth (d) for 0+ Chinook salmon 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), lunar phase (averaged across a specific migration period), and stream discharge during a specific migration period (average of data from O'Kane and Orick gages, USGS 2006).

Independent variables for modeling growth (dependent variable) included travel time, travel rate, average water temperature, average stream discharge, and average lunar phase. Physical variables were once again averaged across a specific migration period. Stream temperature and stream discharge were not included together in any regression models because they were highly correlated ($p < 0.001$). During the travel time and growth experiments (4/13 – 7/22), average daily stream temperatures at the upper trap site ranged from 6.4 - 23.7 ^{o}C (43.5 - 74.7 ^{o}F) and average daily stream discharge ranged from 9 - 770 cfs (O'Kane gage, USGS 2006). Average daily stream temperatures at the lower trap site ranged from 8.0 - 19.2 ^{o}C (46.4 - 66.6 ^{o}F) and average daily stream discharge ranged from 42 – 2,910 cfs (Orick gage, USGS 2006). Thus, the experiments were conducted over a fairly wide range of environmental variables.

Minimum, average, and maximum stream temperatures for each day during the trapping period were determined from data collected by temperature probes at the trapping site. Descriptive statistics were used to determine the average stream temperature during the course of the study. Single factor ANOVA was used to test for significant variation in monthly stream temperatures in YR 2006 and the previous five 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 2006; the same test was applied to the previous five year average. Regression was used to examine the relationship of the daily stream gage height on average daily stream temperature for YR 2006, and the relationship of average discharge during each trapping season on average stream temperature each season ($n = 6$) (excluding YR 2000).

If data violated tests of statistical assumptions, data was transformed with Log (x+1) to approximate normality (Zar 1999). The term 'transformed' in this paper refers to the log(x+1) transformation. "X" could be the independent or dependent variable in linear regression, or the response variable for a given treatment using ANOVA. Power is defined as the probability of correctly rejecting the null hypothesis when it is false; and can also be thought of as the probability of detecting differences that truly exist (Zar 1999). The level of significance (Alpha) for tests with six or seven 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 seven data points, alpha was set at 0.05.

RESULTS

The rotary screw trap operated from 3/25/06 - 7/16/06 and trapped 111 nights out of a possible 113. The fyke net operated from 7/16/06 - 8/12/06 and trapped 24 nights out of a possible 27. The trapping rate in YR 2006 was 96% compared to 97% for the previous six year average (ranged from 92 - 99%). Days missed trapping in YR 2006 occurred in April (n = 2), July (n = 2), and August (n = 1).

Species Captured

Juvenile Salmonids

Species captured in YR 2006 included: juvenile Chinook salmon (*Oncorhynchus tshawytscha*), juvenile steelhead trout (*O. mykiss*), and coastal cutthroat trout (*O. clarki clarki*). No juvenile coho salmon (*O. kisutch*) or juvenile pink salmon (*O. gorbuscha*). were captured in YR 2006. Juvenile coho salmon have not been captured for the seventh consecutive year. A total of 57,193 juvenile salmonids were captured in YR 2006 (Figure 2).

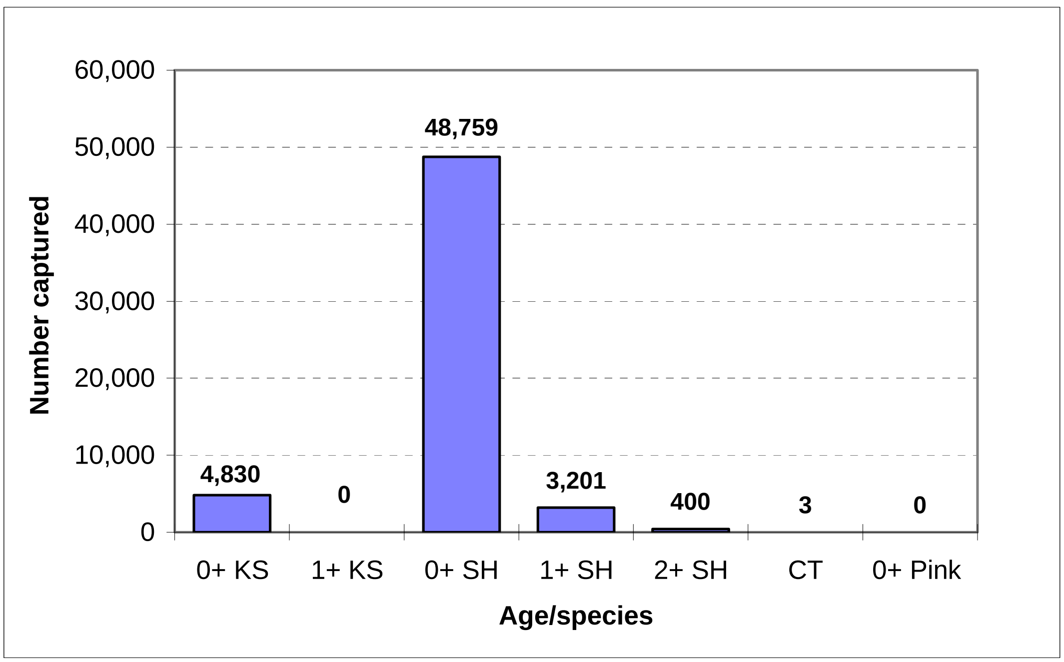

Figure 2. Total juvenile salmonid trap catches (n = 57,193) from March 26 through August 12, 2006, upper Redwood Creek, Redwood Valley, Humboldt County, CA. Numeric values above columns represent actual catches. 0+ KS = young-of-year Chinook salmon, 1+ KS = age 1 and older Chinook salmon, 0+ SH = young-of-year 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.

The total trap catch of juvenile salmonids in YR 2006 was slightly higher than catches in YR 2005, and much less (74%) than trap catches for the previous six year average (Table 3). Aside from 1+ Chinook salmon and 0+ pink salmon catches, the greatest reduction (96%) in trap catches in YR 2006 occurred with 0+ Chinook salmon. 0+ steelhead trout and cutthroat trout were the only juvenile salmonids captured in greater numbers in YR 2006 compared to YR 2005 (Table 3).

Table 3. Comparison of juvenile salmonid trap catches in YR 2006 with YR 2005 and the previous six year average catch, upper Redwood Creek, Humboldt County, Ca.

	Actual Catches			
Age/species*	YR 2005	Previous six year average	YR 2006	Percent reduction in YR 2006**
0+ KS	9,329	113,955	4,830	95.8
1+ KS	0	11	0	100.0
0+ SH	41,671	92,578	48,759	47.3
1+ SH	4,912	11,305	3,201	71.7
2+ SH	628	1,039	400	61.5
CT	2	4	3	25.0
0+ Pink	2	3	0	100.0
Total:	56,544	218,895	57,193	73.9

* Age/species definitions are the same as in Figure 2.
** Comparisons are with the previous six year average (YRS 2000-05).

Miscellaneous Species

The trap captured several species besides anadromous salmonids in YR 2006, including: prickly sculpin (*Cottus asper*), coast range sculpin (*Cottus aleuticus*), sucker (*Catostomidae* family), three-spined stickleback (*Gasterosteus aculeatus)*, juvenile (ammocoete) lamprey and adult Pacific Lamprey (*Entosphenus tridentatus*) (Table 4).

Amphibian catches in YR 2006 included: coastal (Pacific) giant salamander (*Dicamptodon tenebrosus*), rough skinned newt (*Taricha granulosa granulosa*), yellow legged frog (*Rana muscosa*), and tailed frog tadpole (*Ascaphus truei*) (Table 4). Numerous and at times, countless, aquatic and semi-aquatic invertebrates were also captured in the trap.

Table 4. Miscellaneous species captured in YR 2006 compared to catches in YR 2005 and the previous six year average catch, upper Redwood Creek, Humboldt County, CA.

	Actual Catches		
Species Captured	YR 2005	Previous six year average	YR 2006
Prickly Sculpin	1	5	3
Coast Range Sculpin	13	93	16
Sucker	3	7	15
3-Spined Stickleback	92	99	79
Brown Bullhead	3	1	0
Adult Pac. Lamprey	9	35	25
Juvenile Lamprey	2,210	2,190	648
Pac. Giant Salamander	147	112	185
Painted Salamander	1	1	0
Rough Skinned Newt	18	30	12
Red-Legged Frog	2	1	0
Yellow-Legged Frog	25	14	8
American Bullfrog	0	1	0
Tailed Frog*	4	5	61

* 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 2006 were variable over time, with apparent multi-modal catch distributions for each species at age.

0+ Chinook salmon daily catches in YR 2006 (n = 4,830) ranged from 0 - 276 individuals, and averaged 35 fish per day. The previous six year daily catch ranged from 0 - 10,700 and averaged 884 per day. Daily 0+ Chinook salmon captures in YR 2006 expressed as a percentage of total 0+ Chinook salmon catch in YR 2006 (n = 4,830) ranged from 0.0 – 5.8%, and averaged 0.7%. The peak catch in YR 2006 occurred 6/16/06.

0+ steelhead trout daily catches in YR 2006 (n = 48,759) ranged from 0 - 2,495 individuals, and averaged 348 per day. The previous six year daily catch ranged from 0 - 6,993 individuals and averaged 711 per day. Daily 0+ steelhead captures in YR 2006 expressed as a percentage of total 0+ steelhead catch in YR 2006 (n = 48,759) ranged from 0.0 - 5.2% and averaged 0.7%. The peak catch in YR 2006 occurred 6/13/06.

1+ steelhead trout daily catches in YR 2006 (n = 3,201) ranged from 0 - 113, and averaged 23 per day. The previous six year daily catch ranged from 0 - 727 individuals and averaged 87 per day. Daily 1+ steelhead trout captures in YR 2006 expressed as a percentage of total 1+ steelhead trout catch in 2006 (n = 3,201) ranged from 0.0 – 3.5% and averaged 0.7%. The peak catch in YR 2006 occurred on 5/24/06.

2+ steelhead trout daily catches in YR 2006 (n = 400) ranged from 0 - 17, and averaged three individuals per day. The previous six year daily catch ranged from 0 - 45 individuals and averaged eight per day. Daily 2+ steelhead trout captures in YR 2006 expressed as a percentage of total 2+ steelhead trout catches in YR 2006 (n = 400) ranged from 0.0 – 4.3%, and averaged 0.7%. The peak catch in YR 2006 occurred on 4/30/06.

Days Missed Trapping

Five days were not trapped during the course of the study due to high flow events and high debris loads in the livebox, or due to stream temperatures that reached lethal levels in late July. 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 = 5 d) during the emigration period of March 25 through August 12 (as a percentage of total without missed days in parentheses), upper Redwood Creek, Humboldt County, CA., 2006.

Age/spp.*	Catch	Population Level
0+ KS	37 (0.76%)	431 (1.65%)
0+ SH	765 (1.57%)	-
1+ SH	14 (0.44%)	51 (0.19%)
2+ SH	8 (2.00%)	26 (1.39%)

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

0+ Chinook Salmon

Trap catches of 0+ Chinook salmon by month in YR 2006 were markedly lower than the previous six year average catch by month (Figure 3). The majority of 0+ Chinook salmon catches in YR 2006 occurred in May and June (n = 4,034 or 83.5% of total catch), as did the majority of catches for the previous six year average (n = 82,638 or 72.5% of total average catch). The correlation of 0+ Chinook salmon catches with study years indicated a non-significant negative relationship (n = 7, p = 0.27, r = 0.52, slope is negative, power = 0.17).

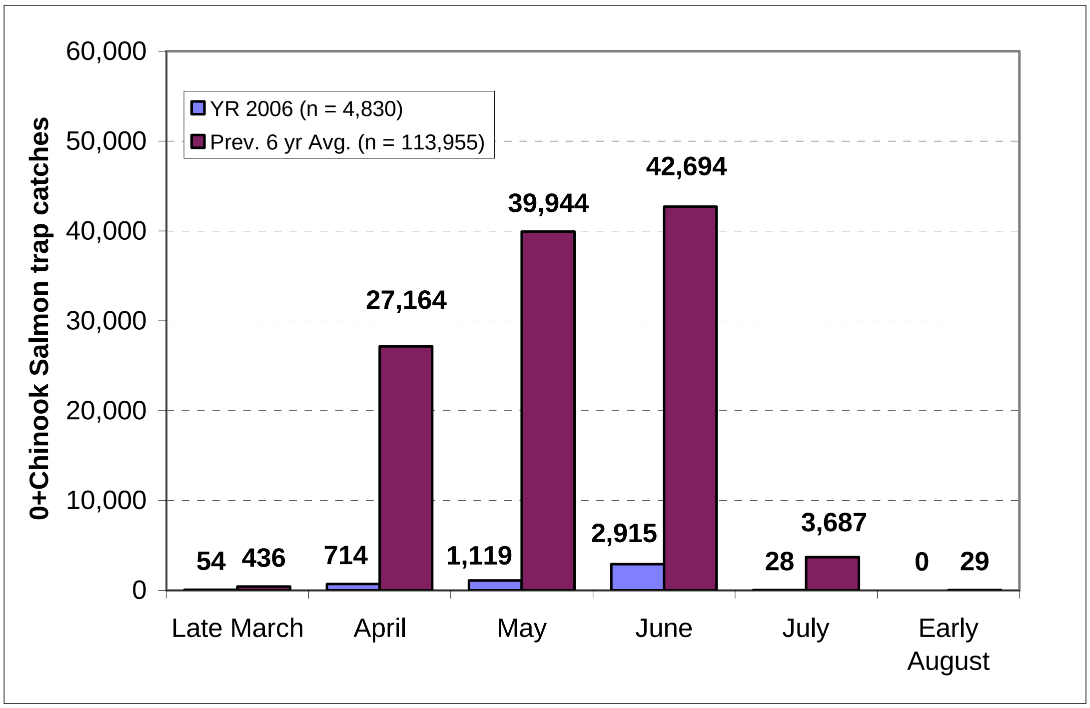

Figure 3. Comparison of the total 0+ Chinook salmon trap catch by month in YR 2006 with the previous six year average, upper Redwood Creek, Humboldt County, CA. Numeric values represent actual catches.

0+ Steelhead Trout

Trap catches of 0+ steelhead trout by month in YR 2006 were much lower than the previous six year average catch by month (Figure 4). The majority of 0+ steelhead trout catches in YR 2006 occurred in May and June (n = 36,828 or 75.5% of total catch), compared to catches in June and July (n = 63,850 or 69.0% of total) for the previous six year average. June was the month with the highest catches for both YR 2006 and the previous six year average.

The linear correlation of 0+ steelhead trout trap catches with study years indicated a non-significant negative relationship (n = 7, p = 0.54, r = 0.28, slope is negative, power = 0.08) (Appendix 4). However, the line of best fit using a polynomial relationship showed a negative trend over the seven years, and was able to correlate 84% of the variation in trap catches to study years (Appendix 4).

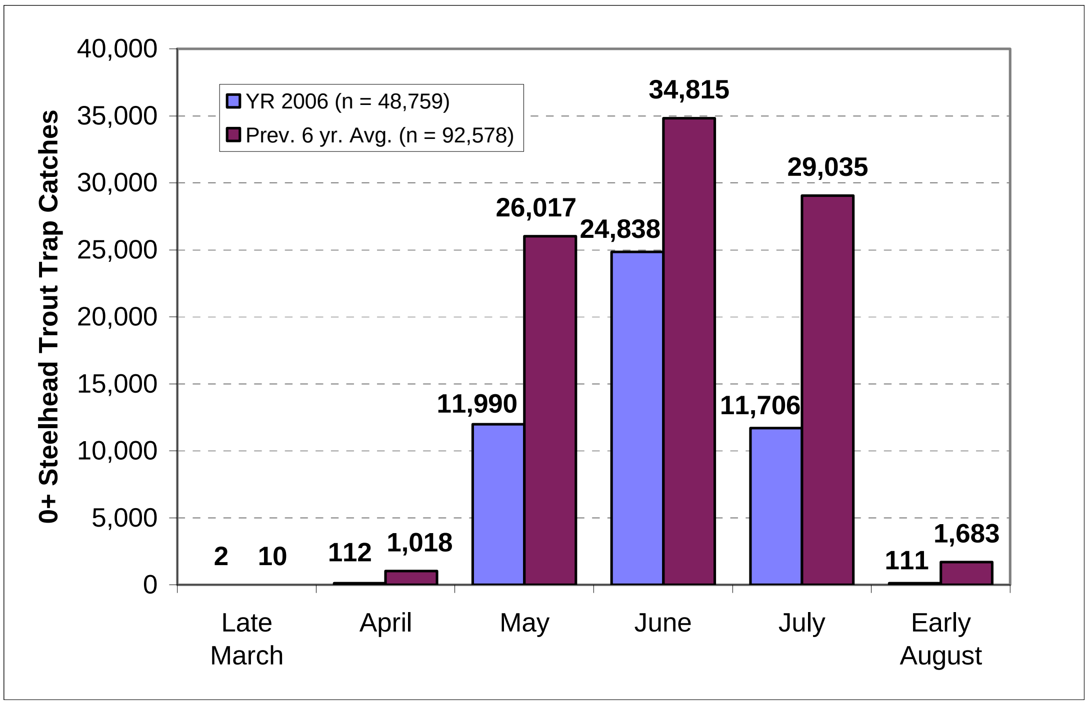

Figure 4. Comparison of the total 0+ steelhead trout trap catch by month in YR 2006 with the previous six year average, Upper Redwood Creek, Humboldt County, CA. Numeric values represent actual catches.

1+ Steelhead Trout

Trap catches of 1+ steelhead trout by month in YR 2006 were markedly lower than the previous six year average catch by month (Figure 5). The majority of 1+ steelhead trout catches in YR 2006 occurred in May and June (n = 2,664 or 83.2% of total catch), compared to the majority of catches in April and May (n = 8,656 or 76.6% of total) for the previous six year average. The highest catches occurred in May for both YR 2006 and the previous six year average. The correlation of 1+ steelhead trout trap catches with study years indicated a non-significant negative relationship (n = 7, p = 0.11, r = 0.65, slope is negative, power = 0.35).

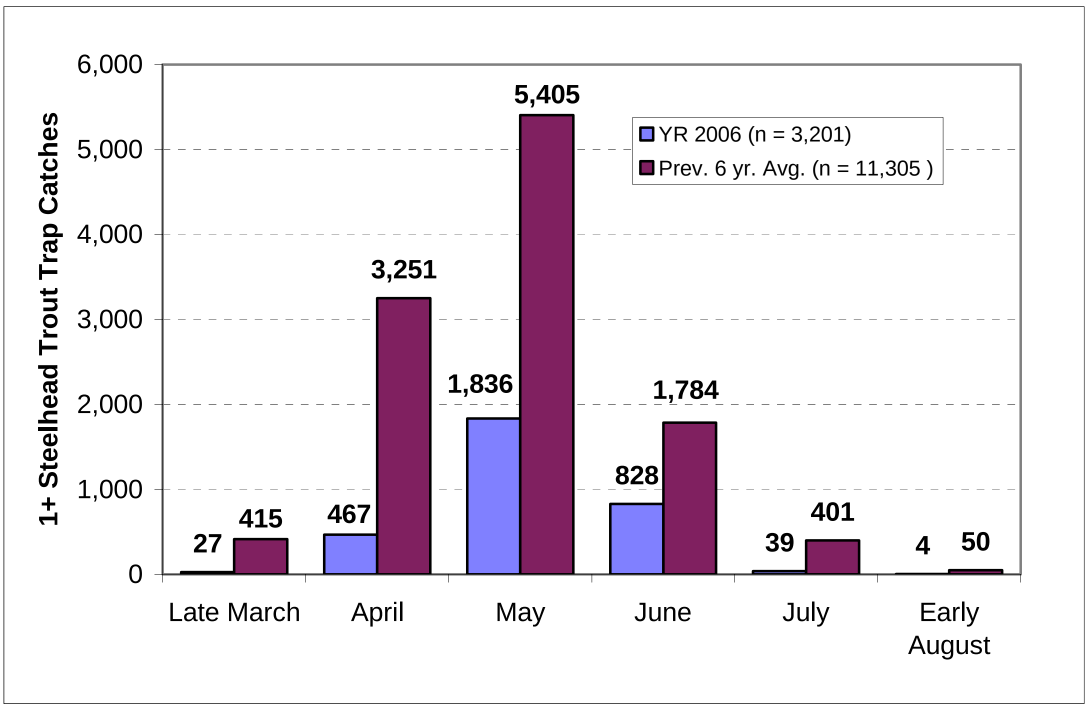

Figure 5. Comparison of total 1+ steelhead trout catches by month in YR 2006 with the previous six year average, Upper Redwood Creek, Humboldt County, CA. Numeric values represent actual catches.

2+ Steelhead Trout Catches

Trap catches of 2+ steelhead trout by month in YR 2006 were markedly lower than the previous six year average catch by month (Figure 6). The majority of 2+ steelhead trout catches in YR 2006 occurred in April and May (n = 328 or 82.0% of total catch), as did catches for the previous six year average (n = 714 or 68.7% of total catch). The highest catches occurred in April for YR 2006, compared to May for the previous six year average. The correlation of 2+ steelhead trout trap catches with study years indicated a non-significant negative relationship ($n = 7$, $p = 0.29$, $r = 0.47$, power = 0.16).

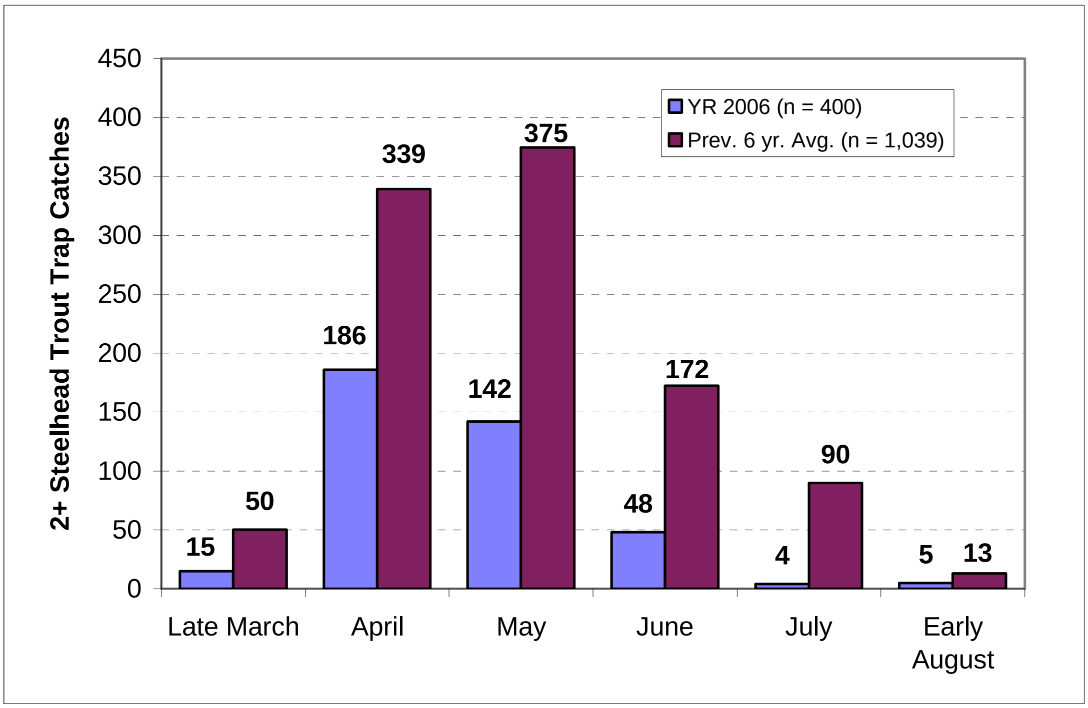

Figure 6. Comparison of 2+ steelhead trout trap catches by month in YR 2006 with the previous six year average, Upper Redwood Creek, Humboldt County, CA. Numeric values represent actual catches.

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

By Day

Linear regressions of average daily stream temperature (^{o}C), average daily discharge (cfs), daily gage height (ft.), or trapping day number (uses correlation tests) on daily catches of all salmonids combined, 0+ Chinook salmon, 0+ steelhead trout (except for daily stream temperature) and 1+ steelhead trout violated regression assumptions [even with log(x+1) transformations], and results were not valid. The transformed average daily stream temperature on transformed 0+ steelhead trout catches passed regression assumption tests (n = 3), and a significant positive relationship was detected ($p < 0.001$, $R^2 = 0.40$, positive slope, power = 1.0). The transformed number of 2+ steelhead trout daily catches was negatively related to the transformed average daily stream temperature ($p < 0.001$, $R^2 = 0.51$, negative slope, power = 1.0), positively related to average daily discharge (cfs) ($p < 0.001$, $R^2 = 0.40$, positive slope, power = 1.0), positively related to daily gage height (ft.) ($p < 0.001$, $R^2 = 0.44$, positive slope, power = 1.0), and negatively related to the trapping day number ($p < 0.001$, r = 0.70, 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 5) on daily catches. The majority of daily trap catches occurred during average daily stream temperatures of 13.1 – 21.9 ^{o}C for Chinook salmon (72.7% of total 0+KS catch), 10.7 – 22.3 ^{o}C for 0+ Steelhead trout (91.7% of total 0+SH catch), 9.2 – 17.9 ^{o}C for 1+ Steelhead trout (92.0% of total 1+SH catch), and 7.4 to 17.9 ^{o}C for 2+ steelhead trout (94.6% of total 2+SH catch). The peak catch occurred during an average daily steam temperature of 17.1 ^{o}C for 0+ Chinook (n = 276), 14.4 ^{o}C for 0+ steelhead trout (n = 2,495), 12.4 ^{o}C for 1+ steelhead trout (n = 113), and 10.6 ^{o}C for 2+ steelhead trout (n = 17). The peak catch of 0+ trout was mostly comprised of emergent fry (Avg. FL = 30.0 mm).

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); rather, peak catches occurred during the descending limb of the hydrograph. 0+ steelhead trout followed a similar pattern to 0+ Chinook salmon for most of the peaks in catches; however, the largest peak catch (n = 2,495) occurred during a slight increase in stream gage height (0.36 in.). 1+ steelhead trout peak catches showed more variation than young-of-year fish: three of the five peaks in catches occurred when the stream was stable (not dropping or increasing), one occurred when the stream was dropping, and the largest peak catch (5/24/06, n = 113) occurred when the stream rose 3.48 in (8.8 cm). 2+ steelhead trout peak catches in relation to the stream hydrograph showed variation as well: two peak catches occurred when the stream rose 1.32 and 3.48 in., and four peaks occurred during a decrease in gage height. The largest peak catch (n = 17) of 2+ steelhead trout occurred on 4/30/06 when the stream had dropped 0.84 in.

By Week

The transformed weekly catches of 0+ Chinook salmon were significantly related to week number (Correlation, $p < 0.01$, r = 0.62, negative slope) and stream temperature (Regression, $p < 0.05$, $R^2 = 0.30$, negative slope); no significant relationships with gage height, stream discharge or 0+ Chinook salmon trapping efficiencies were detected ($p > 0.05$ for each test) (Appendix 5). Week number explained 62% of the variation in weekly catches of 0+ Chinook salmon. The weekly catches of 0+ steelhead trout were significantly related to average stream discharge (Regression, $p < 0.05$, $R^2 = 0.30$, negative slope) and gage height (Regression, $p < 0.05$, $R^2 = 0.25$, negative slope); no significant relationships with stream temperature (Regression, $p > 0.05$) or week number

(Correlation, $p > 0.05$) were detected (Appendix 5). 1+ steelhead trout weekly catches were not significantly related to any variable tested ($p > 0.05$ for each test). In contrast, 2+ steelhead trout weekly catches were significantly related to average weekly gage height (Regression, $p < 0.001$, $R^2 = 0.49$, positive slope) and average weekly stream discharge (Regression, $p < 0.001$, $R^2 = 0.48$, positive slope); and the transformed 2+ steelhead trout weekly catches were significantly related to average weekly stream temperature (Regression, $p < 0.00001$, $R^2 = 0.76$, negative slope), and week number (Correlation, $p < 0.001$, $r = 0.71$, negative slope). Average stream temperature explained more of the variation (76%) in 2+ steelhead trout weekly catches than other variables tested (Appendix 5).

Trapping Efficiencies

0+ Chinook Salmon

We fin clipped and released 2,779 young-of-year Chinook salmon upstream of the trap site during 71 efficiency trials over the course of trapping in YR 2006. The average number used in our weekly trials (includes 2 - 6 trials) was 174, and ranged from 4 - 368 (per week). Weekly trapping efficiencies in YR 2006 ranged from 5.1 – 63.2%, and averaged 20.2% (Table 6). Average weekly and seasonal (total number of recaptures/total number marked) trapping efficiencies in YR 2006 were much less than efficiencies for the previous six year average (Table 6).

0+ Chinook salmon weekly trap efficiencies in YR 2006 significantly increased over time (Correlation, $p < 0.001$, $r = 0.78$, positive slope, power = 0.98). Transformed weekly trap efficiencies were negatively related to the transformed gage height (Regression, $p < 0.001$, $R^2 = 0.65$, negative slope, power = 0.99). Weekly trap efficiencies (non-transformed) were also negatively related to the transformed stream discharge (Regression, $p < 0.001$, $R^2 = 0.64$, negative slope, power = 0.99).

Table 6. Comparison of 0+ Chinook salmon trapping efficiency in YR 2006 with the previous six year average, Upper Redwood Creek, Humboldt County, CA.

	0+ Chinook salmon trap efficiency (percentage)		
	Weekly trapping efficiency		
Study Year	Range	Average	Seasonal
2006	5.1 - 63.2	20.2	21.9
2000-05	31.3 - 68.4*	46.8	45.5**

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

1+ Steelhead Trout

We fin clipped and released 1,773 1+ steelhead trout upstream of the trap site during 64 efficiency trials over the course of trapping in YR 2006. The average number used in our weekly trials (includes 2 - 6 efficiency trials) was 118, and ranged from 6 - 242 (per week). Weekly trapping efficiencies in YR 2006 ranged from 5.9 – 33.3%, and averaged 13.6% (Table 7). Average weekly and seasonal (total number of recaptures/total number of marked releases) trapping efficiencies in YR 2006 were much less than efficiencies for the previous six year average (Table 7).

The correlation of time (trapping week number) and the regressions of gage height and stream discharge on 1+ steelhead trout weekly trapping efficiencies violated test assumptions, and results were not valid (NCSS 97).

Table 7. Comparison of 1+ steelhead trout trapping efficiency in YR 2006 with the previous six year average, Upper Redwood Creek, Humboldt County, CA.

	1+ Steelhead Trout Trap Efficiency (percentage)		
	Weekly trapping efficiency		
Study Year	Range	Average	Seasonal
2006	5.9 – 33.3	13.6	11.7
2000-05	16.9 – 42.3*	27.7	29.1**

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

2+ Steelhead Trout

We fin clipped and released 267 2+ steelhead trout upstream of the trap site during 56 efficiency trials over the course of trapping in YR 2006. The average number used in our weekly trials (includes 1 - 6 efficiency trials) was 20, and ranged from 5 - 43 (per week).

Weekly trapping efficiencies in YR 2006 ranged from 10.0 – 33.3%, and averaged 17.2% (Table 8). Average weekly and seasonal (total number of recaptures/total number marked) trapping efficiencies in YR 2006 were slightly less than efficiencies for the previous six year average (Table 8).

Similar to 1+ steelhead trout trap efficiencies, the correlation of time (trapping week number) and the regressions of gage height and stream discharge on 2+ steelhead trout weekly trapping efficiencies violated test assumptions, and results were not valid (NCSS 97).

Table 8. Comparison of 2+ steelhead trout trapping efficiency in YR 2006 with the previous six year average, Upper Redwood Creek, Humboldt County, CA.

	2+ Steelhead Trout Trap Efficiency (percentage)		
	Weekly trapping efficiency		
Study Year	Range	Average	Seasonal
2006	10.0 – 33.3	17.2	17.1
2000-05	10.9 – 26.2*	18.3	19.7**

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

Population Estimates

0+ Chinook Salmon

The population estimate (or production) of 0+ Chinook salmon emigrating from upper Redwood Creek in YR 2006 equaled 26,093 with a 95% CI of 23,009 – 29,178. Population estimate error (or uncertainty) equaled ± 11.8% or 3,084 individuals. Population emigration in YR 2006 was lower than emigration in YR 2005 (N = 39,614) by 34% and markedly lower than the previous six year average (N = 332,374) by 92%.

Correlation of time (study year) on yearly population estimates indicated a non-significant negative relationship (p = 0.23, r = 0.52, power = 0.20) (Figure 7).

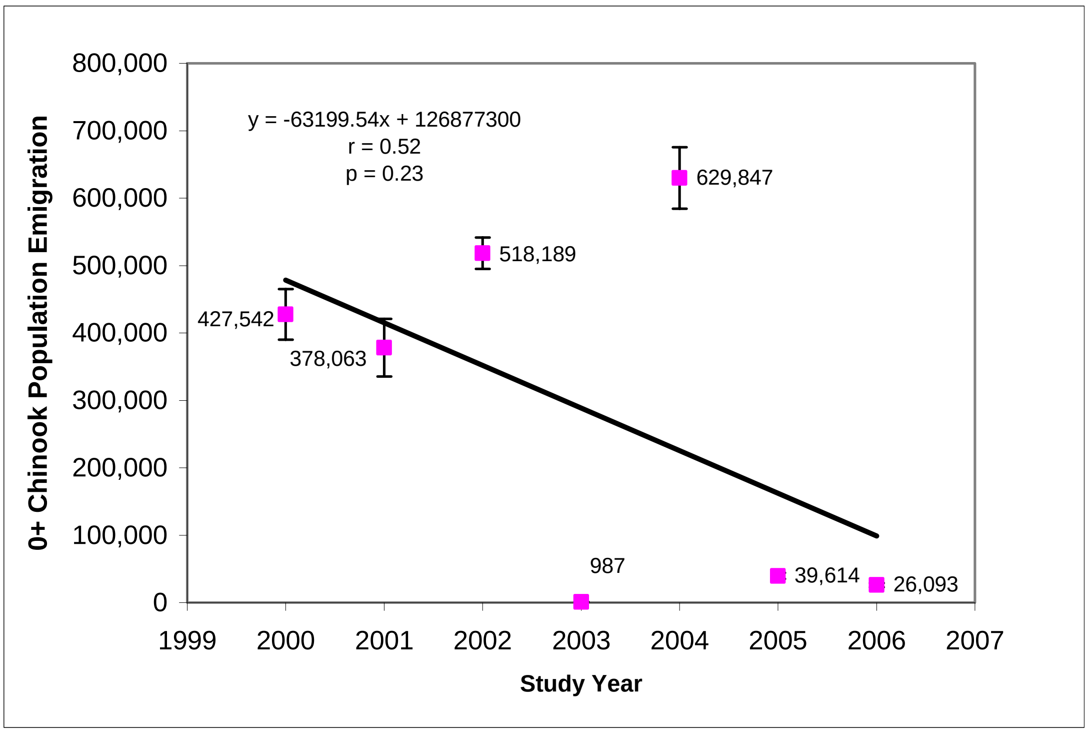

Figure 7. 0+ Chinook salmon population estimates (error bars are 95% confidence interval) in seven consecutive years. Lack of 95% CI for YRS 2003, 2005 and 2006 is due to scale of Y axis. Numeric values next to box represent number of individuals. Line of best fit is a regression line, with corresponding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

Relationship of potential redd scour with population emigration

Peak stream flows capable of scouring adult Chinook salmon redds occurred on 12/30/05 (peak cfs = 6,420; duration of nine hours) and 12/31/05 (peak cfs = 6,030; duration of two hours) (Klein pers. com. 2003, USGS 2006). Using the regression equation modeled with data from YRS 2000-05 ($Y = -468109.8x + 488401.3$, where $x = 0$ for non bedload mobilizing flows, and $x = 1$ for bedload mobilizing flows), the expected population size of 0+ Chinook salmon in YR 2006 (Y) equaled 20,300 individuals. Thus, the mark/recapture estimate of 26,093 was 28.5% (or 5,792 individuals) greater than the expected 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 seven study years ($p < 0.001$, $R^2 = 0.91$, slope is negative, and power = 1.0). The variation in peak stream flow (in this case, bedload mobilizing flow and non-bedload mobilizing flow) during the redd incubation period explained 91% 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 2006 was about 92% less than values for the previous six year average (Table 9).

Table 9. Estimated population of 0+ Chinook salmon per stream mile, stream kilometer, and watershed acreage upstream of the trap site, YRS 2000-2006.

Study Year	0+KS/mi	0+KS/km	0+KS/acre
2000	11,555	7,186	6.58
2001	10,218	6,354	5.82
2002	14,005	8,709	7.97
2003	27	17	0.01
2004	17,023	10,586	9.69
2005	1,071	666	0.61
Average:	8,983	5,586	5.11
2006	705	439	0.40

0+ Chinook salmon population emigration by month in YR 2006 was severely reduced compared to emigration by month for the previous six year average (Figure 8). The biggest reductions in YR 2006 occurred in April (92.6% or 118,006 individuals) and May (96.1% or 107,017 individuals).

The majority of 0+ Chinook salmon population emigration occurred in April and June in YR 2006 (80.7.% of total) compared to April and May for the previous six year average (71.9% of total) (Figure 8). Population emigration during April – June accounted for 97.3% of the total for YR 2006 compared to 92.6% of the total for the previous six year average.

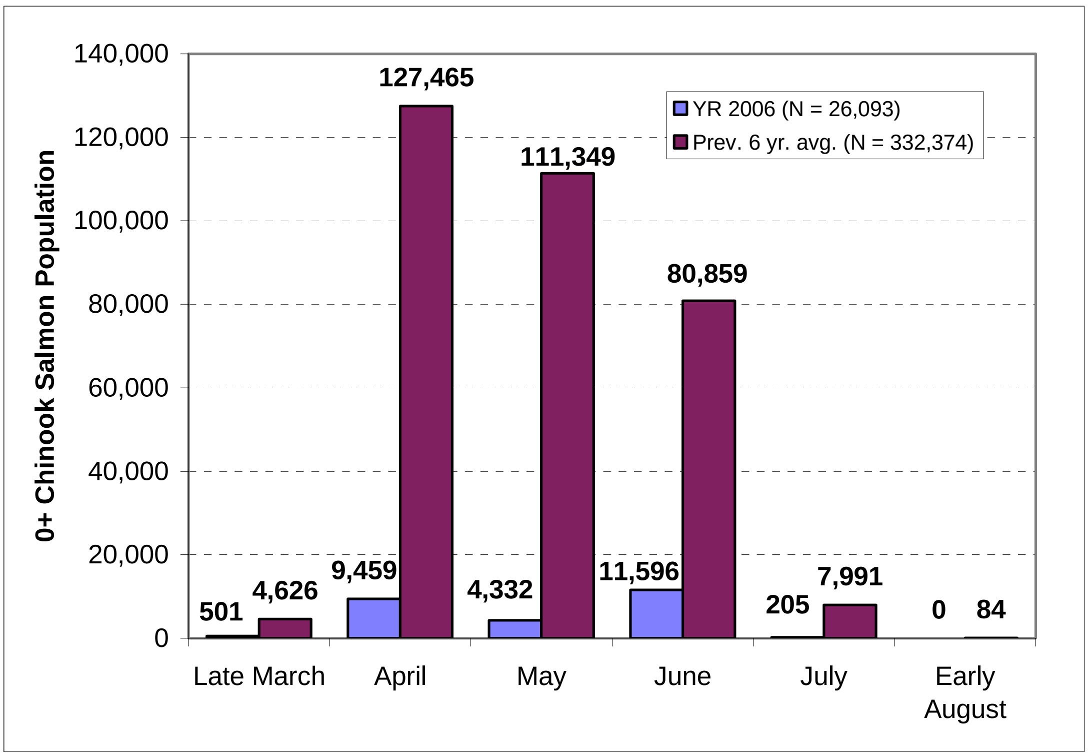

Figure 8. Comparison of 0+ Chinook salmon population emigration by month in YR 2006 with the previous six year average, upper Redwood Creek, Humboldt County, CA. Age/species abbreviation is the same as in Figure 2. Numeric values above columns represent number of individuals.

The peak in weekly population emigration in YR 2006 occurred 6/18 – 6/24 (Table 10, Figure 9). For the seven years of data, two peaks occurred in April, one occurred in May, one occurred in late May/early June, and three peaks occurred in June (Table 10). The largest weekly peak occurred in YR 2004 (N = 165,782 individuals) and the smallest occurred in YR 2003 (N = 316 individuals) (Table 10). The average FL (mm) for 0+

Chinook salmon migrants during the two modes in emigration equaled 39.4 mm for 4/16 – 4/22, and 70.7 mm for 6/18 – 6/24 (Figure 9).

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

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

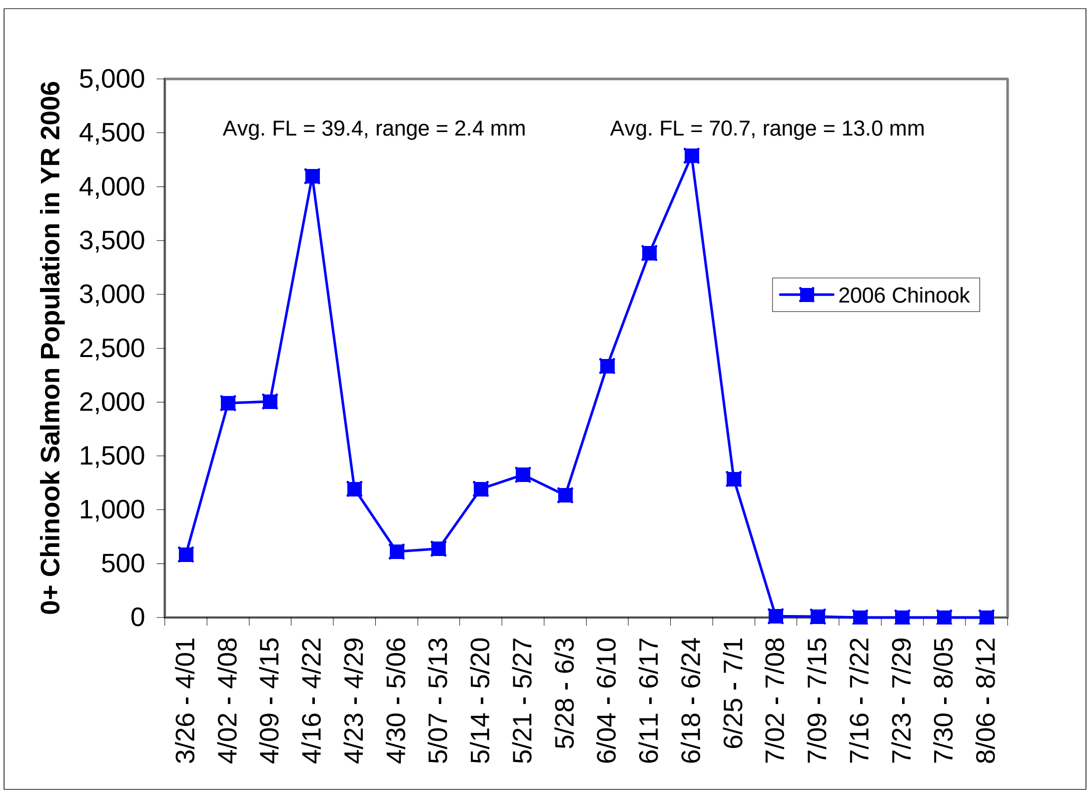

Figure 9. 0+ Chinook salmon population emigration in YR 2006, upper Redwood Creek, Humboldt County, CA.

The number and percentage of 0+ Chinook salmon migrants grouped into fry or fingerling categories varied among study years (Table 11). In YR 2006, 40% of the migrants were estimated as fry, and 60% were estimated as fingerlings. The previous six year average (N = 332,374) consisted of 54% fry and 46% fingerlings. A statistically lesser proportion of fry and a higher proportion of fingerlings were present in YR 2006 compared to the previous six year average (Chi-square, $p < 0.0001$). There was a significant, non-random distribution in the percentages of fry and fingerlings in YR 2006 as well (Chi-square, $p < 0.0001$).

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)
2005	22,957 (58)	16,657 (42)
6 yr avg.	178,009 (54)	154,365 (46)
YR 2006	10,390 (40)	15,703 (60)

0+ Chinook salmon fry and fingerling migrants showed differences in abundance and migration timing in YR 2006 compared to the previous six year average (Figure 10). For the previous six 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 during 5/28 – 6/10, and gradually decreased to low values by late July (Figure 10). In YR 2006, fry (Ave. FL = 39.6 mm) migration also occurred near the onset of trapping, reached a peak value during the third week in April (one week after the peak for the previous six year average), and quickly decreased to low values by May 1; fingerling (Ave. FL = 61.8 mm) migration began in late April/early

May, reached a smaller peak May 21 – May 27, and a larger peak during 6/18 – 6/24; and descended to low values near the beginning of July (Figure 10). The noticeable two modes to the distributions for YR 2006 and the previous six year average do not necessarily indicate two different runs of adult Chinook salmon entered upper Redwood Creek because of great differences in FL or Wt. For example, average FL for fry during 4/16/06 – 4/22/06 was 39.4 mm, compared to the average fingerling FL of 70.7 mm for 6/18/06 – 6/24/06. Had there been two runs of adults at different times, we would expect the FL's during 6/18/06 – 6/24/06 to be nearly the same as 4/16/06 – 4/22/06.

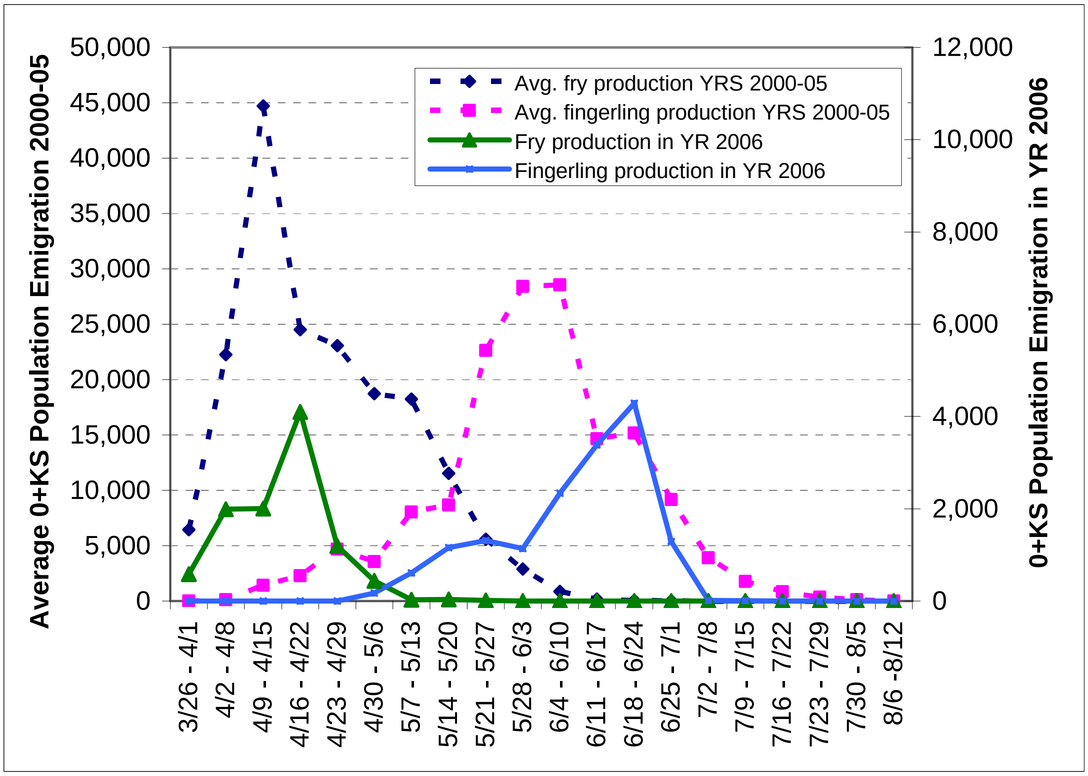

Figure 10. Comparison of estimated 0+ Chinook salmon fry and fingerling abundance and migration timing in YR 2006 (uses second "Y" axis) with previous six year average, upper Redwood Creek, Humboldt County, CA. Age/species abbreviation is the same as in Figure 2.

1+ Steelhead Trout

The population estimate (or production) of 1+ steelhead trout emigrating from upper Redwood Creek in YR 2006 equaled 26,248 with a 95% CI of 22,728 – 29,767. Population estimate error (or uncertainty) equaled $\pm$ 13.4% or 3,520 individuals. Population emigration in YR 2006 was slightly higher than emigration in YR 2005 (N = 26,176), and lower than the previous six year average (N = 40,831) by 36%.

Correlation of time (study year) on yearly population estimates showed a significant negative relationship ($p < 0.05$, $r = 0.79$, power = 0.63) (Figure 11).

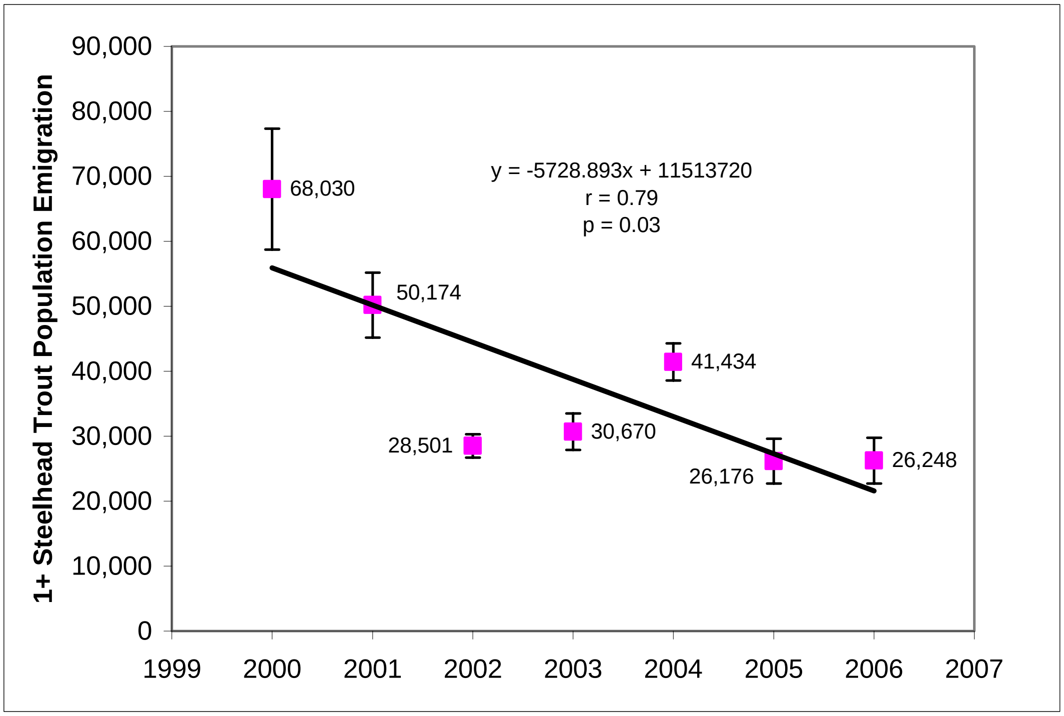

Figure 11. 1+ steelhead trout population estimates (error bars are 95% confidence interval) in seven consecutive years. Numeric values next to box represent number of individuals. Line of best fit is a regression line, with corresponding equation, correlation value (r), and p value.

The number of 1+ steelhead trout (at population level) per mile, kilometer, and watershed acreage upstream of the trap site in YR 2006 was about 36% less than values for the previous six year average (Table 12). Highest values occurred in YR 2000 and lowest values occurred in YR 2005.

Table 12. Estimated population of 1+ steelhead trout per stream mile, stream kilometer, and watershed acreage upstream of the trap site, YRS 2000-06.

Study Year	1+SH/mi	1+SH/km	1+SH/acre
2000	1,839	1,143	1.05
2001	1,356	843	0.77
2002	770	479	0.44
2003	829	515	0.47
2004	1,120	696	0.64
2005	707	440	0.40
Average:	1,104	686	0.63
2006	709	441	0.40

1+ steelhead trout monthly population emigration in YR 2006 was less than monthly emigration for the previous six year average (Figure 12). Emigration peaked in May in YR 2006 (N = 14,041 or 53% of total) and for the previous six year average (N = 17,478 or 43% of total) (Figure 12). In YR 2006, 21,637 individuals (or 82% of total) emigrated in May and June, compared to 28,032 (or 69% of total) migrants that emigrated in April and May for the previous six year average. The largest reduction in emigration in YR 2006 occurred during April (N = 6,206 or 59%); emigration during late March, July, and early August in YR 2006 was also severely reduced (reduction of 92 – 98%).

The peak in 1+ steelhead trout weekly emigration in YR 2006 occurred later than other study years (Table 13). For the seven study years, five peaks occurred during May and two peaks occurred during late April. The largest weekly peak occurred in YR 2000 (N = 16,244), and the smallest occurred in YR 2006 (N = 4,062) (Table 13).

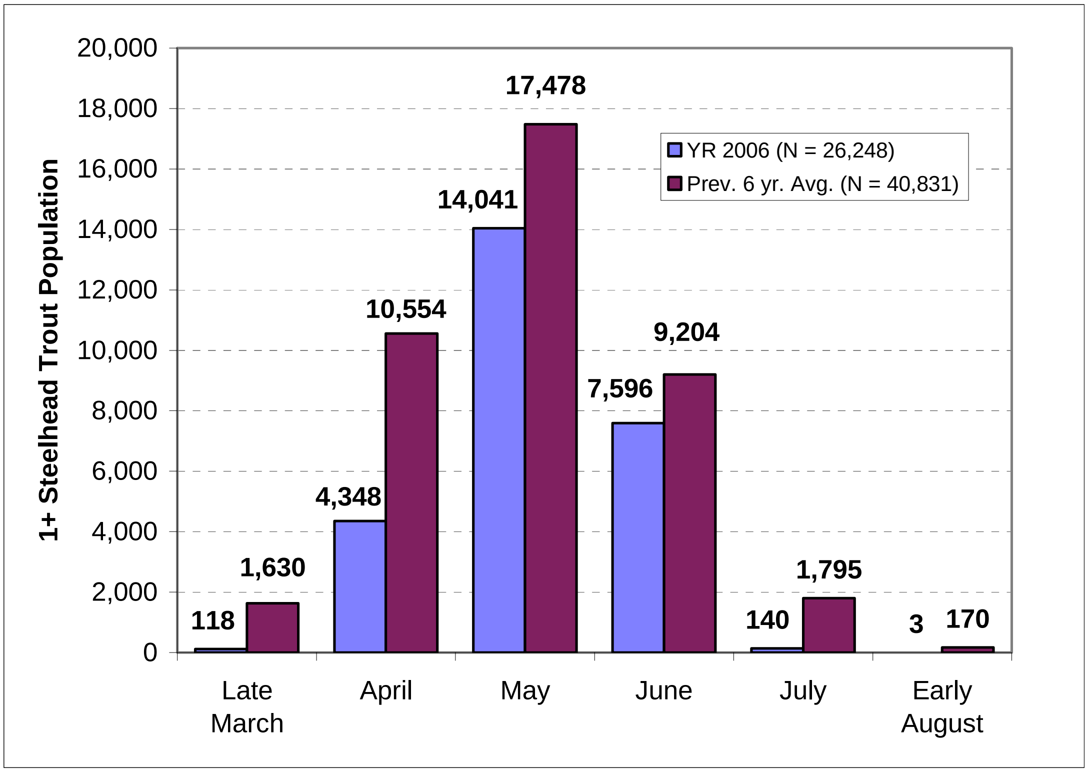

Figure 12. Comparison of 1+ steelhead trout population emigration by month in YR 2006 with the previous six year average, upper Redwood Creek, Humboldt County, CA. Numeric values above columns represent number of individuals.

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

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

2+ Steelhead Trout

The population estimate (or production) of 2+ steelhead trout emigrating from upper Redwood Creek in YR 2006 equaled 1,866 with a 95% CI of 1,423 – 2,309 (Figure 13). Population estimate error (or uncertainty) equaled $\pm$ 23.7% or 443 individuals. Population emigration in YR 2006 was 21.1% less than emigration in YR 2005 (N = 26,176), and 68.6% lower than the previous six year average (N = 5,949).

Correlation of time (study year) on yearly population estimates showed a non-significant negative relationship ($p > 0.10$, $r = 0.63$, power = 0.31) (Figure 13).

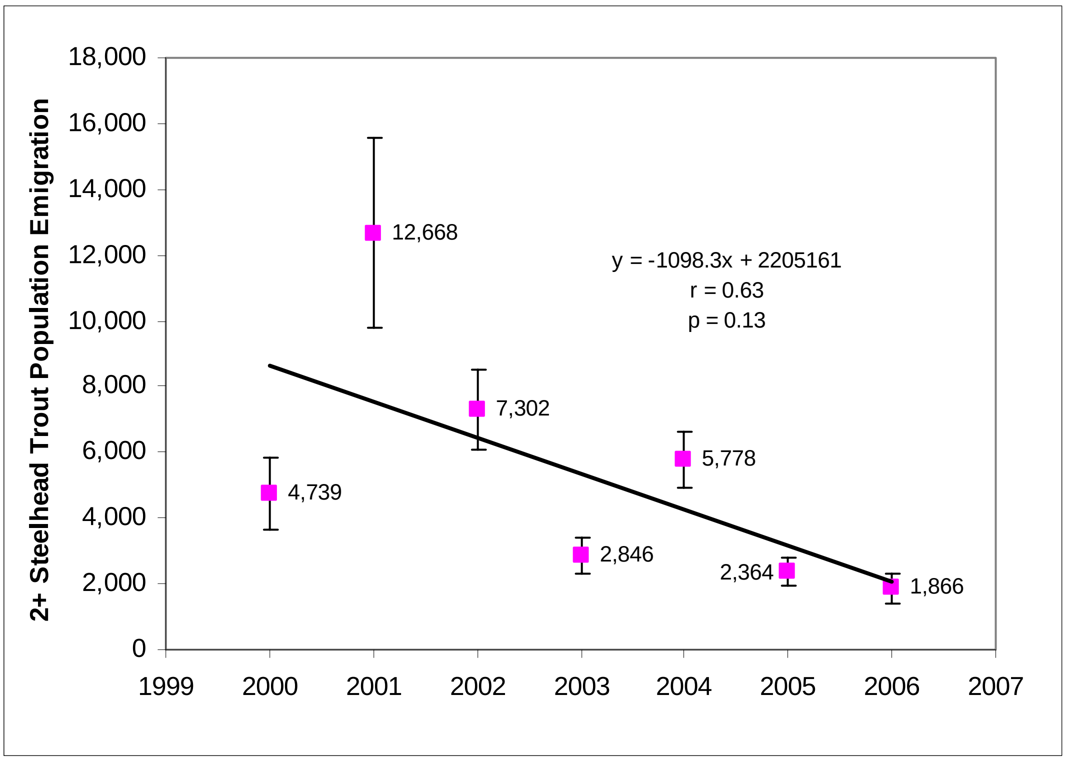

Figure 13. 2+ steelhead trout population estimates (error bars are 95% confidence interval) in seven consecutive years. Numeric values next to box represent number of individuals. Line of best fit is a regression line, with corresponding equation, correlation value (r), and p value.

The number of 2+ steelhead trout (at population level) per mile, kilometer, and watershed acreage upstream of the trap site in YR 2006 was about 69% less than values for the previous six year average (Table 14). Highest values occurred in YR 2001 and lowest values occurred in YR 2006.

Table 14. Estimated population of 2+ steelhead trout per stream mile, stream kilometer, and watershed acreage upstream of the trap site, YRS 2000-06.

Study Year	2+SH/mi	2+SH/km	2+SH/acre
2000	128	80	0.07
2001	342	213	0.19
2002	197	123	0.11
2003	77	48	0.04
2004	156	97	0.09
2005	64	40	0.04
Average:	161	100	0.09
2006	50	31	0.03

2+ steelhead trout monthly population emigration in YR 2006 was less than monthly emigration for the previous six year average (Figure 14). Emigration peaked in May in YR 2006 (N = 845 or 45% of total) compared to April for the previous six year average (N = 2,018 or 34% of total) (Figure 14). In YR 2006, 1,567 individuals (or 84% of total) emigrated in April and May, compared to 3,931 (or 66% of total) migrants that emigrated in April and May for the previous six year average. The largest reduction in population emigration in YR 2006 occurred during April (1,296 individuals or 64% reduction); emigration during late March, May, June, July, and early August in YR 2006 was also severely reduced (reduction of 56 – 98%) compared to the monthly emigration for the previous six year average.

The peak in 2+ steelhead trout weekly emigration in YR 2006 occurred in late April/early May (Table 15). For the previous six study years, three peaks occurred during April and three peaks occurred during May. The largest weekly peak occurred in YR 2001 (N = 1,463), and the smallest occurred in YR 2003 (N = 363) (Table 15).

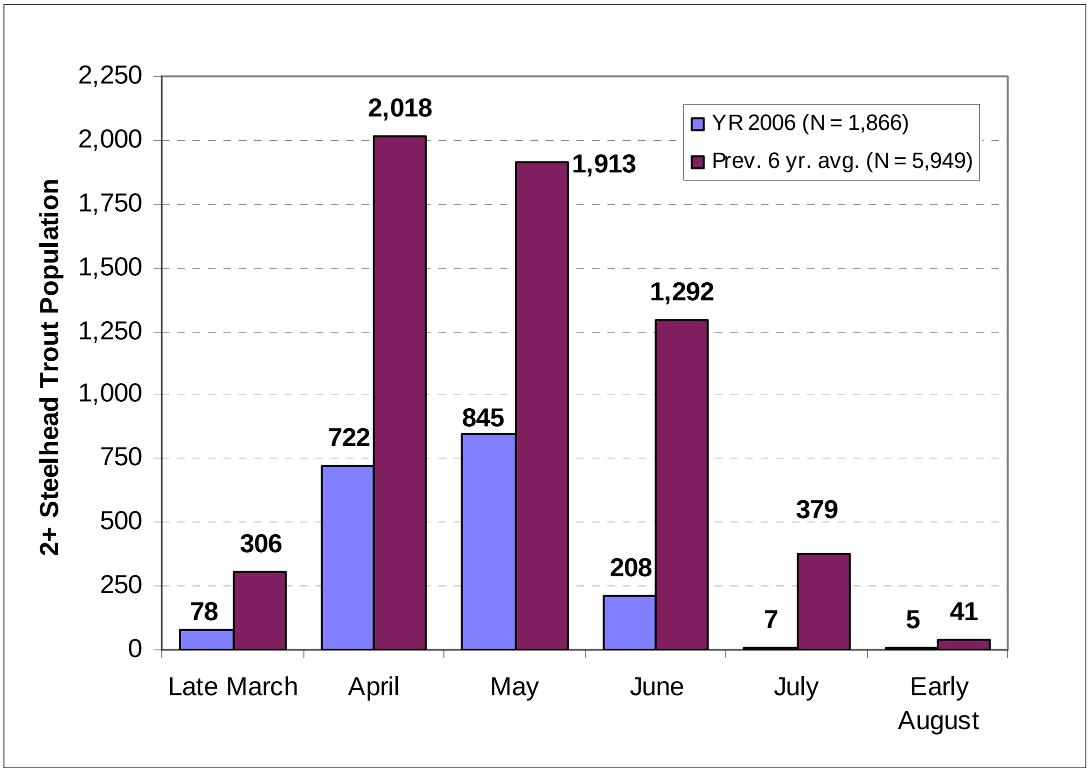

Figure 14. Comparison of 2+ steelhead trout population emigration by month in YR 2006 with the previous six year average, upper Redwood Creek, Humboldt County, CA. Numeric values above columns represent number of individuals.

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

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

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 averaged by week, and Time (trapping week number)

The transformed 0+ Chinook salmon weekly population emigration was positively related to the stream gage height at the trapping site (Regression, $p < 0.01$, $R^2 = 0.36$), stream discharge (Regression, $p < 0.05$, $R^2 = 0.29$); and negatively related to stream temperature (Regression, $p < 0.001$, $R^2 = 0.25$) and week number (Correlation, $p < 0.001$, $r = 0.76$) (Appendix 6). The variation in gage height explained 36% of the variation in weekly population emigration.

1+ steelhead trout weekly population emigration was significantly related to week number (Correlation, $p < 0.05$, $r = 0.32$, slope is negative). A non-significant relationship was detected with stream discharge (Regression, $p > 0.05$). Regressions of gage height and stream temperature by week violated test assumptions, and results were not valid for either test (Appendix 6).

The transformed 2+ steelhead trout weekly population emigration was positively related to stream gage height (Regression, $p < 0.01$, $R^2 = 0.43$) and stream discharge (Regression, $p < 0.001$, $R^2 = 0.62$), and negatively related to stream temperature (Regression, $p < 0.01$, $R^2 = 0.50$) and week number (Correlation, $p < 0.01$, $r = 0.68$) (Appendix 6). Models with gage height or stream discharge explained 43 and 62%, respectfully, of the variation in population emigration. The variation associated with stream temperature explained 50% of the variation in weekly emigration. The correlation of week number with emigration ($r = 0.68$, or $R^2 = 0.46$) determined that 68% of the variation (in emigration) can be associated with week number (Appendix 6).

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 2006, the ratio of 0+ steelhead trout to 1+ steelhead trout to 2+ steelhead trout equaled 26:14:1 compared to the previous six year average ratio of 16:7:1. In YR 2005, the ratio was 18:11:1. The ratio of 1+ steelhead trout to 2+ steelhead trout was 14:1 in YR 2006, and 7:1 for the previous six 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 2006 and the previous six 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
2006	63.4	34.2	2.4
Prev. 6 yr Avg.	65.1	30.8	4.1
All years combined	66.2	29.7	4.1

* Uses actual catches instead of population estimate.

Relationships Between Juvenile Steelhead Age Classes

Non-significant negative relationships were found for the regression of 0+ steelhead trout catches (x variable) in YRS 2000 - 2005 on the next year's 1+ steelhead trout population estimate (YRS 2001 – 2006, y variable) ($p > 0.10$, $R^2 = 0.11$, slope sign is negative, power = 0.08); and for 0+ steelhead trap catches in YRS 2000 - 2004 on 2+ steelhead population estimates (y variable) in YRS 2002 - 2006 ($p = 0.49$, $R^2 = 0.26$, slope is negative, power = 0.08). A significant positive relationship was found for the relationship of 1+ steelhead trout population estimates on the following year's 2+ steelhead population estimate ($p < 0.05$, $R^2 = 0.78$, slope is positive, power = 0.80).

We detected a significant, positive correlation between 1+ and 2+ steelhead trout population emigration by week in YR 2006 (correlation, $p < 0.01$; $r = 0.65$; power = 0.93). The pattern of weekly outmigration for 1+ and 2+ steelhead trout tracked fairly well, such that when 2+ steelhead trout migration increased, decreased, or remained stable, so did 1+ steelhead trout migration for many (13/20 or 65%) of the weeks.

Fork Lengths and Weights

<u>0+ Chinook Salmon</u>

We measured (FL mm) 2,123 and weighed (g) 1,684 0+ Chinook salmon in YR 2006 (Table 17). Average FL in YR 2006 was about 8% less than the average FL in YR 2005; average Wt in YR 2006 was about 33% less than the average Wt in YR 2005 (Table 17). Average FL and Wt in YR 2006 were slightly higher than the previous five year average (excludes YR 2003). The mode in YR 2006 was 39 mm for FL and 0.5 g for Wt. Average FL and Wt did not significantly change over study years 2000 - 2002, and 2004 – 2006 (Correlation: FL, $p = 0.47$, $r = 0.37$, slope is positive, power = 0.10; Wt, $p = 0.40$, $r = 0.42$, power = 0.11). Using an adjusted alpha of 0.10 to account for low sample size ($n = 6$), linear regression detected a significant negative relationship of population size on average FL's ($p = 0.05$, $R^2 = 0.65$, power = 0.54) and average Wt ($p = 0.08$, $R^2 = 0.58$, power = 0.43), 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 - 2006, upper Redwood Creek, Humblodt County, CA.

	0+ Chinook Salmon						
		Fork Length (mm)			Weight (g)		
Study Year	(N)*	n	Avg.	SEM	n	Avg.	SEM
2000	427,542	3,661	55.5	0.2	913	2.03	0.04
2001	378,063	2,719	51.9	0.2	778	1.73	0.04
2002	518,189	3,517	52.4	0.2	1,545	1.70	0.03
2003	987	573	67.3	0.3	499	3.43	0.05
2004	629,847	3,571	50.8	0.2	1,593	1.61	0.03
2005	39,614	2,489	60.4	0.3	1,751	3.09	0.05
5 yr Avg.**			54.2			2.03	
2006	26,093	2,123	55.5	0.3	1,684	2.07	0.04

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

0+ Chinook salmon average weekly FL's in YR 2006 were numerically close to values for the five year average during the first six weeks of trap operation (Figure 15). Average weekly FL (mm) significantly increased over time (weeks) in YR 2006 and for the five year average (Correlation, $p < 0.0001$, $r = 0.97$ and 0.99, slope is positive, power = 1.0

for each test) (Figure 15). The increases in average FL over time indicate growth was taking place, and from 4/02/06 – 7/01/06 0+ Chinook salmon grew 0.36 mm/d. This value was 0.05 mm/d less than growth in YR 2005. Kruskal-Wallis One-Way ANOVA on Ranks showed that the median weekly FL in YR 2006 (53.4 mm) was not significantly different than the median weekly FL of the five year average (54.1 mm) ($p = 0.78$).

Average weekly Wt's in YR 2006 were also numerically close to values for the five year average during the first six weeks of trap operation (Figure 16). Average weekly Wt (g) significantly increased over time (weeks) in YR 2006 and for the five year average (Correlation, $p < 0.001$, $r = 0.95$ and 0.98, power = 1.0) (Figure 16). The increases in average Wt over time show growth was taking place, and from 4/02/06 – 7/01/06 0+ Chinook salmon grew 0.04 g/d. This value was 0.01 g/d less than growth in YR 2005. The average weekly Wt (g) (2.14 g) in YR 2006 was not significantly different than the average weekly Wt (1.96 g) for the previous five year average (excludes YR 2003) (ANOVA, $p > 0.05$, power = 0.07).

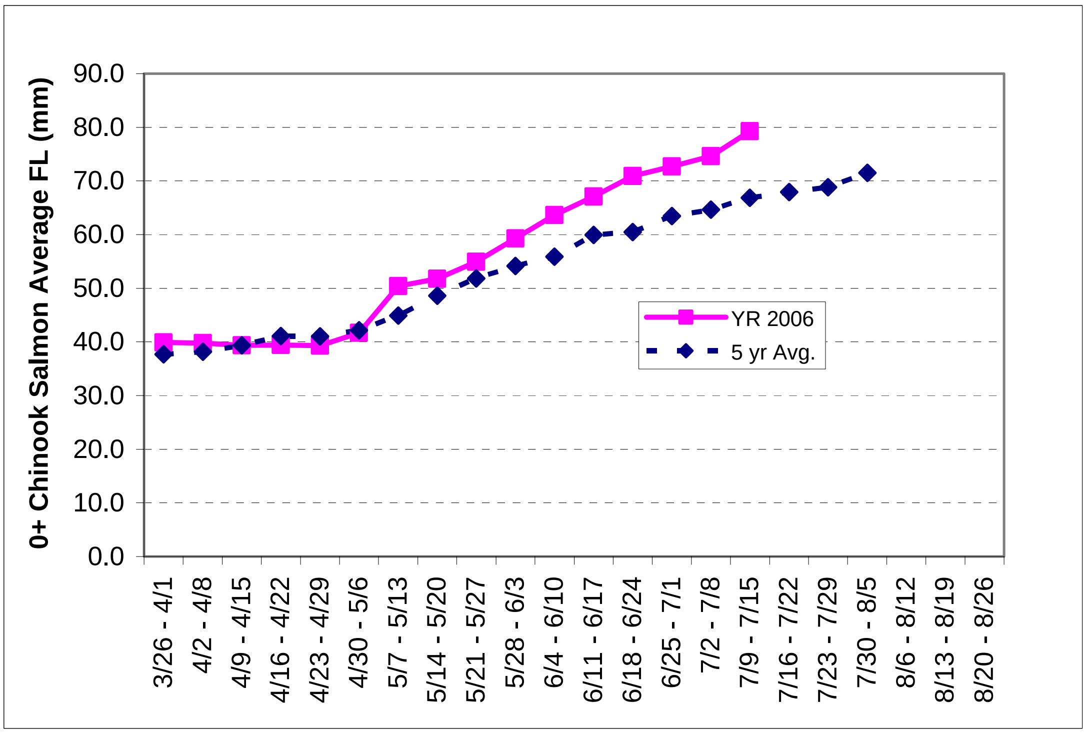

Figure 15. 0+ Chinook salmon average weekly fork lengths (mm) in YR 2006 and the average of five years, upper Redwood Creek, Humboldt County, CA.

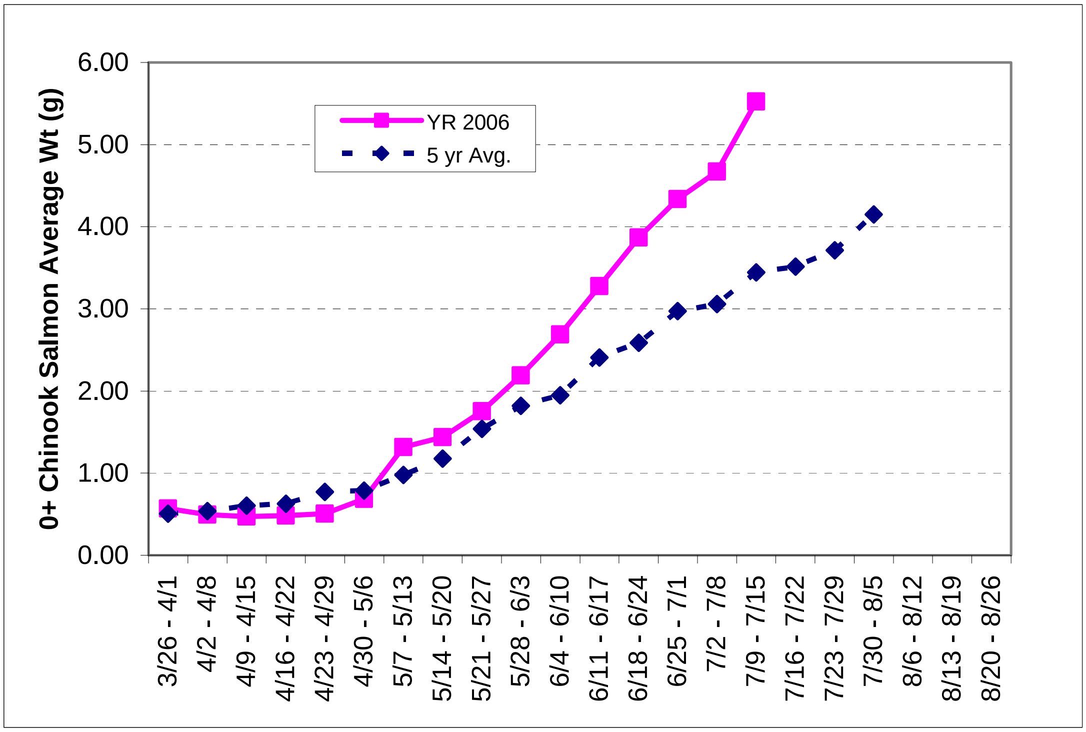

Figure 16. 0+ Chinook salmon average weekly weights (g) in YR 2006 and the average of five years, upper Redwood Creek, Humboldt County, CA.

0+ Steelhead Trout

We measured (FL mm) 2,670 0+ steelhead trout in YR 2006 (Table 18). Average FL in YR 2006 was less than previous study years (Table 18). The mode in FL in YR 2006 was 30 mm.

Average FL did not significantly change over the seven study years (Correlation, $p = 0.44$, $r = 0.35$, slope is negative, power = 0.11). Linear regression detected a non-significant negative relationship of seasonal catch on average FL by season ($p = 0.41$, $R^2 = 0.14$, power = 0.11).

Average weekly FL (mm) significantly increased over time (weeks) in YR 2006 (Correlation, $p < 0.001$, $r = 0.90$, power = 1.0) and for the previous six year average (Correlation, $p < 0.001$, $r = 0.96$, power = 1.0) (Figure 17). The increases in average FL over time show growth was taking place, and from 4/30/06 – 8/12/06 0+ steelhead trout grew 0.22 mm/d. The average weekly FL (mm) (36.49 mm) in YR 2006 was not significantly different than the average weekly FL (37.88 mm) for the previous six year average (ANOVA, $p > 0.05$, power = 0.08).

Table 18. 0+ steelhead trout total catch and average fork length (mm) for study years 2000 - 2006, upper Redwood Creek, Humboldt County, CA.

	0+ Steelhead Trout						
		Fork Length (mm)			Weight (g)		
Study Year	(Catch)	n	Avg.	SEM	n	Avg.	SEM
2000	55,126	2,669	40.9	0.2	-	-	-
2001	102,408	1,136	39.0	0.3	-	-	-
2002	124,426	3,228	38.7	0.2	-	-	-
2003	102,954	3,338	38.5	0.2	-	-	-
2004	128,885	3,615	37.5	0.2	-	-	-
2005	41,671	3,661	42.3	0.2	-	-	-
6 yr Avg.			39.5			-	
2006	48,759	2,670	35.9	0.2	-	-	-

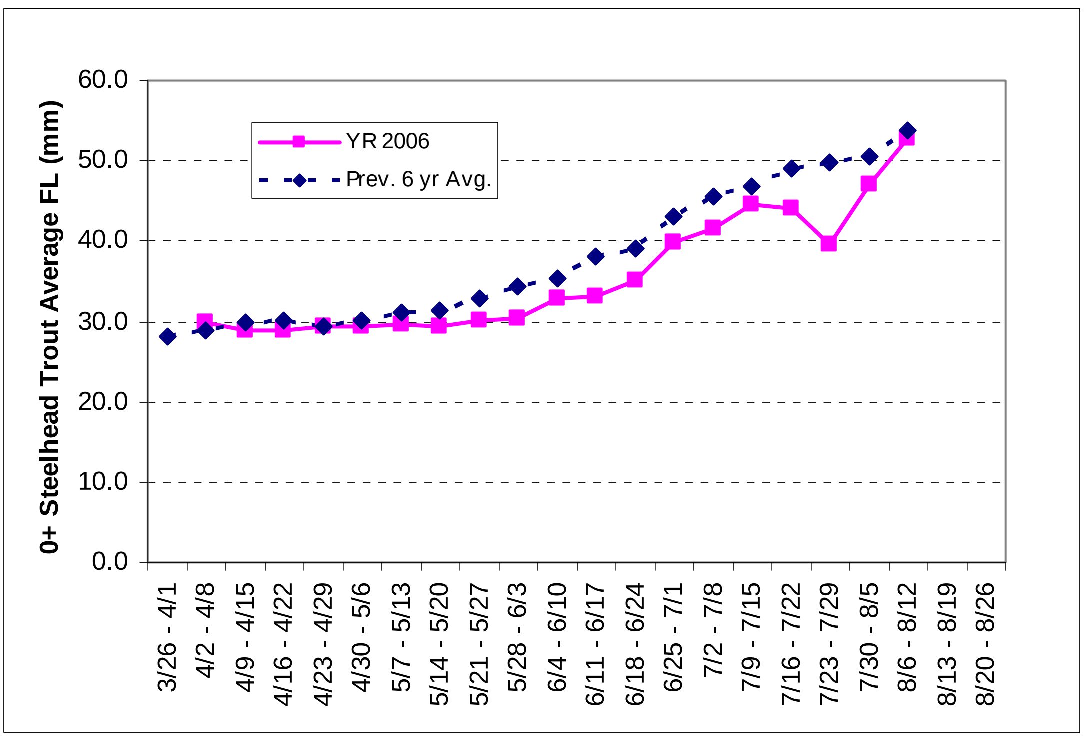

Figure 17. 0+ steelhead trout average weekly fork lengths (mm) in YR 2006 and the previous six year average, upper Redwood Creek, Humboldt County, CA.

1+ Steelhead Trout

We measured (FL mm) 1,961 and weighed (g) 1,683 1+ steelhead trout in YR 2006 (Table 19). Average FL and Wt in YR 2006 was less than values for the previous six year average (Table 19). The mode in FL in YR 2006 was 82 mm, and the mode for Wt in YR 2006 was 5.9 g.

Average FL significantly decreased over study years 2000-06 (Correlation, $p < 0.10$, $r = 0.72$, power = 0.46); whereas average Wt did not (Correlation, $p > 0.10$, $r = 0.57$, slope is negative, power = 0.24). Linear regression detected a significant positive relationship of population estimate on average FL ($p < 0.05$, $R^2 = 0.65$, power = 0.68, n = 7), and a non-significant positive relationship for average Wt ($p > 0.10$, $R^2 = 0.32$, power = 0.24).

Table 19. 1+ steelhead trout population estimates, and average fork length (mm) and weight (g) for study years 2000 - 2006, upper Redwood Creek, Humboldt County, CA.

	1+ Steelhead Trout						
		Fork Length (mm)			Weight (g)		
Study Year	(N)*	n	Avg.	SEM	n	Avg.	SEM
2000	68,030	2,721	92.4	0.2	1,455	8.29	0.09
2001	50,174	2,761	91.9	0.3	908	9.27	0.11
2002	28,501	3,049	86.7	0.3	1,356	7.79	0.14
2003	30,670	3,064	84.8	0.3	1,633	7.14	0.09
2004	41,434	3,191	85.7	0.3	1,441	7.57	0.10
2005	26,176	2,473	88.1	0.2	1,592	8.02	0.09
6 yr Avg.			88.3			8.01	
2006	26,248	1,961	85.7	0.3	1,683	7.48	0.09

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

The pattern of 1+ steelhead trout FL over time showed some similarity to the previous six year average (Figure 18). The transformed average weekly FL (mm) for 1+ steelhead trout in YR 2006 did not significantly change over time (weeks) (Correlation, $p > 0.05$, $r = 0.43$, slope is positive, power = 0.46). Average FL (mm) by week for the previous six year average did not significantly change over time as well (Correlation, $p > 0.05$, $r = 0.21$, slope is positive, power = 0.14) (Figure 18). Kruskal-Wallis One-Way ANOVA on Ranks determined the median weekly FL in YR 2006 (84.0 mm) was not significantly different than the median weekly FL of the previous six year average (87.8 mm) ($p > 0.05$).

The pattern of 1+ steelhead trout Wt over time also showed some similarity to the previous six year average (Figure 19). 1+ steelhead trout average weekly Wt (g) in YR 2006 did not significantly change over time (weeks) (Correlation, $p > 0.05$, $r = 0.31$, slope is positive, power = 0.23). Average Wt (g) by week for the previous six year average did not significantly change over time as well (Correlation, $p > 0.05$, $r = 0.24$, slope is positive, power = 0.17) (Figure 19). Single factor ANOVA determined the average weekly Wt in YR 2006 (7.16 g) was significantly less than the average weekly Wt for the previous six year average (8.26 g) ($p < 0.05$, power = 0.70).

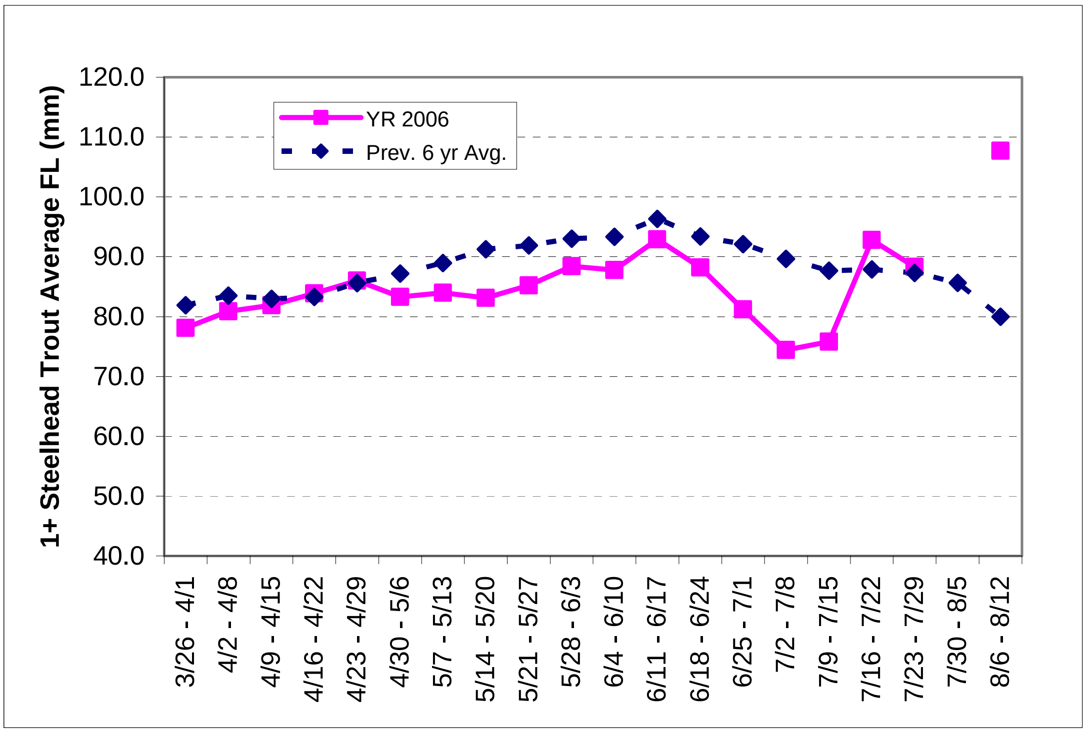

Figure 18. 1+ steelhead trout average weekly fork lengths (mm) in YR 2006 and the previous six year average, upper Redwood Creek, Humboldt County, CA.

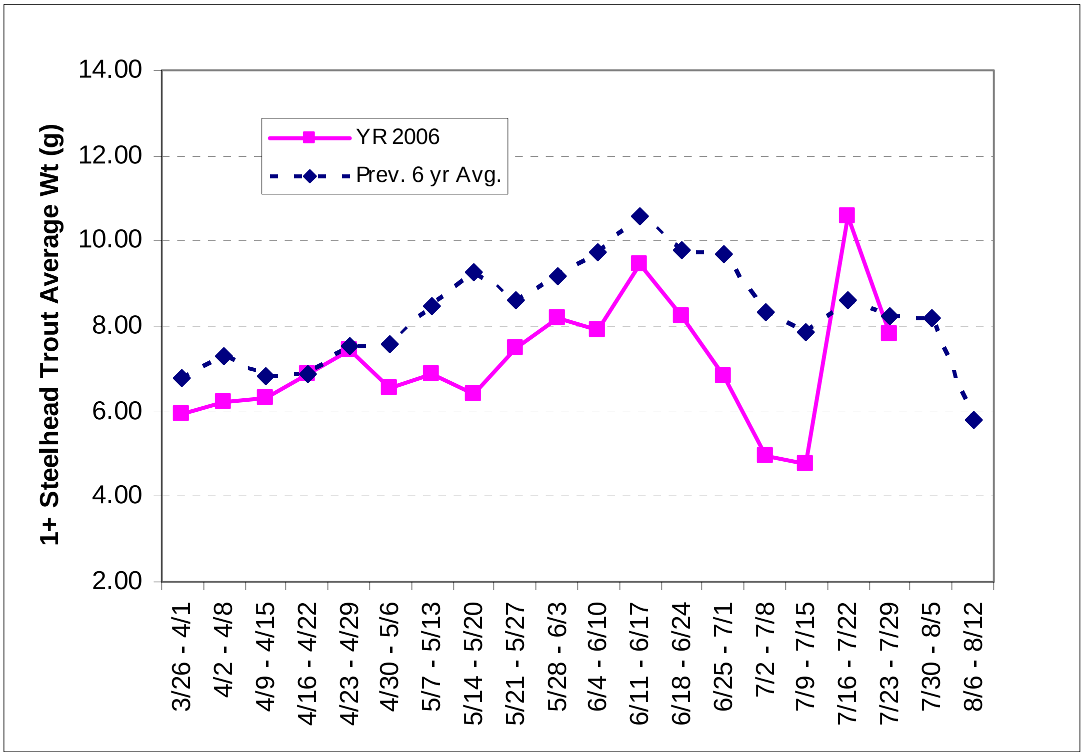

Figure 19. 1+ steelhead trout average weekly weights (g) in YR 2006 and the previous six year average, upper Redwood Creek, Humboldt County, CA.

2+ Steelhead Trout

We measured (FL mm) 396 and weighed (g) 391 2+ steelhead trout in YR 2006 (Table 20). Average FL and Wt in YR 2006 was the second highest for the seven study years (Table 20). The mode in FL in YR 2006 was 121 mm, and the modes for Wt in YR 2006 were 18.4, 40.7, and 41.5 g. Average FL and Wt over study years 2000 - 2006 did not significantly change over time (Correlation: FL, $p > 0.10$, slope is negative, $r = 0.18$, power = 0.06; Wt, $p > 0.10$, $r = 0.21$, power = 0.07).

Linear regression detected a non-significant relationship of population estimate on average FL ($p > 0.10$, $R^2 = 0.03$, slope is negative, power = 0.06) and average Wt ($p > 0.10$, $R^2 = 0.04$, slope is negative, power = 0.07).

Table 20. 2+ steelhead trout population estimates, and average fork length (mm) and weight (g) for study years 2000 - 2006, upper Redwood Creek, Humboldt County, CA.

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

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

The pattern in 2+ steelhead trout average weekly FL over the study period in YR 2006 was similar to the pattern for the previous six year average (Figure 20). Highest values in YR 2006 occurred during the first six weeks of trapping, and the lowest values occurred during weeks 10 (5/28 – 6/3) and 12 (6/11 – 6/17) (Figure 20). 2+ steelhead trout average weekly FL (mm) significantly decreased over time (weeks) in YR 2006 (Correlation, $p < 0.01$, $r = 0.65$, slope is negative, power = 0.85), as did the previous six year average FL (Correlation, $p < 0.05$, $r = 0.54$, slope is negative, power = 0.71). Median weekly FL in YR 2006 (153.1 mm) was not significantly different than the median weekly FL for the previous six year average (149.4 mm) (Kruskal-Wallis One-Way ANOVA on Ranks, $p > 0.05$). Average weekly 2+ steelhead trout FL in YR 2006 was significantly greater than the average weekly 1+ steelhead trout FL in YR 2006 (ANOVA, $p < 0.0001$, power = 1.0).

The pattern in 2+ steelhead trout average weekly Wt over the study period in YR 2006 was very similar to FL data in YR 2006, and the previous six year average Wt (Figure 21). Highest values in YR 2006 occurred during the first four weeks of trapping, and the lowest values occurred during weeks 10 (5/28 – 6/3) and 12 (6/11 – 6/17) (Figure 21).

2+ steelhead trout average weekly Wt (g) significantly decreased over time (weeks) in YR 2006 (Correlation, $p < 0.05$, $r = 0.58$, slope is negative, power = 0.69); as did the previous six year average Wt (Correlation, $p < 0.05$, $r = 0.54$, slope is negative, power = 0.70) (Figure 21). Median weekly Wt in YR 2006 (41.61 g) was not significantly different than the median weekly Wt for the previous five year average (37.90 g) ($p > 0.05$). 2+ steelhead trout average weekly Wt in YR 2006 was significantly greater than average weekly Wt for 1+ steelhead trout in YR 2006 (ANOVA, $p < 0.0001$, power = 1.0).

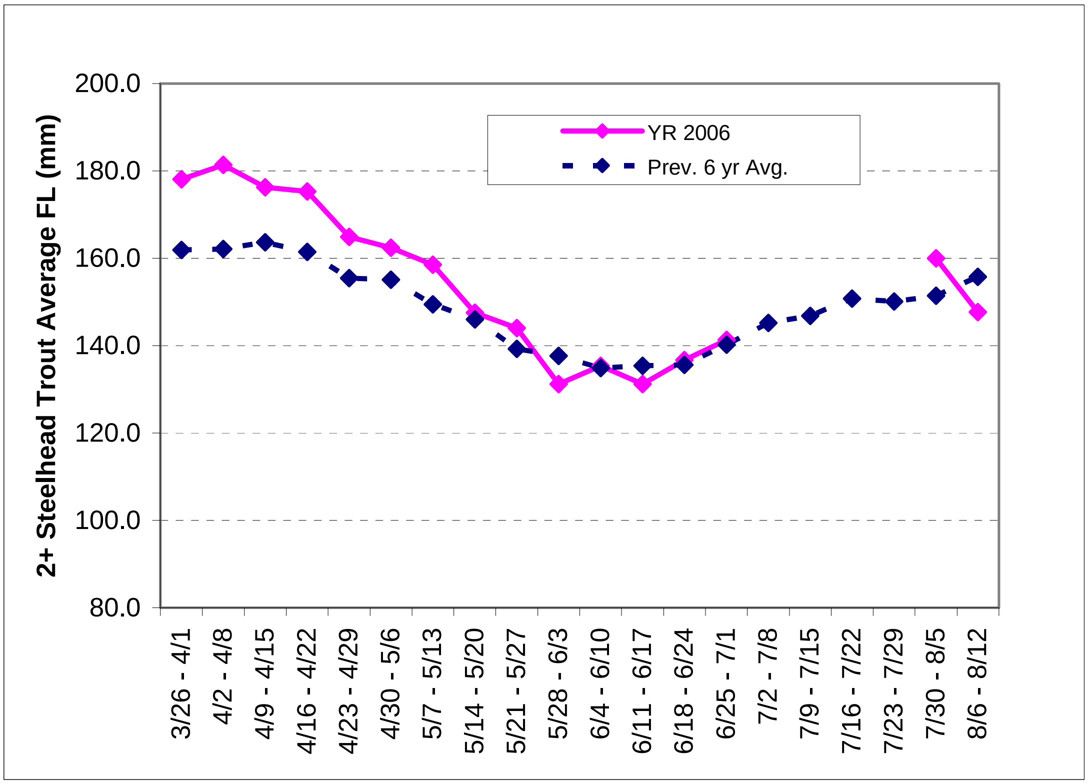

Figure 20. 2+ steelhead trout average weekly fork lengths (mm) in YR 2006 and the previous six year average, upper Redwood Creek, Humboldt County, CA.

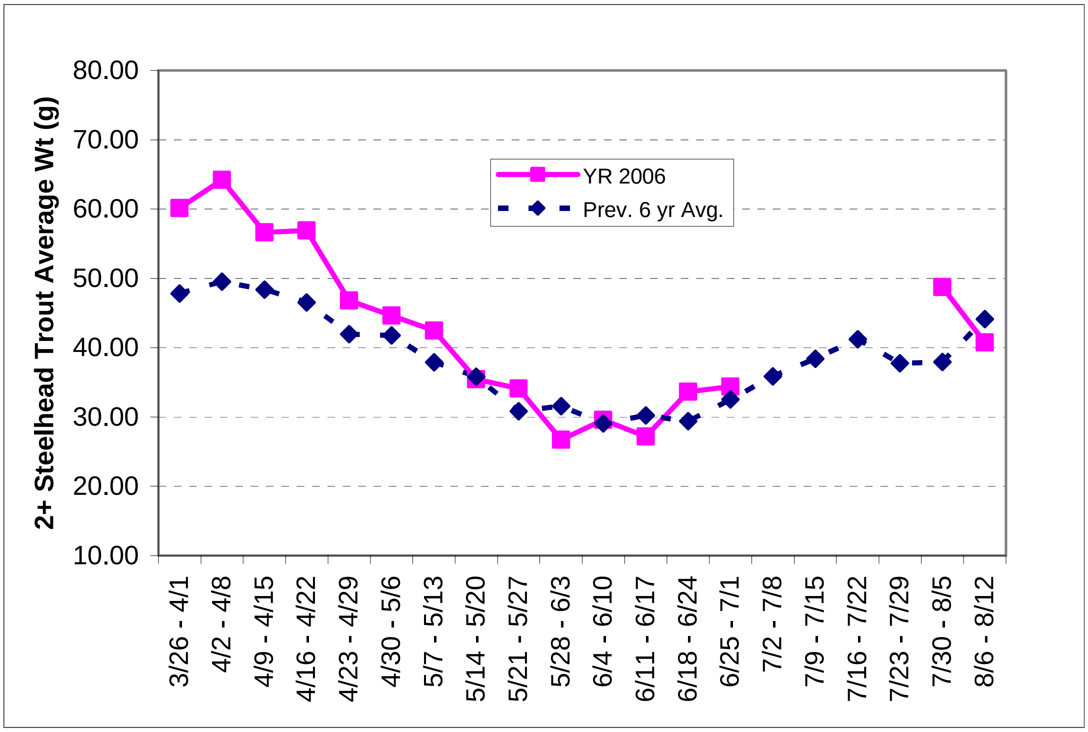

Figure 21. 2+ steelhead trout average weekly weights (g) in YR 2006 and the previous six year average, upper Redwood Creek, Humboldt County, CA.

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 2006 and for the previous six year average (Table 21). Contingency tests (2x2) showed there were significant differences in the proportions of pre-smolt and smolt designations for 1+ steelhead trout and 2+ steelhead trout in YR 2006 with the previous six year average (Chi-square, $p < 0.0001$; power = 1.00 for each test). For both tests (1+SH and 2+SH) there were comparatively more smolt designations in YR 2006. 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, $p > 0.05$ for each test); however, smolt percentages for 1+ steelhead trout were positively related to stream discharge (Regression, $p < 0.05$, $R^2 = 0.57$, power = 0.55) and negatively related to stream temperature (Regression, $p < 0.05$, $R^2 = 0.69$, power = 0.62). For 2+ steelhead trout, the percentage of smolts in a given year was inversely related to population size (Regression, $p < 0.05$, $R^2 = 0.65$, power = 0.69), inversely related to stream temperature (Regression, $p < 0.10$, $R^2 = 0.58$, power = 0.44), and positively related to stream discharge (Regression, $p < 0.10$, $R^2 = 0.47$, power = 0.39). No relationships were found with average fish size

(Regression, $p > 0.10$). 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 2006 and the previous six 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
2006	0.0	20.1	79.9	0.0	0.8	99.2
6 yr Avg.*	4.0	66.9	29.1	0.1	26.2	73.7

* Study years 2000 – 2005.

Additional Experiments

Re-migration

We did not recapture any of the 1+ and 2+ steelhead trout marked and released with elastomer (n = 183) in YR 2005 during the YR 2006 trapping period. We also did not recapture any pit tagged fish from YR 2005 (0+ Chinook, n = 555; 1+ steelhead, n = 46; 2+ steelhead, n = 147) in YR 2006. To date, we have found no evidence of 0+ Chinook salmon, 1+ steelhead trout, and 2+ steelhead trout re-migrating upstream of the trap site to be caught moving downstream the following year.

Travel Time, Travel Rate, and Growth

0+ Chinook Salmon

We recaptured 28 pit tagged 0+ Chinook salmon at the lower trap in YR 2006 (Table 22). Percent recapture per release group ranged from 0.0 - 44.4% (Table 22).

Initial fork lengths of recaptured juveniles ranged from 68 – 86 mm, and averaged 73.4 mm (Appendices 7 and 8). Time to travel the 29 miles between traps ranged from 2.5 – 20.5 d, and averaged 8.0 d (median = 6.5 d, mode = 3.5 d). Travel time was not significantly related to FL or Wt at time 1 or time 2, stream discharge or stream temperature (Regression, $p > 0.05$ for each test). The regression of lunar phase on travel time failed regression assumption tests, and results were not valid (NCSS 97).

Travel rate (mi/d) ranged from 1.4 – 11.6 mi/d, and averaged 5.5 mi/d (median = 4.5 mi/d, mode = 8.3 mi/d) (Appendix 7). Travel rate was weakly related to FL at time 1

(Regression, $p < 0.05$, $R^2 = 0.17$, positive slope, power = 0.61). Travel rate was also inversely related to lunar phase (Regression, $p < 0.05$, $R^2 = 0.22$, negative slope, power = 0.74). The regression of lunar phase and FL at time 1 on travel rate was significant (Regression, $p < 0.01$, $R^2 = 0.37$, slope is positive for FL at time 1 and negative for lunar phase, power = 0.63). No statistical relationships of water temperature or stream discharge with travel rate were detected ($p > 0.05$).

Table 22. Release groups, sample size, and percent recapture of pit tagged 0+ Chinook salmon released from upper Redwood Creek, and recaptured in lower Redwood Creek, Humboldt County, CA., 2006.

Pit Tagged 0+ Chinook Salmon			
Release Group	Sample Size	No. of Recaptures	Percent Recapture
6/10/2006	22	7	31.82
6/13/2006	15	2	13.33
6/15/2006	13	1	7.69
6/18/2006	17	3	17.65
6/20/2006	18	8	44.44
6/22/2006	21	3	14.29
7/01/2006	12	4	33.33
7/05/2006	3	0	0.00
Sum:	121	28	

Multiple fish released from the same release group (6/20/06, n = 18) were recaptured at the lower trap on the same day (6/24/06, n = 6 recaptures) (Appendix 7). 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 = 7) for the 6/10/06 release group ranged from 4.5 - 18.5 days (Appendix 7). The size of recaptured pit tagged 0+ Chinook salmon at time 2 (recapture day) was positively related to initial size at release (Regression, FL: $p < 0.0001$, $R^2 = 0.51$, power = 1.0; Wt: $p = 0.00001$, $R^2 = 0.53$, power = 1.0). The final average FL of recaptured pit tagged 0+ Chinook ranged from 71 – 87 mm, and averaged 76.5 mm; final Wt ranged from 3.51 – 6.51 g, and averaged 4.71 g (Appendix 8).

Sixteen (57%) of the 28 recaptured 0+ Chinook salmon showed positive growth in FL and seventeen (61%) showed positive growth in Wt. Twelve fish showed no change in FL, and 11 showed no change in Wt. Unlike YR 2005, none of the pit tagged recaptures in YR 2006 decreased in size (FL, Wt). On average, the 0+ Chinook salmon experienced a positive percent change in FL of 3.9% (Table 23). 0+ Chinook salmon showed, on average, positive growth in FL for absolute growth rate (Avg. = 0.24 mm/d), relative growth rate (Avg. = 0.003 mm/mm/d), and specific growth rate scaled [Ave. = 0.323 %(mm/d)] (Table 23).

On average, pit tagged 0+ Chinook salmon in YR 2005 traveled downstream to the lower trap in less time and at a greater rate than pit tagged Chinook salmon in YR 2006 (Table 23). There were only slight differences between average growth indices in YR 2005 and YR 2006, with the exception of relative growth rate being equal among years (Table 23). As expected, there were no significant differences in emigrational parameters or growth indices (FL) among study years (Kruskal-Wallis One-Way ANOVA on Ranks, $p > 0.05$ for each test).

Table 23. Comparison of travel time (d), travel rate (mi/d), and various growth statistics in YR 2005 and YR 2006 for pit tagged 0+ Chinook salmon recaptured at the lower trap, Redwood Creek, Humboldt County, CA.

	Pit Tagged 0+ Chinook Salmon Recaptures	
	Average Values (median in parentheses)	
Variable	YR 2005 (n = 27)	YR 2006 (n = 28)
Emigrational		
Travel Time (d)	7.5 (5.5)	8.0 (6.5)
Travel Rate (mi/d)	8.2 (5.3)	5.5 (4.5)
Growth Index(FL)		
% Change in FL	3.65 (2.47)	3.87 (2.82)
AGR*	0.22 (0.19)	0.24 (0.30)
RGR*	0.003 (0.002)	0.003 (0.004)
SGRsc*	0.279 (0.232)	0.323 (0.395)

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

The relationship of travel time on various FL and Wt growth indices was significant and positive (Appendix 9). Travel time explained more of the variation (84%) in percent change in FL than any other variable tested (Appendix 9 and Figure 22). Percent change in FL, absolute growth rate (FL), specific growth rate scaled (FL), and relative growth rate (FL) were also positively related to lunar phase (Regression, $p < 0.05$ for each test). Lunar phase explained up to 29% of the variation in growth in FL (Appendix 9).

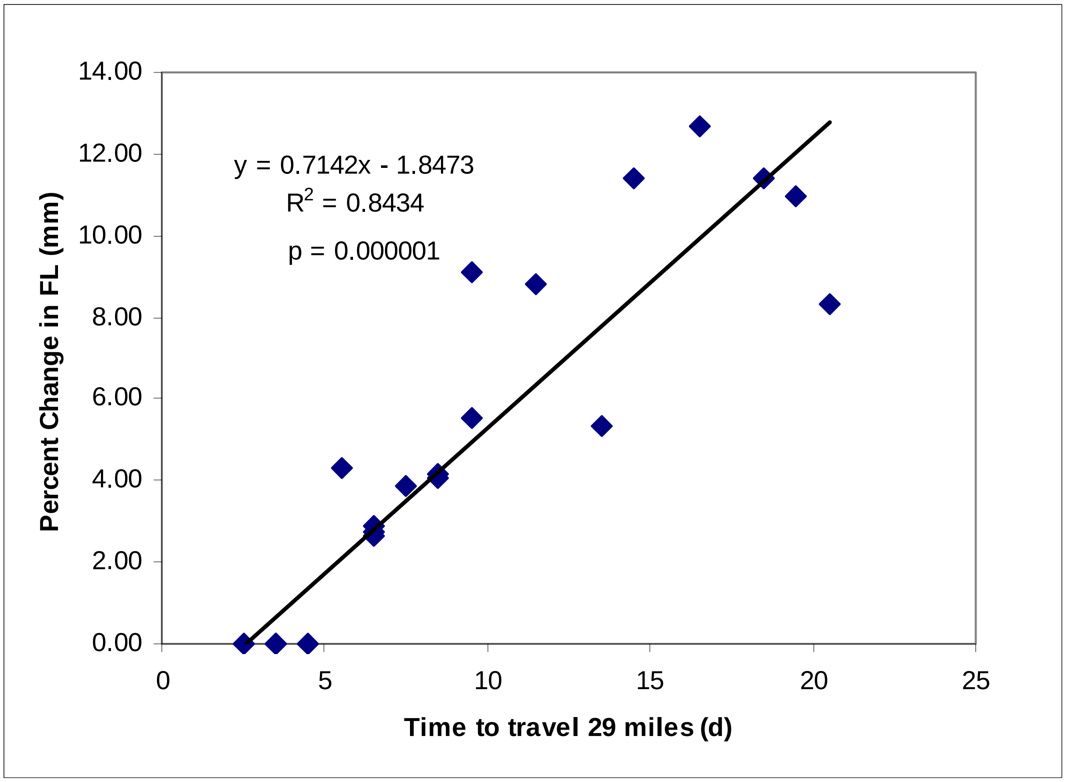

Figure 22. Linear regression of travel time (d) on percent change in FL (mm) for pit tagged 0+ Chinook salmon recaptured at the lower trap in Redwood Creek, Humboldt County, CA. 2006. Although 28 data points were used in the regression, fewer than 17 are visible due to symbol overlap.

Separate growth statistics were determined for recaptured pit tagged 0+ Chinook salmon individuals showing only positive growth (Table 24). On average, the pit tagged Chinook salmon absolute growth rate equaled 0.424 mm per day for FL, and 0.080 g per day for Wt (Table 24).

Table 24. Growth statistics for recaptured pit tagged 0+ Chinook salmon that showed positive growth in FL (n = 16) and Wt (n = 17), Redwood Creek, Humboldt County, CA., 2006.

	Positive Growth							
	% Change in		AGR*		SGRsc*		RGR*	
	FL	Wt	FL	Wt	FL	Wt	FL	Wt
Min.	2.6	5.0	0.290	0.023	0.385	0.504	0.004	0.005
Max.	12.7	39.7	0.740	0.204	0.916	4.800	0.010	0.051
Avg.	**6.8**	**17.5**	**0.424**	**0.080**	**0.566**	**1.739**	**0.006**	**0.019**
SD**	3.5	12.0	0.127	0.046	0.163	0.990	0.002	0.011

* 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).

** Standard deviation of the mean.

0+ Chinook Salmon (Pit Tagged) Recaptures in Redwood Creek Estuary

Seven pit tagged 0+ Chinook salmon released at the upper trap site were recaptured in the Redwood Creek estuary (Dave Anderson, pers. comm. 2006) (Table 25). Period of growth ranged from 17.5 – 107.5 d, and averaged 34 d. Percent change in FL (Regression, $p < 0.00001$, $R^2 = 0.99$, power = 1.0) and Wt (Regression, $p < 0.00001$, $R^2 = 0.99$, power = 1.0) was positively related to the period of growth. AGR (FL), SGRsc (FL), and RGR (FL) were each positively related to the period of growth as well (Regression, p ranged from 0.005 – 0.04, R^2 ranged from 0.61 – 0.81, power ranged from 0.61 – 0.96). No significant relationships were detected with the period of growth on AGR (Wt), SGRsc (Wt), and RGR (Wt) (Regression, $p > 0.05$ for each test).

Table 25. Growth statistics for pit tagged 0+ Chinook salmon released at the upper trap and recaptured in the Redwood Creek estuary, Redwood Creek, Humboldt County, CA., 2006.

		Pit tagged 0+ Chinook Salmon Recaptures in Redwood Creek Estuary							
Initial Size		% Change in:		AGR*		SGRsc*		RGR*	
FL (g)	Wt (g)	FL	Wt	FL	Wt	FL	Wt	FL	Wt
74	4.2	12.2	43.1	0.367	0.074	0.468	1.462	0.005	0.018
72	4.2	5.6	12.1	0.229	0.029	0.309	0.654	0.003	0.007
70	3.9	7.1	10.5	0.286	0.023	0.394	0.570	0.004	0.006
72	3.8	6.9	16.0	0.244	0.030	0.328	0.725	0.003	0.008
75	4.7	6.7	15.1	0.244	0.035	0.315	0.685	0.003	0.007
74	4.1	16.2	53.9	0.436	0.080	0.546	1.568	0.006	0.020
70	4.0	97.1	223.1	0.636	0.073	0.634	1.096	0.009	0.021
Avg.		21.7	53.4	0.349	0.049	0.428	0.966	0.005	0.012

* Abbreviations are the same as in Table 24.

0+ Steelhead Trout

We recaptured three out of 50 0+ steelhead trout marked (partial fin clips) and released (July 19, 2006) from the upper trap site at the lower trap in Redwood Creek. Two of the recaptures occurred on the sixth day following release, and the third recapture occurred on the seventh day. Travel rate equaled 4.8 mi/d for the two recaptures, and 4.1 mi/d for the third recapture.

1+ Steelhead Trout

We recaptured six pit tagged 1+ steelhead trout at the lower trap in YR 2006 (Table 26). Percent recapture per release group ranged from 0.0 – 9.1%, with an overall recapture rate of 2.4% (Table 26).

Table 26. Release groups, sample size, and recaptures of pit tagged 1+ steelhead trout released from upper Redwood Creek, and recaptured in lower Redwood Creek, Humboldt County, CA., 2006.

Pit Tagged 1+ Steelhead Trout			
Release Group	Sample Size	No. of Recaptures	Percent Recapture
4/23/2006	1	0	0.00
4/26/2006	34	1	2.94
4/30/2006	22	1	4.55
5/06/2006	25	0	0.00
5/13/2006	46	0	0.00
5/24/2006	25	0	0.00
5/31/2006	39	2	5.13
6/05/2006	10	0	0.00
6/13/2006	7	0	0.00
6/15/2006	5	0	0.00
6/22/2006	22	2	9.09
7/01/2006	7	0	0.00
7/05/2006	3	0	0.00
Sum:	246	6	

Initial fork lengths of recaptured juveniles ranged from 67 – 107 mm, and averaged 87.3 mm (Table 27). Time to travel the 29 miles between traps in YR 2006 ranged from 2.5 – 57.5 d, and averaged 20.8 d (median = 15.5 d) (Table 27). In YR 2005, travel time (for elastomer and pit tagged 1+ steelhead trout; n = 5) ranged from 2.0 – 35.0 d, and averaged 12.4 d (median = 10.0 d). Travel time in YR 2006 was not significantly related to FL or Wt at time 1 or time 2, average stream discharge, average stream temperature, or average lunar phase (Regression, $p > 0.05$ for each test).

Travel rate (mi/d) ranged from 0.5 – 11.6 mi/d, and averaged 3.95 mi/d (median = 2.1 mi/d, mode = 8.3 mi/d) (Table 27). Using alpha of 0.10 due to small sample size (n = 6), travel rate was weakly related to FL at time 1 (Regression, $p = 0.06$, $R^2 = 0.62$, positive slope, power = 0.50), Wt at time 1 (Regression, $p = 0.02$, $R^2 = 0.76$, positive slope, power = 0.75), average water temperature during the migratory phase (Regression, $p = 0.04$, $R^2 = 0.69$, positive slope, power = 0.61), and average lunar phase (Regression, $R^2 = 0.71$, negative slope, power = 0.66). No significant relationships were detected with FL at time 2, Wt at time 2, and average stream discharge (Regression, $p > 0.10$ for each test).

Table 27. 1+ steelhead trout travel time experiments in YR 2006, Redwood Creek, Humboldt County, CA.

1+ Steelhead Trout Pit Tagged Recaptures at Lower Trap					
Age/species	Initial FL mm	Date Released*	Date Recaptured**	Travel time (d)	Travel rate (mi/d)
1+ SH	67	4/26/06	5/26/06	29.5	1.0
1+ SH	83	4/30/06	6/27/06	57.5	0.5
1+ SH	87	5/31/06	6/11/06	10.5	2.8
1+ SH	79	5/31/06	6/21/06	20.5	1.4
1+ SH	101	6/22/06	6/25/06	2.5	11.6
1+ SH	107	6/22/06	6/27/06	4.5	6.4
Avg.	87.3			20.8	4.0

* Released at upper trap (RM 33). ** Recapture at lower trap (RM 4).

The final size of recaptured pit tagged 1+ steelhead trout ranged from 77 – 118 mm, and averaged 97.5 mm; final Wt ranged from 4.91 – 17.81 g, and averaged 10.24 g (Appendix 10). The final size (FL, Wt) was not related to initial size at release (Regression, $p > 0.10$ for each test).

Four (67%) of the six recaptured 1+ steelhead trout showed positive growth in FL and Wt. Two fish showed no change in FL, and two fish lost Wt. Percent change in FL ranged from 0.00 – 42.2%, and averaged 12.6%; and AGR (FL) ranged from 0.00 – 0.61 mm/d and averaged 0.31 mm/d (Appendix 10).

The relationship of travel time (d) on percent change in FL (Figure 23) and Wt was significant and positive for each test (Appendix 11). Travel time explained 97% of the variation in percent change in FL and Wt for pit tagged 1+ steelhead trout recaptured at the lower trap (Regression, $p < 0.001$ for each test). Growth rate indices (AGR, SGRsc and RGR) were inversely related to travel rate, and travel rate explained 73 – 99% of the variation in growth indices (Appendix 11). AGR (FL) was best modeled by multiple regression involving travel time and lunar phase (Appendix 11; Regression, $p < 0.05$, Adj. $R^2 = 0.84$, positive slope for both variables, power = 0.50). AGR (WT), SGRsc (FL, WT), and RGR (FL, WT) were best modeled using the single variable of travel rate (Appendix 11). Growth rate indices (AGR, SGRsc, and RGR) were each positively related to lunar phase (Regression, $p < 0.05$, R^2 ranged from 0.68 – 0.77) and, with the exception of AGR (FL), were negatively related to water temperature (Regression, $p < 0.05$, R^2 ranged from 0.60 – 0.70).

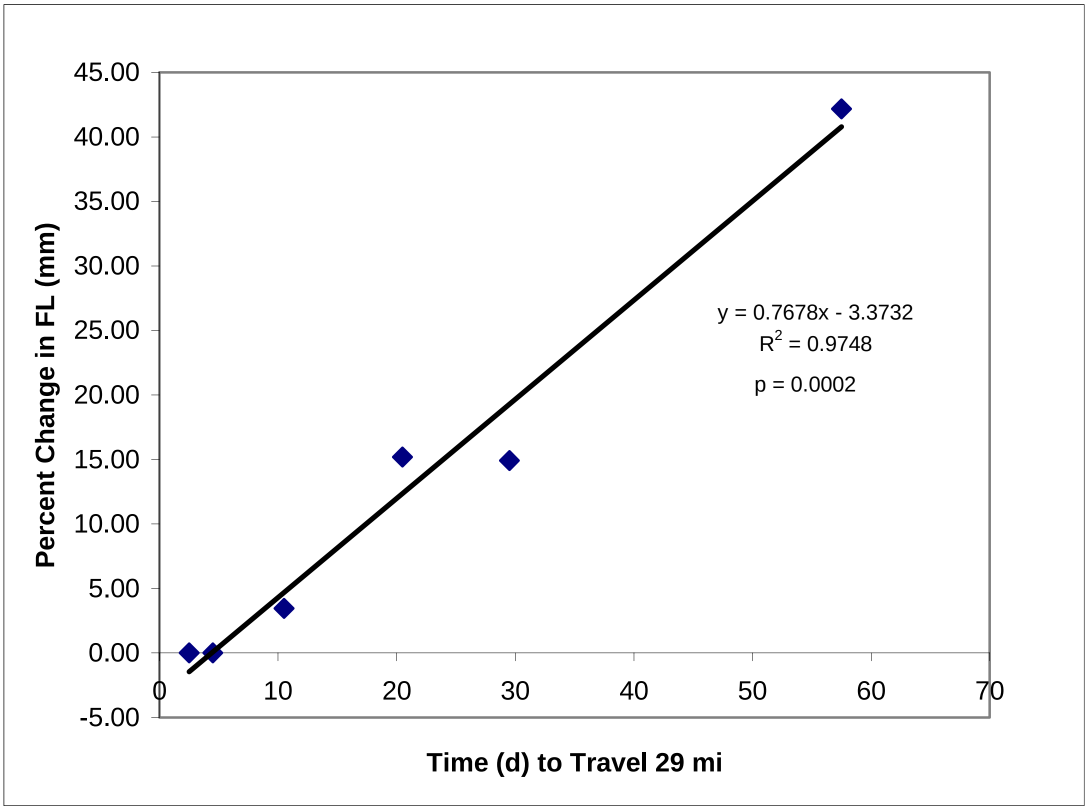

Figure 23. Linear regression of travel time (d) on percent change in FL (mm) for pit tagged 1+ steelhead trout (n = 6) recaptured at the lower trap in Redwood Creek, Humboldt County, CA., 2006.

Assessing Pit Tag Retention

On June 21 and June 22 we re-scanned a total of 38 pit tagged 0+ Chinook salmon prior to downstream release; all scanned fish retained their pit tag. On April 14 we re-scanned 13 2+ steelhead trout for pit tags, and all fish retained tags.

Delayed Mortality

0+ Chinook Salmon

A total of 11 delayed mortality experiments were conducted with 0+ Chinook salmon (n = 154) in YR 2006 (Appendix 12). A total of 121 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. No mortalities attributable to fin clipping, pit tagging, or handling occurred over a 24 - 48 hour period (Appendix 12).

1+ Steelhead Trout

A total of 24 delayed mortality experiments were conducted with 1+ steelhead trout (n = 415) in YR 2006 (Appendix 13). One pit tagged steelhead trout died immediately after tagging, and a second pit tagged steelhead died during the 34 hr test period (Appendix 13).

2+ Steelhead Trout

A total of 16 delayed mortality experiments were conducted with 2+ steelhead trout (n = 72) in YR 2006 (Appendix 14). No mortalities 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 2006 ranged from 0.00 - 0.26%, and using all data, was 0.22% of the total captured and handled (Table 28). This level of trap mortality is very low, and considered negligible.

Juvenile salmonid trapping mortality in YR 2006 (0.22%) fell below the range for study years 2000 – 2005; and was much lower that the previous six year average (0.48%) (Table 29).

Table 28. Trapping mortality for juvenile salmonids captured in YR 2006, upper Redwood Creek, Humboldt County, CA.

	Trap Mortality in YR 2006		
Age/spp.	No. captured	No. of mortalities	Percent mortality
0+ Chinook	4,830	1	0.02
0+ Steelhead	48,759	125	0.26
1+ Steelhead	3,201	2	0.06
2+ Steelhead	400	0	0.00
Cutthroat trout	3	0	0.00
Overall:	57,193	128	0.22

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

	Trap Mortality		
Study Year	No. captured	No. of mortalities	Percent mortality
2000	191,761	934	0.49
2001	239,262	1,631	0.68
2002	361,433	1,480	0.41
2003	111,514	362	0.32
2004	352,860	1,192	0.34
2005	56,544	368	0.65
2006	57,193	128	0.22
Average (2000-05)			0.48

Stream Temperatures

The average daily (24 hr period) stream temperature from 3/26/06 – 8/12/06 was 15.15 ^{o}C (or 59.3 ^{o}F) (95% CI = 14.27 – 16.03 ^{o}C), with daily averages ranging from 6.35 – 25.38 ^{o}C (43.4 – 77.7 ^{o}F). In 2006, the average daily stream temperature exceeded 20 ^{o}C (68 F) for 39 d (26%) out of 140 d of record. The average daily stream temperature in YR 2006 from 3/26/06 – 8/05/06 (truncated to compare with other study years) was 14.87 ^{o}C (58.8 ^{o}F) (Table 30). Average stream temperature did not significantly change over study years (Correlation, $p > 0.10$, power = 0.26)

Average stream temperature during the trapping period in YR 2006 was the third lowest of the current six years of data, and slightly lower than the five year average (Table 30). The average stream temperature during the majority of the trapping period for YRS 2001 – 2006 was inversely related to the average stream discharge during the trapping period (Regression, $p < 0.05$, $R^2 = 0.83$, slope is negative, power = 0.90).

Table 30. Stream temperatures (^oC) (standard deviation in parentheses) at the trap site during the trapping period in YR 2006 and previous five 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**	14.5 (5.3)	6.1	28.4	58.1 (9.5)	43.0	83.1
2004	15.8 (4.6)	6.7	28.8	60.5 (8.2)	44.1	83.8
2005**	13.5 (4.3)	6.2	25.8	56.4 (7.8)	43.2	78.4
5 Yr. Avg.*	15.2 (1.1)	5.7	28.8	59.3 (2.0)	42.3	83.8
2006**	14.9 (5.2)	5.7	29.5	58.8 (9.4)	42.3	85.1

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

Average monthly stream temperatures during the majority of the trapping season (April – July) in YR 2006 ranged from 8.7 – 21.1 ^oC (47.7 – 70.0 ^oF) (Table 31). Highest stream temperatures occurred in the later part of the trapping season (June and July) each study year. The transformed average monthly stream temperature (^oC) among study years was not significantly different (ANOVA, $p = 0.97$, power = 0.08).

Table 31. Average stream temperature (^oC) by month (^oF in parentheses) at the trapping site in study years 2001 - 2006, upper Redwood Creek, Humboldt County, CA.

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

The MWAT during the trapping period in YR 2006 at the trap site was 24.1 ^{o}C (75.4 ^{o}F) and occurred on 7/25/06 (Table 32). MWMT in YR 2006 was 28.0 ^{o}C (82.4 ^{o}F) and also occurred on 7/25/06 (Table 32).

Table 32. Maximum weekly average temperature (MWAT) and maximum weekly maximum temperature (MWMT) for stream temperatures ^{o}C (^{o}F in parentheses) at the trap site in upper Redwood Creek, Humboldt County, CA., study years 2001 – 2006.

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

* 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 2006 (Correlation, $p < 0.0001$, $r = 0.96$, slope is positive, power = 1.0) (Figure 24).

Similar to past study years, average daily stream temperature in YR 2006 was significantly related to the stream gage height at the trapping site (Regression, $p < 0.0001$, $R^2 = 0.84$, slope is negative, power = 1.0).

The minimum stream temperature in YR 2006 (not truncated) was 5.7 ^{o}C (42.3 ^{o}F) and occurred on 4/16/06 and 4/17/06); the maximum stream temperature was 29.5 ^{o}C (85.1 ^{o}F) and occurred on 7/24/06 (Figure 24).

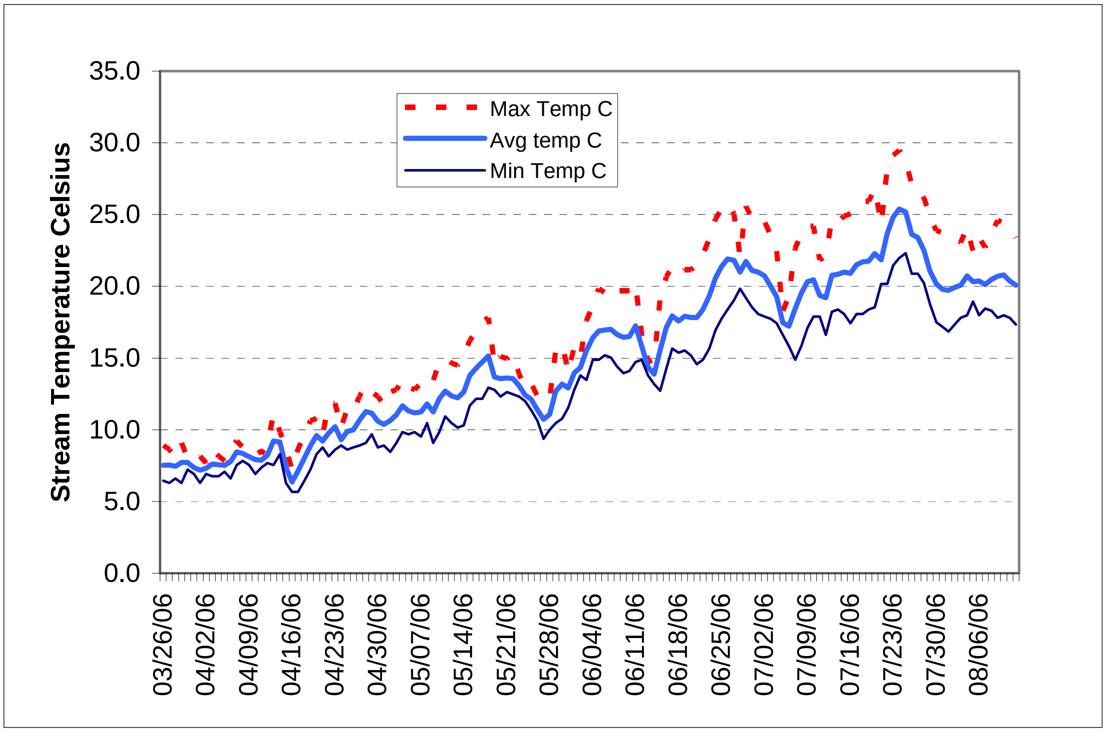

Figure 24. Average, minimum, and maximum stream temperature (Celsius) at the trap site, upper Redwood Creek, Humboldt County, CA.

The previous five year average daily stream temperature also increased over time (Correlation, $p < 0.0001$, $r = 0.98$, slope is positive, power = 1.0) (Figure 25). Median daily stream temperature in YR 2006 (14.3 ^{o}C) was not significantly different than the median (15.5 ^{o}C) for the previous five year average (Kruskal-Wallis One-Way ANOVA on Ranks, $p = 0.15$).

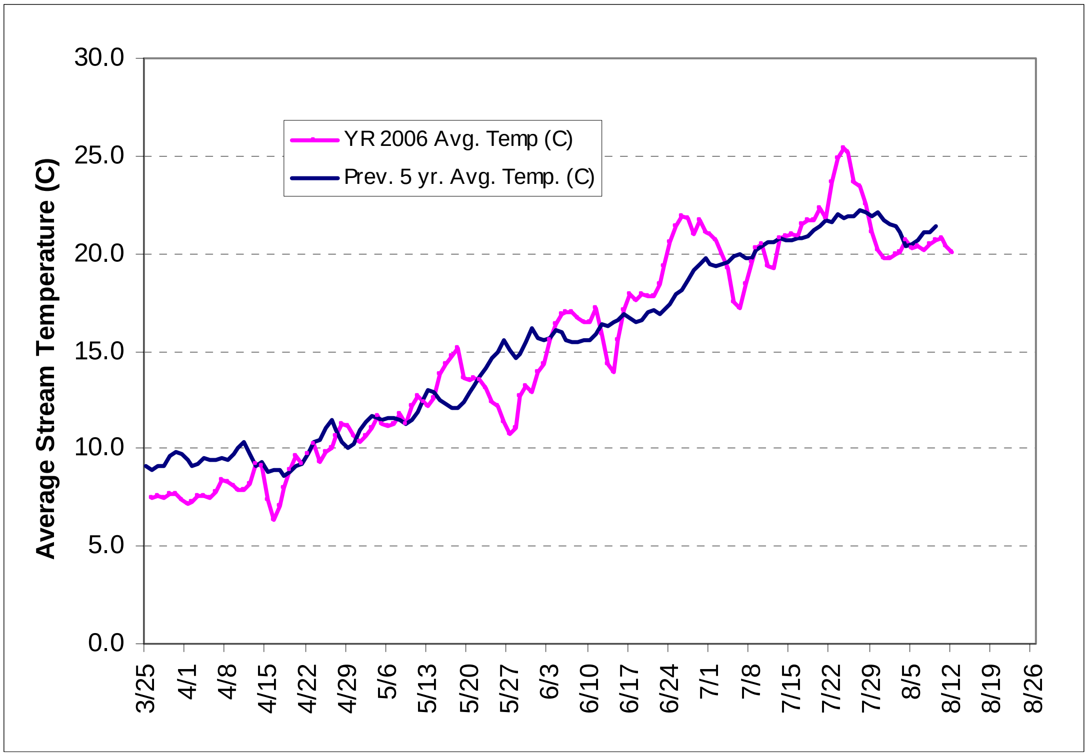

Figure 25. Average daily stream temperatures (Celsius) during the trapping period in YR 2006 and the average of previous five study years, upper Redwood Creek, Humboldt County, CA.

Lethal Stream Temperatures in late July

Numerous 0+ juvenile steelhead trout were observed dead in the stream and trap live box beginning July 23, 2006 (Figure 26). Stream temperatures in the afternoon during the fish kill ranged from 28 – 29.5 ^{o}C (82.4 – 85.1 ^{o}F), with the highest maximum temperature (29.5 ^{o}C or 85.1 ^{o}F) and the greatest 24 hr average (25.4 ^{o}C or 77.7 ^{o}F) occurring on July 24, 2006 (Figure 26). From July 23 – July 25, 2006 lethal stream temperatures occurred from about 2 – 7 pm (Figure 26). Although the far majority of mortalities were for 0+ steelhead trout, several older juvenile steelhead trout (1+ and 2+) were also killed near the trap site. On July 25, 2006 I conducted a delayed mortality test for 0+ steelhead trout (n = 50) from 11:00 – 17:00 (duration of 6.0 hrs) to investigate influences of stream temperature on survival (Table 33). Only 36% of the 0+ steelhead trout survived (Table 33). Dissolved oxygen concentrations (mg/l) in the livecar (used for holding fish) and the stream during the experiment ranged from 8 – 10 mg/l.

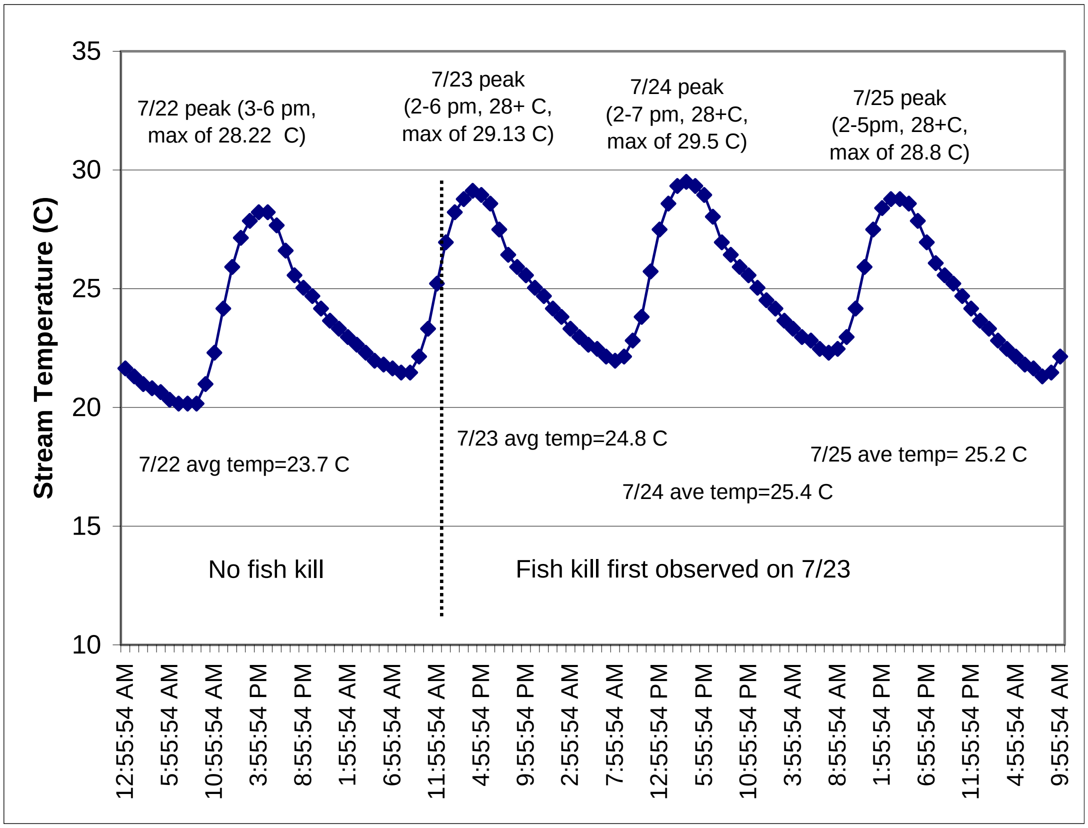

Figure 26. Hourly stream temperatures (Celsius) before and during juvenile steelhead die offs in upper Redwood Creek, Humboldt County, CA., 2006.

Table 33. 0+ steelhead trout delayed mortality test results, upper Redwood Creek, Humboldt County, CA., 2006.

0+ Steelhead Trout Delayed Mortality Test Results

Date	Test Duration (hrs)	n	Average Water Temperature (^oC)	Morts/total	Percent Mortality
6/12-6/13	24	30	15.1	0/30	0.00
6/21-6/22	24	30	17.8	0/30	0.00
7/20-7/21	24	29	21.9	0/29	0.00
7/25-7/25	6	50	26.4	32/50	64.00

DISCUSSION

The main goal of our downstream migration study in upper Redwood Creek is to estimate and monitor the production of Chinook salmon, steelhead trout, and coho salmon (if present) in a reliable, long-term manner. Redwood Creek is a difficult, if not impossible stream to monitor for adult salmon and steelhead populations on a long term basis using traditional techniques (weirs and spawning ground surveys) due to run timing, precipitation, hydrology, water depth, and stream turbidity. However, “quantifying juvenile anadromous salmonid populations as they migrate seaward is the most direct assessment of stock performance in freshwater” (Seiler et al. 2004). In addition, studies in various streams have found that smolt numbers can relate to stream habitat quality, watershed condition, restoration activities, the number of parents that produced the cohort, and future adult populations.

The seventh consecutive year of trapping in upper Redwood Creek occurred during a wet water year with respect to rainfall amounts in Redwood Valley and average stream discharge measured at the O’Kane gaging station. Rainfall in WY 2006 (250 cm) was the highest of the 21 year record (ranged from 90 – 250 cm), however, stream discharge in WY 2006 (351 cfs) was the sixth highest of the 35 year record (ranged from 44 – 421 cfs). Rainfall during the majority of the trapping period was below the historic and previous six year average; average monthly stream discharge, in contrast, was greater than the historic and previous six year average by a factor of 1.35. The month of April accounted for most of the rainfall during the trapping period, and was also the month with the highest average streamflow. The lowest values in rainfall and stream discharge during the majority of the trapping period occurred in July.

The environmental conditions for downstream migrant trapping in YR 2006 were not as harsh or as difficult to operate the trap compared to previous study years, with the exception to the lethal stream temperatures encountered in late July. Two days of trapping were missed due to high streamflow in April, two days were missed due to high stream temperatures in late July, and one day was missed due to trap malfunction (fyke net) in early August. The five days we missed trapping were generally 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 1.65%, 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 smolt emigration (production) from areas upstream of the trapping site.

0+ Chinook Salmon

0+ Chinook salmon (ocean-type) emigrating from upper Redwood Creek were the most numerous migrant captured by the smolt trap for four out of seven years. Low catches occurred in YRS 2003, 2005, and 2006; and the total catch in YR 2006 was 96% less than the average catch of the previous six years.
The population of 0+ Chinook salmon emigrating from upper Redwood Creek was variable over the seven consecutive years of study; production was greater than 350,000 individuals for the first three years, less than 1,000 in the fourth year, the fifth year experienced the greatest peak of 630,000 and for the past two years, production was less than 40,000. The reduction in emigration in YR 2006 (92% reduction from previous six year average, 34% reduction from YR 2005 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 late December and early February 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 emigrating from upper Redwood Creek. Since we currently do not count adults or have an index of adult escapement, it is not possible to state that a major change in spawning distribution occurred and was reflected by low juvenile emigration in YR 2006. The emigrant population passing the rotary screw trap in lower Redwood Creek in YR 2006 (N = 85,149) does not give much supportive evidence (similar to data of YR 2005 compared to YR 2004) for a change in population distribution because it was 35% less than emigration in YR 2005 (Sparkman 2007b). Had there been a drastic change in the distribution of adult Chinook salmon in the watershed, holding additional factors constant, there should have been an increase in the number of migrants passing the lower trap compared to the previous year. Data from the lower trap was able to show: 1) the severe decrease in 0+ Chinook salmon numbers was not limited to upper Redwood Creek, and included the entire Redwood Creek watershed upstream of where Prairie Creek enters Redwood Creek, and 2) production of 0+ Chinook salmon in YR 2006 was greater in areas downstream of the upper trap site. Unfortunately, peaks in stream flow (> 11,000 cfs) measured in lower Redwood Creek in December 2005 and February 2006 were 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, 2004, and 2005 were frequently 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. At least some adult Chinook salmon were present in upper Redwood Creek in mid November to late November 2005 because pairs of adult Chinook Salmon were observed in spawning areas upstream of the trap site (author). However, we have no estimate of the number of adult fish that migrated and spawned upstream of the trap site in YRS 2002, 2004, and 2005.

Although we do not know how many adult Chinook salmon were present upstream of the trap site in the 2005/06 spawning season, we do know that for each severely reduced population estimate (YRS 2003, 2005, and 2006), high flows capable of mobilizing bedload and scouring or jostling redd gravels occurred when Chinook salmon redds were present. For the 2006 cohort, high flows occurred on 12/28/05 (5,220 cfs, duration = 1hr.), 12/30/05 (6,420 cfs, duration = 9 hrs.), 12/31/05 (6,030 cfs, duration = 2 hrs.), and 02/02/06 (5,500 cfs, duration = 5 hrs.). Several investigators have shown that the scour of redds due to high stream flows or floods can often cause severe decreases in the production of juvenile salmonids (Gangmark and Bakkala 1960, McNeil 1966, Holtby and Healey 1986, Montgomery et al. 1996, Devries 1997, Schuett-Hames et al. 2000, Seiler et al. 2002, Don Chapman pers. comm. 2003, and Greene et al. 2005); and that estimates of mortality attributable to high flows and redd scour can reach 90% (Schuett-Hames et al. 2000). Greene et al. (2005) were able to show that the flood recurrence interval during Chinook salmon intragravel development was the second most important variable in their models used to predict the return rate of adult Chinook salmon. They further report that “large flow events may be a key factor in regulating Chinook salmon populations in the Skagit River basin, Washington” (Greene et al. 2005). Three of the seven current study years in upper Redwood Creek experienced flows capable of scouring spawning redds or jostling the gravels/cobbles that make up the redds, with poor production of each cohort the following spring.

This year, utilizing seven data points, linear regression detected a significant negative relationship with bedload mobilizing flow and the subsequent production of 0+ Chinook salmon juveniles ($p < 0.001$, $R^2 = 0.92$, power = 1.0). 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 91% of the variation in the seasonal 0+ Chinook salmon population estimate over the seven 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 Chinook salmon 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 YRS 2003, 2005, and 2006 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 YRS 2003 or 2005 to be captured as one-year-olds the following year (let alone in significant numbers), thus holding over is an unlikely explanation for the drastic decrease observed in YR 2006.

0+ Chinook salmon monthly population emigration was severely reduced from the previous six year average, with the biggest monthly reductions occurring in April (92.6% or 118,006 individuals) and May (96.1% or 107,017 individuals). The majority of juvenile Chinook salmon in YR 2006 migrated downstream during April - June (97%% of total emigration), similar to the pattern for the previous six year average (April – June, 93% of emigration). However, highest numbers emigrated during June in YR 2006, compared to April for the previous six year average. Weekly population emigration in YR 2006 was positively related, albeit weakly, to stream gage height (R^2 = 0.36) and stream discharge (R^2 = 0.29); and negatively related to average stream temperature (R^2 = 0.25) and week number (r = 0.76). Thus, more 0+ Chinook salmon were emigrating earlier in the season when stream temperatures were lower and stream discharge was higher compared to later in the season. Very similar results were found in YR 2005 (Sparkman 2005).

The 0+ Chinook salmon (ocean-type) migrants in upper Redwood Creek exhibit two different juvenile migratory life histories (fry and fingerling) based on size (FL, WT) and time of downstream migration. The fry (Avg. FL = 40 mm in YR 2006) are migrating shortly after emergence from spawning redds, and therefore are much smaller than the fingerlings (Avg. FL = 62 mm in YR 2006) which have reared in the stream for a longer period of time prior to passing the trap site. Although there is overlap in downstream migration, temporal differences in migration timing between the two life history forms are evident by the two peaks in migration. For example, the first weekly peak in population emigration in YR 2006 occurred during 4/16/06 – 4/22/06 (N = 4,096), and consisted of fry with an average FL of 39 mm; the second peak occurred during 6/18/06 – 6/24/06 (N = 4,287) and consisted of fingerlings with an average FL of 71 mm.

The two noticeable weekly peaks or modes to the distribution (both YR 2006 and previous six year average) do not necessarily indicate two different runs of adult Chinook salmon entered upper Redwood Creek because of great differences in FL or WT. If the modes represented two different runs of adults, we would expect the FL's during each peak to be nearly the same. In other words, if the second mode represented a different group of adult fish, then their progeny should be smaller than what was observed due to differences in redd emergence timing (later than the progeny for the first group of adults, assuming differences in intragravel water temperatures have a negligible affect on emergence timing), and the amount of time available to gain FL or WT in the stream (less time for growth if emerge from redds much later than the first group, assuming differences in water temperatures have a negligible affect on growth). A more likely explanation is that the fingerlings were born near the same time as the fry but further upstream; and grew in size as they remained in the stream and as they migrated downstream to be later captured. Some of the fingerlings could also have been fry born just upstream of the trap site that temporarily resided (upstream of the trap site) prior to downstream migration.

The emigration of 0+ Chinook salmon fry in YR 2006 began near the onset of trapping, peaked in mid April, and tapered off to very low values by mid May. Fingerling migration in upper Redwood Creek began in very low numbers in April, peaked in mid-

June, and tapered to low values by early July. Factors that can influence the temporal component to fry and fingerling migration are: 1) time of adult spawning, 2) how far upstream of the trap the adults spawned, 3) time from egg deposition to fry emergence from redds, and 4) travel rate, among other factors.

Large numbers of Chinook salmon fry emigrate soon after redd emergence in upper Redwood Creek, with percentages ranging from 1 – 69% of the total Chinook salmon emigrant population per study year. The percentages of juvenile Chinook salmon migrating as fry (40% of total or 10,390 individuals) or fingerlings (60% of total or 15,703 individuals) in YR 2006 were statistically different than for the previous six year average, such that a lesser proportion of fry and a higher proportion of fingerlings were present in YR 2006. As expected, the proportion of fry and fingerlings present in YR 2006 was statistically non-random (eg different than a 50/50 ratio).

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

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

I used linear regression to investigate any relationships between average stream flow (surrogate for habitat space), average stream temperature, and seasonal 0+ Chinook population estimate on the percentage of emigrating fry each year in upper Redwood Creek. None of the regression models were significant, and in fact, the regressions were highly non-significant ($p > 0.70$); therefore, no relationships between measured habitat variables or juvenile Chinook salmon population size on the percentage of fry in any given year were detected (ie no density-dependent relationship was detected). The mechanism for fry dispersal in upper Redwood Creek, based upon our data, could be genetic. With respect to space or habitat availability and fry movement, downstream migrant trapping in Prairie Creek offers additional support. Prairie Creek is known as a relatively pristine stream, with old growth Redwood forests, cool stream temperatures, and high degrees of habitat complexity; yet, each year, regardless of the number of adults (and egg deposition) and subsequent juvenile production, Chinook salmon fry are captured in traps every year as they migrate downstream (Roelofs and Klatte 1996; Roelofs and Sparkman 1999, Walt Duffy pers. com. 2005).

The average size (FL, Wt) of 0+ Chinook salmon emigrants in YR 2006 was slightly greater (by 1.3 mm, and 0.07 g) than the previous six year average. The larger than average size in YR 2006 will most likely not compensate for the severe reduction in population emigration in YR 2006. Although size is frequently related to increased survival to adulthood (Zabel and Achord 2004), the small increase observed in YR 2006 is offset by the severe decrease in population numbers. In YR 2006, there were about 90% less fingerlings than the previous six year average, and about 94% less fry. The number of fingerlings emigrating in YR 2006 was so low compared to previous years (excluding YR 2003 and 2005) that far fewer adults are expected to return, regardless of the average FL and Wt in YR 2006.

Linear regression detected a significant negative relationship of seasonal 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 average size (FL, Wt) for a given population estimate over the seven study years was not related to the percentage of fry or fingerlings in the population estimate; thus ruling out that average size by study year is more related to the number of fry than to the total population at large. The density-dependent relationship of population numbers on average size suggests that rearing space or carrying capacity (and food availability) upstream of the trap site is limiting the average size of Chinook salmon juveniles at higher population abundances. However, the current carrying capacity is expected to be much less than the carrying capacity of the past because Redwood Creek has changed over time, and is currently considered sediment and temperature impaired by the USEPA. If habitat is limiting the size of smolts at higher abundances, successful watershed restoration in the upper basin should allow for the juvenile Chinook salmon to gain a larger size than currently observed, even if the 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 in any given year increased over the study period. Average weekly FL and Wt in YR 2006 followed a similar pattern over time; starting out low and relatively stable for the first 6 weeks, then increasing throughout the end of the study period.

The emigrants were small in size during the first six weeks because the vast majority of catches were emergent fry (fry that emerge from redds and immediately migrate downstream). The rather sharp increase in FL and Wt by week in YR 2006 was attributable to the increasing percentage of fingerlings in the catch over time compared to fry ($p < 0.001$ for each test). Unwin (1985) reported a similar finding in his trapping studies in New Zealand. The relationships of weekly FL and Wt in YR 2006 with the previous five year average were numerically similar for the first six weeks, thereafter average weekly FL's and Wt's in YR 2006 were greater than the five year average. These increases in weekly FL's and Wt's indicate growth was taking place within the study periods. The rough or group estimate of growth rate from 4/02/06 to 7/01/06 equaled 0.36 mm/d for FL and 0.04 g/d for Wt; these values were very close to those determined in YR 2005 (0.41 mm/d and 0.05 g/d). A growth rate of 0.36 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 ($n = 28$) 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 lower trap in Redwood Cr (RM 4) captured 32% of the pit tagged 0+ Chinook salmon released at the upper trap. The recapture of pit tagged 0+ Chinook salmon per release group in YR 2006 (as well as YR 2005) was variable. For one release group (6/20/06, n = 18 released), six individuals were recaptured on the same day at the lower trap (6/24/06), 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, seven individuals from the 6/10/06 release group (n = 22) were recaptured at the lower trap anywhere from 4.5 – 18.5 d after release from the upper trap; these fish did not travel as a group. Travel time for 0+ Chinook salmon smolts in YR 2006 to migrate the 29 miles downstream ranged from 2.5 – 20.5 d, and averaged 8.0 d; these values were also very similar to data collected in YR 2005 (Avg. travel time = 7.5 d). On average, 0+ Chinook salmon in YRS 2005 and 2006 moved downstream to the lower trap in fewer days than 2+ steelhead trout (n = 7, range = 2 to 35 d, Avg. = 13 d) and 1+ steelhead trout (n = 9, range = 2 to 32 d, Avg. = 15 d) in YR 2004 (Sparkman 2004c, study 2i3), and fewer days than 1+ steelhead trout in YR 2005 (n = 5, Avg. travel time = 12 d) and YR 2006 (n = 6, Avg. = 21 d). Thus, for the past two years, 0+ Chinook salmon traveled the 29 miles downstream in less days than juvenile steelhead trout. The travel time for 0+ Chinook salmon smolts 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, 3) stream discharge, or 4) lunar phase. Smith et al. (2003) found that travel time decreased with increasing discharge for wild sub-yearling Chinook salmon in the Salmon River, however, they also state that the longest travel time occurred during the highest stream discharge.

Travel rate in YR 2006 ranged from 1.4 – 11.6 mi/d (2.3 – 18.7 km/d), and averaged 5.5 mi/d (8.8 km/d). Average travel rate in YR 2006 was lower than the average travel rate in YR 2005 by about 2.7 mi/d, however, the difference was non-significant. The upper range in travel rate in YR 2006 (18.7 km/d) for Chinook salmon fingerlings in Redwood Creek was lower than that observed in the upper Rogue River (24.0 km/d) (Healey 1991); however, the average travel rate (8.8 km/d) from upper Redwood Creek in YR 2006 was much higher than the average (1.6 km/d) put forward by Allen and Hassler (1986). Raymond (1968) found that the average travel rate for yearling Chinook salmon smolts (stream-type) in a free flowing section of the Columbia River was 24 km/d during lower river discharges and 40 km/d during moderate river discharges.

Unlike travel time, we were able to successfully model travel rate using linear regression. Travel rate (mi/d) for Chinook salmon emigrating from upper Redwood Creek to lower Redwood Creek was weakly related ($R^2 = 0.17$) to smolt size (FL or Wt) at time 1 (initial release), such that with a greater initial size we observed a slightly higher travel rate. Travel rate was also weakly related to lunar phase ($R^2 = 0.22$). The best model describing travel rate included both FL or Wt at time 1 and lunar phase (Adj. $R^2 = 0.37$). Travel rate was positively related to fish size at time 1 and negatively related to the lunar phase during the migratory period; however, the linear model left considerable amounts of variation unexplained (63%). Similar to travel time in YR 2006, travel rate was not related to stream discharge, stream temperature, or fish size at time 2 ($p > 0.05$). Healey (1991) reported results from a study in the Rogue River, Oregon in which the travel rate of spring Chinook salmon fingerlings was positively related to fish size and stream discharge in one year, and negatively related to stream discharge in the following year. Quinn (2005) reported that the rate at which 0+ Chinook salmon traveled downstream in the Columbia River was positively related to size. Achord et al. (2007) were able to determine that the variability in stream-type juvenile Chinook salmon (Age-1) travel rate among study years in the Columbia River was related to stream temperatures during Autumn and Spring, and stream discharge during March. They found that even small increases in temperature (0.325 ^{o}C for Autumn and 0.29 ^{o}C for Spring), or flow (625 cfs) would decrease the median passage date by 1 d (Achord et al. 2007). Unfortunately, there appears to be a lack of data in the literature to compare individual travel time and travel rate with data collected on juvenile Chinook salmon (ocean-type) in Redwood Creek. Many of the studies using pit tags with juvenile Chinook salmon are within the Columbia River system, which for the most part is not comparable to Redwood Creek; Redwood Creek is much smaller in size, does not have impoundments, and the stream flow is unregulated, among other differences.

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

In YR 2006, 57% of the 28 recaptured 0+ Chinook salmon fingerling smolts showed positive growth in FL, 43% showed no change in FL, 61% showed positive growth in Wt, and 39% showed no change in Wt. Absolute growth rate (FL) in YR 2006 ranged from 0 - 0.74 mm/d, and averaged 0.24 mm/d. The average value (0.24 mm/d) was slightly higher (by 0.02 mm/d) than the average for study year 2005. Average absolute growth rate (FL) in YR 2006 was comparable to the group growth rate for Chinook salmon fingerlings in the Nitinat River (0.21 mm/d) and about 2/3 less than the group growth rate determined in the Cowichan River (0.62 mm/d), British Columbia (Healey 1991). Koehler et al. (2006) determined that ocean-type juvenile Chinook salmon grew 0.50 – 0.67 mm/d in the littoral areas of Lake Washington, WA during March – June. Kjelson et al. (1982) *in* Koehler et al. (2006) determined the growth rate of juvenile Chinook salmon (Fall Race) in the Sacramento River equaled 0.33 mm/d. Connor and Burge (2003) reported a growth rate of 1.3 mm/d for Chinook salmon smolts in the Snake River. Weber and Fausch (2005) placed wild ocean-type Chinook salmon juveniles into enclosures along the margin of the Sacramento River and determined the average specific growth rate (Wt) over three years ranged from about 0.03 – 0.045 g/d, which was much higher than the average specific growth rate (un-scaled) we determined for Redwood Creek Chinook salmon in YR 2006 (0.01 g/d). The average absolute growth rate for recaptured pit tagged fingerlings (0.24 mm/d) in Redwood Creek was about 23% less than the group growth rate calculated for fry and fingerlings in YR 2006 using the average weekly FL data (0.36 mm/d). However, the latter estimate includes fry (which may have a higher absolute growth rate than fingerlings) and probably is not influenced by zero growth like the average for the individual growth rates were. For example, the absolute growth rate for pit tagged Chinook salmon juveniles in Redwood Creek showing only positive growth ranged from 0.29 - 0.74 mm/d and averaged 0.424 mm/d, which was higher than the group estimate previously calculated (0.36 mm/d) by 0.064 mm/d.

The growth (positive, negative, or zero) of the 28 recaptured pit tagged 0+ Chinook salmon was successfully modeled using linear regression. Models with migration variables (travel time, travel rate) explained more of the variation in growth than other variables tested, similar to data collected in YR 2005. Travel time in YR 2006 was the single most important variable describing the variation in percent change in FL (R^2 = 0.84) and Wt (R^2 = 0.60), and SGRsc (Wt) (R^2 = 0.39); and travel rate was the most important variable for modeling AGR FL (R^2 = 0.72), SGRsc FL (R^2 = 0.69), and RGR FL (R^2 = 0.68). Percent change in FL was positively related to travel time, and travel time explained 84% of the variation in growth; absolute growth rate (FL) was negatively related to travel rate, and travel rate explained 72% 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; and fish that traveled at a faster rate to the lower trap did not gain as much weight as those fish which traveled slower. This in turn suggests fish that took a longer amount of time to migrate downstream had more time to forage for food, feed, and convert the food to growth. The energy required for foraging was offset by the amount or quality of food eaten. Fish that traveled at a higher rate spent more time traveling downstream (expending energy) than foraging for food. Beamer et al. (2004) found that the growth of juvenile ocean-type Chinook salmon (in Skagit Bay) was positively related to the amount of time that the juveniles spent in the delta; and Achord et al. (2007) found that the growth of juvenile Chinook salmon in the Snake River was positively related to travel time.

Various growth indices were also positively related (albeit weakly, R^2 = 0.15 to 0.29) to the average lunar phase encountered during a specific individual's migration period, which suggests: 1) 0+ Chinook salmon spent more time catching prey items than migrating downstream during higher moon illuminations, and 2) visibility during higher moon illuminations favor the ability to capture food items. The significant, inverse relationship of lunar phase on travel rate indicated that pit tag juveniles reduced the rate of travel, which would then offer more time to forage for food. No significant relationships between any growth index and stream temperature or stream discharge were detected, even though the range in values for each was fairly wide. Marine et al. (2004) found that growth rates of wild juvenile Chinook salmon in laboratory settings declined at temperatures ranging from 21 – 24 ^{o}C.

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 = 0.51, power =1.0). Fifty one 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 pit tagged fish at the lower trap were more likely to have been the larger pit tagged fish released 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, 2005, and 2006 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 seven study years equaled 68 individuals, or 0.001% of the total juvenile Chinook salmon catch.

When present, 1+ Chinook salmon from upper Redwood Creek are more likely to be progeny of fall/winter-run Chinook salmon adults than from spring-run adults (Stream-type) because few if any spring-run Chinook salmon are observed during spring and summer snorkel surveys in Redwood Creek (Dave Anderson, pers. comm. 2004). For example, in 22 years of adult summer steelhead snorkel dives, adult spring Chinook salmon were only observed in one year (1988) and in very low numbers (< 7 individuals) (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) and maximum temperatures (24+ °C or 75 °F) may also prevent any adult spring-run Chinook salmon migration into upper Redwood Creek, or inhibit their ability to over-summer in pools. Thus, a spring run of Chinook salmon adults is probably not responsible for the production of yearling Chinook salmon juveniles in Redwood Creek. Bendock (1995) also found both stream-type and ocean-type juvenile Chinook salmon in an Alaskan stream which only has one adult Chinook salmon race; and Connor et al. (2005) reported that fall Chinook salmon in the Snake River produced juveniles exhibiting an ocean-type or stream-type juvenile life history. Teel et al. (2000) found that for some populations of coastal Chinook salmon, ocean-type and stream-type juveniles were genetically undifferentiated, and probably arose from a common ancestor. They further report that the stream-type life history probably evolved after the ocean-type colonized (post glacial period) the rivers in study.

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

0+ Steelhead Trout

Considerable numbers of young-of-year steelhead trout migrate downstream from upper Redwood Creek during spring and summer months; over seven consecutive study years we captured 604,229 individuals. 0+ steelhead trout were the most numerous juvenile salmonid captured in the trap for three out of seven years, and were the most numerous age class migrant for juvenile steelhead trout each study year. Clearly, stream habitat upstream of the trap site is important for adult steelhead trout reproduction.

The total catch of 0+ steelhead trout migrating downstream in YR 2006 was the second lowest of all trapping seasons. Trap catches in YR 2006 (n = 48,759) were higher than catches in YR 2005, yet 47% lower than the previous six year average catch (Avg. = 92,578). During study years with relatively high catches, we frequently observed numerous 0+ steelhead trout in margin areas of the stream near the trap site. In contrast, during YR 2006 we observed far fewer juveniles in these margin areas.

Relatively high catches of young-of-year steelhead trout by downstream migrant traps in small and large streams is not uncommon (USFWS 2001, Rowe 2003, Johnson 2004, Don Chapman pers. comm. 2004, Sparkman 2006). Young-of-year steelhead trout downstream migration in upper Redwood Creek is considered to be stream re-distribution (both passive and active) because juvenile steelhead trout normally smolt and enter the ocean at age two, with lesser numbers out-migrating at ages 1 and 3.

The number of 0+ steelhead trout that can remain upstream of the trap site is some function of a fish's disposition to out-migrate (or not out-migrate) and habitat carrying capacity. Meehan and Bjornn (1991) comment that juvenile steelhead trout have a variety of migration patterns that can vary with local conditions, and that the trigger for out-migration can be genetic or environmental. Habitat carrying capacity is generally thought to be related to environmental (hydrology, geomorphology, stream depth and discharge, stream temperatures, cover, sedimentation, etc) and biological variables (food availability, predation, salmonid behavior), and any interactions between the two (Murphy and Meehan 1991). However, a limitation with the view of habitat carrying capacity's affect on migration is that it fails to explain why juvenile fish emigrate when upstream fish densities or population levels are low.

The overall decrease we observed in YR 2006 could be due to a variety of factors: 1) changes in the number of adult steelhead spawning above the trap site, 2) change in redd gravel conditions, 3) change in carrying capacity of stream habitat upstream of trap site, 4) decrease in the percentage of the total population that passively or actively migrates downstream, or 5) some combination of factors 1 - 4. The potential variable of trapping efficiency among study years would not account for the decrease we observed in YR 2006 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 2006 we observed adult steelhead on redds upstream of the trap site, with the latest observation occurring in May. Thus, the majority of steelhead redds in YR 2006 were not subjected to the high, potentially damaging stream flows in December and early February that the Chinook salmon experienced. After February 3, 2006, the highest flows that steelhead trout embryos would have experienced while in redds equaled 1,630 cfs. Flows less than about 5,000 cfs are not expected to mobilize streambed gravels (or redds) (Klein pers. comm. 2003); and in YR 2003, we captured 102,954 0+ steelhead trout that had been in redds when flows reached 3,500 cfs.

A change in the percentage of total juvenile steelhead production in upper Redwood Creek that migrates downstream may account for some of the decrease in catches we observed in YR 2006. 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 2007. However, during late July, 2006 we observed numerous dead 0+ steelhead trout in the stream due to prolonged, lethal stream temperatures (see discussion on stream temperature). Various residents in Redwood Valley also observed dead fish floating downstream in areas upstream and downstream of the trap site during this same time period. Depending upon the extent of the fish kill, fewer 1+ steelhead trout are expected to reach age 1 in YR 2007.

Young-of-year steelhead trout were caught in low numbers (< 65 individuals) from 3/30 – 5/09/06. Thereafter daily catches were generally greater than 40 per day until the end of the trapping period, when less than 20 individuals per day were captured. The average daily catch over the entire trapping period equaled 348. The monthly pattern in downstream migration in YR 2006 was similar to the previous six year average in that catches (and migration) increased until June (peak month) and then decreased to the end of the study period. However, in YR 2006 the majority of catches occurred during May and June (76%) compared to June and July (69%) for the previous six year average. The largest decrease in monthly catches in YR 2006 (compared to the average) occurred in July. Trap catches in July 2006 (n = 11,706) were 60% (or 17,329 individuals) less than the previous six year average catch for July. Trap catches in August 2006 were also much lower (93%) than the average for that month.

The average FL in YR 2006 was the lowest of the current seven study years, and was probably influenced by the high percentage (70%) of fry (FL < 40 mm) in the trap's catch. 0+ steelhead trout fry were captured in each week during the study period, and the mode in FL for all measured 0+ steelhead trout in YR 2006 was 30 mm (size of emergent fry). The average 0+ steelhead trout FL did not significantly change over study years, thus the differences in FL among study years were slight. The lower than expected average FL in YR 2006 changed a significant density-dependent relationship with the number of captured migrants to become non-significant. If there really is a density-dependent relationship, then data from additional study years should provide statistical significance. If watershed restoration activities are successful, and the condition of the watershed improves, then we should see a larger average size of 0+ steelhead trout migrants over time.

Average weekly FL in YR 2006 followed the same pattern over time with the previous six year average of being stable for the first weeks and then gradually increasing to the end of the study period. Unlike the six year average, weekly FL's in YR 2006 were nearly the same for the first nine weeks of trap operation due to emergent fry (FL < 32 mm) dominating the trap's catch. As more and more 0+ steelhead trout parr moved downstream and were captured by the trap, the average weekly FL increased.

During periods of high stream temperatures (eg July and August) we frequently observed young-of-year steelhead trout in upper Redwood Creek utilizing stream areas influenced by groundwater seeps in very high numbers relative to those seen in non-influenced seep areas. However, in YR 2006 (and YR 2005) high stream flows deposited large amounts of sands and small gravels that completely covered the groundwater seeps with the result that very few juvenile steelhead trout were observed in these areas. In addition, the seeps no longer decreased the stream temperature as in previous years. Thus, groundwater influenced refugia areas are not permanent, and can be affected by sedimentation of the streambed and margin areas of the stream.

I doubt that a large majority of the 0+ steelhead population that out-migrates prior to late summer low-flow periods can be viewed as surplus or lost production, which will not augment future adult steelhead populations. Meehan and Bjornn (1991) state that some steelhead populations normally out-migrate soon after emergence from redds to occupy other rearing areas, and I believe we observe this in Redwood Creek as well. Our experiments of marked 0+ steelhead trout released at the upper trap and recaptured 29 miles downstream offers direct evidence that 0+ steelhead trout may travel considerable distances in search of suitable rearing areas. 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 – 2005 ranged from 26,176 – 68,030 and averaged 40,831 individuals. Population emigration in YR 2006 (N = 26,248) was the second lowest of all study years, and 36% less than emigration for the previous six year average. The population of 1+ steelhead trout declined over the seven study years. Linear correlation detected a significant negative trend in 1+ steelhead trout population size over time ($p < 0.05$), which indicates that fewer 1+ steelhead trout were emigrating each year compared to previous years. Thus, our smolt trapping efforts were able to detect a negative trend in 1+ steelhead trout smolt population emigration within seven study 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) ($n = 4$) (Sparkman 2006). 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. However, with data from an additional study year added (2005), the model failed to accurately estimate the population emigrating in YR 2006, and the modeled relationship became non-significant.

The average size of 1+ steelhead trout in YR 2006 (FL = 85.7 mm, Wt = 7.48 g) was the second lowest of the current seven study years. The general trend in FL over study years was significantly negative, however, for Wt no significant differences were detected. The weekly FL and Wt in YR 2006 and for the previous six year average did not significantly change over time. The average weekly FL in YR 2006 was also not significantly different than the average weekly FL for the previous six year average, however, average weekly Wt in YR 2006 was significantly less than the previous six year average ($p < 0.05$). The FL of 1+ steelhead trout over the seven study years was positively related to the population size; with a higher population, we observed a greater FL. This is in contrast to the normal viewpoint of density-dependent relationships in which higher fish densities result in smaller fish sizes. The regression indicates that if stream conditions were favorable for survival, they were also favorable for growth.

Information in the literature indicates that steelhead smolting at age 1 is not uncommon, particularly in streams that are south of British Columbia (Busby et al. 1996, Quinn 2005). The percentage of 1+ steelhead trout migrants showing smolt characteristics in YR 2006 (80%) was significantly higher than the percentage for the previous six year average. These differences are likely to be real because between-observer variation was minimized in three different ways: 1) each crew member used the same protocol, 2) each crew member was thoroughly trained and tested, and 3) some of the crew members had worked on this study for the previous four years. Regressions of 1+ steelhead trout population size or average FL or Wt on the percentage of 1+ steelhead trout showing smolt characteristics each year were non-significant (similar to data in YR 2005); thus for the data tested ($n = 7$), abundance and fish size did not have any influence on the seasonal percentage of smolt designations. However, average stream flow and stream temperature during each study period influenced the percentage of 1+ steelhead trout showing smolt characteristics over the seven study years. During trapping periods with higher average flows, more of the 1+ steelhead trout were in a smolt stage, and with colder temperatures, more of the steelhead trout were also in a smolt stage. Quinn (2005) reported that stream temperatures play an important role in smoltification.

1+ steelhead trout are actively emigrating from upper Redwood Creek because the lower trap in Redwood Creek (RM 4) has consistently captured efficiency trial fish, elastomer marked fish (study years 2001, 2004, and 2005), and pit tagged fish (YRS 2005 and 2006) released from the upper trap site. In addition, 1+ steelhead trout from upper Redwood Creek have been observed in the estuary of Redwood Creek every year since the beginning of this study (Dave Anderson, pers. comm. 2006). We have not observed re-migration of 1+ steelhead trout into upper Redwood Creek based upon elastomer marked releases in YR 2001 (n = 374), YR 2004 (n = 577), and YR 2005 (n = 146); and pit tagged releases in YRS 2005 (n = 46). Each 2+ steelhead trout captured by the trap was inspected for marks and scanned for pit tags, which were applied at age-1. These tests confirmed that the elastomer marked and pit tagged fish did not migrate back upstream to rear for another year and emigrate as 2 year-old steelhead trout smolts. Elastomer mark retention was assumed to be adequate for the studies because Fitzgerald et al. (2004) assessed elastomer mark retention in Atlantic salmon smolts and found that tag retention in the lower jaw was greater than 90% for the first 16 months. Pit tag retention was also assumed to be adequate based upon a study by Newby et al. (2007).

The lower trap in Redwood Creek captured 2.4% of the pit tagged 1+ steelhead trout released at the upper trap in Redwood Valley. The time required to travel 29 miles downstream in YR 2006 ranged from 2.5 – 57.5 d, and averaged 21 d. Average travel time in YR 2006 was much greater than the average travel time in YR 2005 (n = 5, Avg. = 12 d) and YR 2004 (n = 9, Avg. = 15 d). Similar to data on 0+ Chinook salmon in YR 2006, 1+ steelhead trout travel time was not related to: 1) the size of the migrant at time 1 or time 2, 2) stream temperature, 3) stream discharge, or 4) lunar phase. Travel rate (mi/d) in YR 2006 ranged from 0.5 – 11.6 mi/d, and averaged 3.9 mi/d. Travel rate was positively related, albeit weakly, to the size of the fish at time 1. Models with average water temperature or lunar phase during the migratory period explained far more of the variation (69 and 71%) in travel rate compared to fish size; travel rate was positively related to water temperature and negatively related to lunar phase. The positive relationship between travel rate and water temperature may indicate that 1+ steelhead trout were emigrating from upper Redwood Creek at a faster rate because higher stream temperatures were not as favorable for rearing or growth compared to migration during periods of colder stream temperatures.

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 - 2005 ranged from 4:1 to 14:1 and averaged 9:1; in YR 2006 the ratio was 14:1. 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; B. Chesney pers. comm. 2006, among many others). Based upon studies in other streams, the number of returning adult steelhead trout that went to the ocean as one-year-old smolts is relatively low, and usually less than 23% (Pautzke and Meigs 1941; Maher and Larkin 1955; Busby et al. 1996, McCubbing 2002). Based upon a limited number of scale samples (n = 10) from adult steelhead trout in Redwood Creek, 30% of the adults entered the ocean as one-year-old juveniles. The percentage of adult steelhead trout that smolt and enter the ocean at age-1, and the reason(s) for the relative large number of 1+ steelhead trout emigrating from upper Redwood Creek and from the basin of Redwood Creek (Sparkman, 2007b, study 2i3) warrants further investigation.

2+ Steelhead Trout

In several studies investigating steelhead life histories, the majority of the returning adult steelhead spent two or more years as juveniles in freshwater prior to ocean entry (Pautzke and Meigs 1941; Maher and Larkin 1955; Busby et al. 1996, Smith and Ward 2000; McCubbing 2002). For example, Pautzke and Meigs (1941) reported that 84% of returning adult steelhead in the Green River had spent two or more years as juveniles in freshwater. Maher and Larkin (1955) found that 98% of the adult steelhead they examined had spent two or more years in freshwater prior to entering the ocean, and McCubbing (2002) reported 92% of steelhead adults in a British Columbia stream had spent two or more years as juveniles in freshwater. If this applies to steelhead trout in Redwood Creek, then 2+ steelhead trout are the most important (and most direct) group of juvenile steelhead trout that contribute to future adult steelhead trout populations. The paradox for the 2+ steelhead trout smolt is that it is the least numerous juvenile steelhead trout that emigrates from upper Redwood Creek. For example, in YR 2006 the ratio of 0+ steelhead trout to 2+ steelhead trout equaled 26:1, and the ratio of 1+ steelhead trout to 2+ steelhead trout equaled 14:1.

2+ steelhead trout population emigration during 2000 – 2005 ranged from 2,364 – 12,668, and averaged 5,949 individuals. Population emigration in YR 2006 (N = 1,866) was the lowest in seven consecutive years, and 69% less than the average emigration over the previous six years. The pattern or trend in population size over the seven study years was negative, yet non-significant.

The pattern of population emigration in YR 2006 was different than for the previous six year average. The most important month for 2+ steelhead trout emigration in YR 2006 was May compared to April for the six year average. April and May accounted for 84% of the total population emigration in YR 2006 compared to 66% for the six year average. The greatest reduction in emigration in YR 2006 occurred in April (64% reduction), however, emigration in each month was much less than for the previous six year average. Weekly population emigration in YR 2006 was positively related to gage height (R^2 = 0.43) and stream discharge (R^2 = 0.62); and negatively related to average stream temperature(R^2 = 0.50) and week number (r = 0.68). Thus, more 2+ steelhead trout emigrated earlier in the trapping season when stream discharge was higher and stream temperatures were cooler compared to later in the season. These relationships are fairly typical for 2+ steelhead trout population emigration from upper Redwood Creek, and suggest 2+ steelhead trout have adapted to lower stream flows and higher water temperatures by emigrating at a higher percentage of the total prior to these conditions.

The average size of 2+ steelhead trout in YR 2006 (FL = 160 mm, Wt = 45 g) was the second highest of seven study years; however, the average size over study years did not significantly change. Unlike 1+ steelhead trout, the FL (and Wt) of 2+ steelhead trout over the seven study years was not related to emigrant population size. The pattern in weekly FL and Wt in YR 2006 was similar to the pattern for the previous six year average; highest values occurred during the first six weeks of trapping, and the lowest valued occurred during the mid point of the trapping period. For the remaining weeks, the size of 2+ steelhead trout emigrants gradually increased to the end of the study period. Both weekly FL and Wt in YR 2006 (and for the previous six year average) significantly decreased over time (weeks). The decrease in average FL and Wt by week during study year 2006 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 2006 (99%) was the same as YR 2005 (99%), and about 19 percentage points greater than the previous six year average. Smolt percentages in a given year were negatively related to 2+ steelhead trout population size, negatively related to stream temperature, and positively related to stream discharge. Thus, there were less smolt designations for higher population abundances and during study periods with higher stream temperatures. In contrast, there were more smolt designations during study years with a higher stream discharge. Quinn (2005) reported that stream temperatures play an important role in smoltification, and our data shows that 58% of the variation in smolt percentages over seven study years can be attributed to the variation in stream temperature. Average fish size (FL, Wt) by year had no influence on the percentage of 2+ steelhead trout showing smolt characteristics.

2+ steelhead trout are actively emigrating from upper Redwood Creek because the lower trap in Redwood Creek (RM 4) has consistently captured efficiency trial fish and elastomer marked fish released from the upper trap. In addition, 2+ steelhead trout from upper Redwood Creek have been observed in the estuary of Redwood Creek every year since the beginning of this study (Dave Anderson, pers. comm. 2006). We have not observed re-migration of 2+ steelhead trout into upper Redwood Creek based upon elastomer marked releases of 2+ steelhead trout in YRS 2001, 2004, and 2005; and pit tagged releases in YRS 2004 and 2005. These tests confirmed that the elastomer marked fish or pit tagged 2+ steelhead trout did not migrate back upstream to rear for another year and emigrate as 3 year-old steelhead trout smolts. The very low number of 3+ steelhead trout smolts (expanded) observed in the previous six years of study (0.44% of 2+ steelhead trout population) and in YR 2006 (1.5% of total population) provides more evidence that the 2+ steelhead trout are migrating to the ocean, and not just re-distributing in the stream to eventually over-winter a third season.

Although there seems to be few studies that specifically look at steelhead smolt to adult survival, steelhead life history studies in a British Columbia stream (Keogh River) show there is a positive linear relationship between out-migrating 2+ smolts and returning adult steelhead (Ward and Slaney 1988; Ward 2000, Ward et al. 2002). Ward (2000) cites other authors who report similar positive linear relationships between smolts and adults along the British Columbia coast as well (eg Smith and Ward 2000). Survival from smolt to adult can be variable, and may range from an average of 15% (during 1976-1989) to an average 3.5% (during 1990-1995) (Ward 2000). Ward and Slaney (1988), reporting on data from the Keogh River for 1978 – 1982 cohorts, determined survival from smolt to adult ranged from 7% to 26%, and averaged 16%. Meehan and Bjornn (1991) reported steelhead smolt to returning adult survival can be a relative high ranging from 10 – 20% in streams that are coastal to a low survival of 2% in streams where steelhead must overcome dams and travel long distances to reach spawning grounds. It is difficult to make specific inferences about 2+ steelhead smolt to adult survival for upper Redwood Creek steelhead based upon successful studies in the literature because of differences in latitude/longitude, geography, ocean conditions (physical and biological), estuaries, and trap locations in the watershed. However, the belief that the number of 2+ smolts 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 trout is unavailable or un-attainable. 2+ steelhead trout have overcome the numerous components of stream survival that younger steelhead (0+ and 1+) have not yet completely faced (over-summer, over-winter, etc), and 2+ steelhead smolts are the most direct recruit to adult steelhead populations. The 2+ steelhead trout are also an excellent indicator of watershed and stream conditions because they spend the longest amount of time in freshwater habitat. Along these same lines, Ward et al. (2003) reported that the 2+ steelhead smolt was a more reliable response variable with respect to stream restoration than late summer juvenile densities because of being less variable.

0+ Pink Salmon

Pink salmon in California are recognized as a “Species of Special Concern”, and California is recognized as the most southern border for the species (CDFG 1995). Although not in large numbers, pink salmon have been historically observed in the San Lorenzo River, Sacramento River and tributaries, Klamath River, Garcia River, Ten Mile River, Lagunitas River, Russian River, American River, Mad River, and once in Prairie Creek, which is tributary to Redwood Creek at RM 3.7. Pink salmon were observed spawning in the Garcia River in 1937, and the Russian River in 1955 (CDFG 1995). More recently, adult pink salmon were seen spawning in the Garcia River in 2003 (Scott Monday pers. comm. 2004) and in Lost Man Creek (tributary to Prairie Creek) in 2004 (Baker Holden, pers. comm. 2005).

I know of no historic records or anecdotal information documenting pink salmon presence in Redwood Creek prior to our downstream migration trapping efforts. The pink salmon in Redwood Creek are in very low numbers, and prior to study year 2005, were only caught in even numbered years (e.g. YR 2000, YR 2002, and YR 2004). The two individuals caught in YR 2005 may indicate that pink salmon are now spawning upstream of the trap site in even and odd numbered years; however, no pink salmon were captured in YR 2006.

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 seven consecutive study years. We look at every individual fish we catch (total catch over seven years = 1.37 million juvenile salmonids); 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, currently supports coho salmon (Bill Jong, pers. comm. 2003; CDFG 1953); and Prairie Creek (tributary to Redwood Creek at about RM 3.7) supports a fairly stable population of coho salmon. 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. (2006) report that stream temperatures upstream of the trap site are probably too high for successful juvenile coho salmon rearing. Our stream temperature data collected at the trap site during the trapping period 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 seven study years (< 9 individuals each year, total = 27), and only three individuals were captured in YR 2006. All cutthroat trout that were captured were in a smolt stage. An unknown number or percentage of cutthroat trout will residualize in the stream for varying years, and not out-migrate to the estuary and ocean; thus the low trap catches may not necessarily reflect a low population size in upper Redwood Creek. However, if there were large numbers present, we would probably catch much more than we do, as they re-distribute or migrate downstream. For example, juvenile salmonid trapping efforts in Prairie Creek consistently capture cutthroat trout during spring/early summer as they migrate downstream (Roelofs and Klatte 1996; Roelofs and Sparkman 1999, Walt Duffy, pers. comm. 2006).

We did not consider any of the young-of-year steelhead trout to be progeny of cutthroat trout because few aged 1 and older cutthroat trout were captured in any given year (average 4 per year). Upper Redwood Creek has far more older juvenile steelhead trout (1+ and 2+) than cutthroat trout as evidenced by trap catches. In the seven study years, the ratio of 1+ and 2+ steelhead trout combined catches to cutthroat trout catches each year ranged from 1,534:1 to 7,881:1, and using data from all years (pooled) equaled 2,876:1. The ratio in YR 2006 was 1,200:1. Ratios would be even higher if juvenile steelhead trout population data were used instead of catch data. It seems very unlikely that low numbers of cutthroat trout could produce a significant portion of the juvenile trout captures. Therefore, we considered the percentage of 0+ cutthroat trout included in the 0+ steelhead trout catch to be low and negligible.

We used three characteristics to identify coastal cutthroat trout: upper maxillary that extends past the posterior portion of the eye, slash marks on the lower jaws, and hyoid teeth; spotting is also usually more abundant on coastal cutthroat trout. Hybrid juveniles, the product of mating between steelhead trout and cutthroat trout, are commonly noted to be missing one or two of these characters. We have observed less than four individuals in the seven years that could have been hybrid juveniles. Thus, out of 77,664 1+ and 2+ steelhead trout catches, only 0.005% appeared to show hybrid characteristics. Based upon visual identification, the number of potential hybrids (age 1 and greater) is extremely rare in upper Redwood Creek.

Stream Temperatures

Similar to past study years, average daily stream temperature in YR 2006: 1) significantly increased over the study period, 2) was negatively related to stream discharge, and 3) was negatively related to stream gage height. The large influence of stream gage height (or stream discharge) on stream temperatures in Redwood Valley was evidenced by a R^2 of 0.85, which indicates that 85% of variation in temperature can be explained by the variation in gage height over time.

The average stream temperature (truncated to 8/5, Avg. = 14.9 ^{o}C) during the trapping period in YR 2006 was the third lowest of the six consecutive years of temperature data, and slightly below the previous five year average. Average monthly stream temperatures in YR 2006 ranged from 8.7 – 21.1 ^{o}C (47.7 – 70.0 ^{o}F) and were not statistically different than previous study years. The maximum stream temperature recorded in YR 2006 (29.5 ^{o}C, or 85.1 ^{o}F) was the highest on record, and occurred on 7/24/06. MWAT (24.1 ^{o}C or 75.4 ^{o}F) in YR 2006 was also the highest on record, and occurred on July 25th.

For the first time in seven consecutive trapping years, we observed numerous dead juvenile salmonids at the trapping site and areas nearby the trapping site from July 23rd – July 25th. Numerous residents in Redwood Valley both above and below the trap site also witnessed dead fish floating by in the stream, or on the stream bottom. Although most of the fish killed were 0+ steelhead trout, several older juvenile steelhead trout age classes and various amphibians were also killed (pacific giant salamander and yellow-legged frog). The average daily stream temperature was 24.8 ^{o}C (76.6 ^{o}F) on July 23rd, 25.4 ^{o}C or (77.7 ^{o}F) on July 24, and 25.3 ^{o}C (77.5 ^{o}F) on July 25th. Prior to YR 2006, the highest average daily stream temperature during YRS 2001 – 2005 ranged from 22.4 – 23.8 ^{o}C (72.3 – 74.8 ^{o}F).

On July 25th, the delayed mortality experiment on 0+ steelhead trout held from 1100 – 1700 in a live car in the stream showed that only 36% survived the six hour test. The stream temperature during the experiment peaked at 28.8 ^{o}C (83.8 ^{o}F), however, temperatures from 1400 – 1700 were also just above 28 ^{o}C (82.4 ^{o}F). The dissolved oxygen concentration (8 – 10 mg/l) in the stream during this time period was favorable for juvenile salmonid survival; therefore, lethal stream temperatures during the afternoon were most likely responsible for the juvenile fish kill.

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 2006. The migration of 0+ Chinook salmon 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. For example, 44,636 (or 92% of total catch) 0+ steelhead trout passed the trap site prior to when stream temperatures reached lethal levels on July 23, 2006. Migration during and after the period of high stream temperatures dropped considerably, and accounted for only 4,123 (or 8%) of the total 0+ steelhead trout catch.

CONCLUSIONS

The migration of juvenile salmonids from upper Redwood Creek in YR 2006 was the second lowest of the seven current study years for 0+ Chinook salmon and 1+ steelhead trout; and the lowest for 2+ steelhead trout. Compared to the previous six year average, 0+ Chinook salmon experienced the greatest reduction (92%) in population size, which could be attributable to high winter flows which either scoured or jostled redd gravels in late December. 1+ steelhead trout population emigration in YR 2006 was 36% less than the previous six year average, and 2+ steelhead trout in YR 2006 was 69% less than the six year average. All juvenile salmonids showed a negative trend over the seven study years; yet statistical significance was only found for 1+ steelhead trout. However, due to the steepness of the decline (slope of regression line) for each species at age, population data collected thus far over the seven consecutive years does not currently support de-listing Chinook salmon or steelhead trout in Redwood Creek from the Federal Endangered Species Act.

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

The population of 0+ Chinook salmon emigrants in YR 2006 consisted of both fry and fingerlings, with more fingerlings emigrating than fry. The two noticeable peaks in 0+ Chinook salmon migration (separated by about nine weeks) do not indicate two distinct runs of adult Chinook salmon spawned in upper Redwood Creek because of vast differences in the average size of migrants in each peak. The larger migrants associated with the second peak could have been fry born at the same time as the fry that made up the first peak that reared for a longer time in the stream prior to capture. No relationships between the percentage of fry and population size, stream temperature, or stream discharge were detected, thus the mechanism for fry dispersal could be genetic.

The size of emigrating juvenile Chinook salmon and 1+ steelhead trout in YR 2006 was less than the average size for YR 2005 and the previous five year (0+ Chinook) and six year (1+ steelhead trout) average. The average size of 0+ steelhead trout in YR 2006 was the smallest of record, and for 2+ steelhead trout, the average size in YR 2006 was the second highest of record. A density-dependent relationship of emigrant numbers and size was detected for 0+ Chinook salmon over the seven 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 0+ or 2+ steelhead trout.

Twenty-eight pit tagged 0+ Chinook salmon fingerlings and six 1+ steelhead trout from upper Redwood Creek were recaptured 29 miles downstream at the second trap in lower Redwood Creek. Travel time for 0+ Chinook salmon ranged from 2.5 – 20.5 d, and averaged 8.0 d. Travel rate ranged from 1.4 – 11.6 mi/d, and averaged 5.5 mi/d. Travel rate was positively related to FL at time 1 and negatively related to the average lunar phase during the migratory period. 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 14.5 days. Travel time for 1+ steelhead trout ranged from 2.5 – 57.5 d, and averaged 20.8 d; travel rate ranged from 0.5 – 11.6 mi/d, and averaged 3.9 mi/d. The travel rate for 1+ steelhead trout was positively related to size (FL, WT) at time 1 and average water temperature, and negatively related to lunar phase. The single variable model with Wt (g) at time 1 explained more of the variation (76%) than other variables tested. Marked 0+ steelhead trout released at the upper trap were also captured at the lower trap, which indicates that 0+ steelhead trout can migrate considerable distances in search of rearing areas. This experiment could be the first one to document long range dispersal of young of year steelhead trout from spawning areas.

Fifty-seven percent of the downstream migrating pit tagged 0+ Chinook salmon showed positive growth in FL and 61% showed positive growth in Wt; 12 fish showed no change in FL and 11 showed no change in Wt. Growth was positively related to travel time, and travel time explained more of the variation (84%) in growth than any other variable tested. Various growth indices were also positively related, albeit weakly, to lunar phase. The average AGR in FL in YR 2006 equaled 0.24 mm/d, which was slightly higher than AGR in YR 2005 (Avg. = 0.22 mm/d). Based upon two years of data, the working hypothesis concerning 0+ Chinook salmon smolts and growth in Redwood Creek is that fish grow more when they: 1) take more time to migrate downstream, and 2) when the moon illumination is relatively higher during the migratory period. By taking more time to migrate the fish have more time to forage for food and convert the food to growth; and when migrating downstream at a slower rate during higher moon illuminations, they have more time and a better opportunity to successfully prey upon food items. Similar to YR 2005, the final size of recaptured pit tagged 0+ Chinook salmon in YR 2006 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.

Sixty-seven percent of the recaptured pit tagged 1+ steelhead trout showed positive growth in FL and Wt; two fish showed not change in FL, and two fish lost weight. On average, 1+ steelhead trout percent change in FL equaled 12.6% and AGR FL equaled 0.31 mm/d. Pit tagged 1+ steelhead trout exhibited the same relationships of travel time and travel rate on growth as pit tagged 0+ Chinook salmon; 1+ steelhead trout growth was positively related to travel time, and negatively related to travel rate. Similar to 0+ Chinook salmon, travel time or travel rate explained more of the variation in growth than other variables tested. However, the best model describing AGR in FL involved travel time and lunar phase, such that AGR was positively related to both variables. Various growth indices were also negatively related to average stream temperature.

Stream temperatures in late July reached lethal levels, and numerous juvenile steelhead trout were observed dead in the stream. A delayed mortality test showed only 36% of 0+ steelhead trout survived during one afternoon of high stream temperatures. Whether this is representative to the population at large is unknown; yet numerous residents in Redwood Valley also witnessed many dead juvenile salmonids. Lethal stream temperatures occurred during average daily temperatures of 24.8 ^{o}C (76.6 ^{o}F) and higher; and when maximum stream temperatures (in the afternoon) during the fish kill were greater than 28.7 ^{o}C (83.7 ^{o}F). The highest recorded stream temperature in YR 2006 equaled 29.5 ^{o}C (85.1 ^{o}F), and unlike other study years, maximum stream temperatures lasted for more than 3 consecutive hours. Both MWAT and the daily maximum stream temperature in YR 2006 were the highest of record, and may prove as a useful indicator of lethal stream temperatures.

RECOMMENDATIONS

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

The most important recommendation to make is to continue this study over multiple consecutive years (10+) in order to:

1. Collect baseline data for future comparisons.

2. Continue to collect data on juvenile salmonid life histories in upper Redwood Creek.

3. 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.

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

5. 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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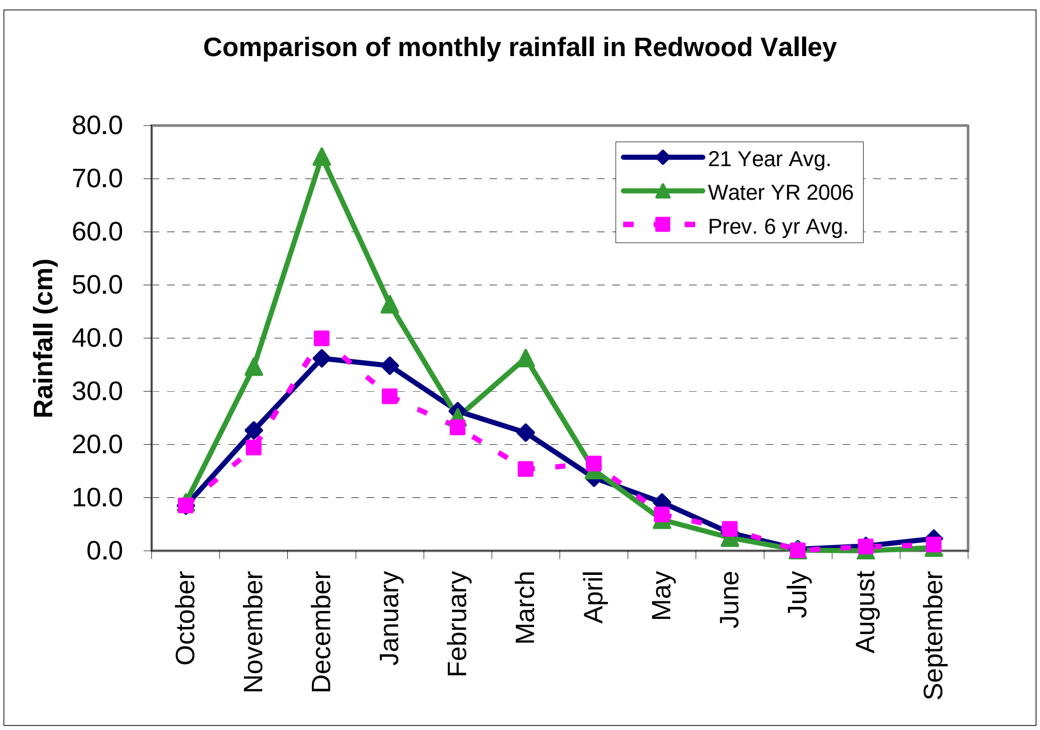
APPENDICES

Appendix 1. Comparison of 21 year average annual rainfall with average of previous six water years (2000 - 2005) and water year 2006 at Hinz family residence, Redwood Valley, Redwood Creek, Humboldt County, California.

Month	Annual Rainfall* (centimeters) Historic Average	Average of previous 6 water years (2000-05)	Water Year 2006
Oct.	8.5	8.5	9.1
Nov.	22.6	19.4	34.6
Dec.	36.2	39.9	74.1
Jan.	34.8	29.1	46.4
Feb.	26.3	23.2	25.1
Mar.	22.2	15.4	36.3
Apr.	13.8	16.4	15.2
May	9.1	6.8	5.8
June	3.4	4.1	2.5
July	0.3	0.0	0.1
Aug.	0.9	0.8	0.0
Sept.	2.3	1.2	0.6
Total:	180.4	164.8	249.9

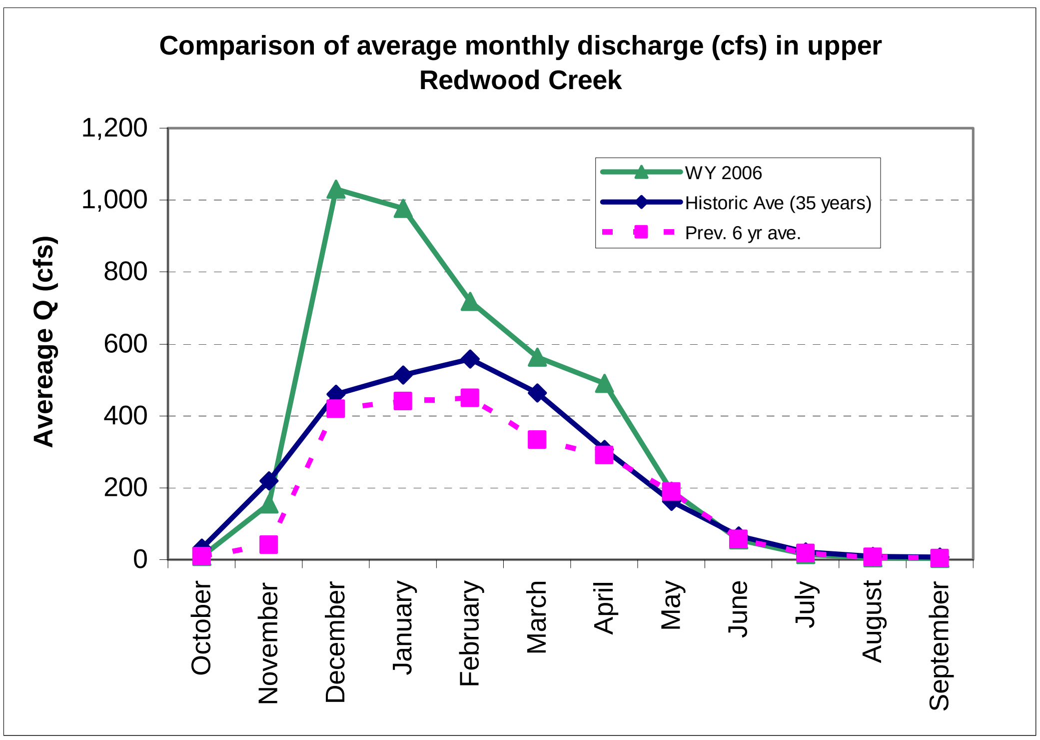
* Data courtesy of Redwood National Park, Vicki Ozaki pers. comm. 2006.



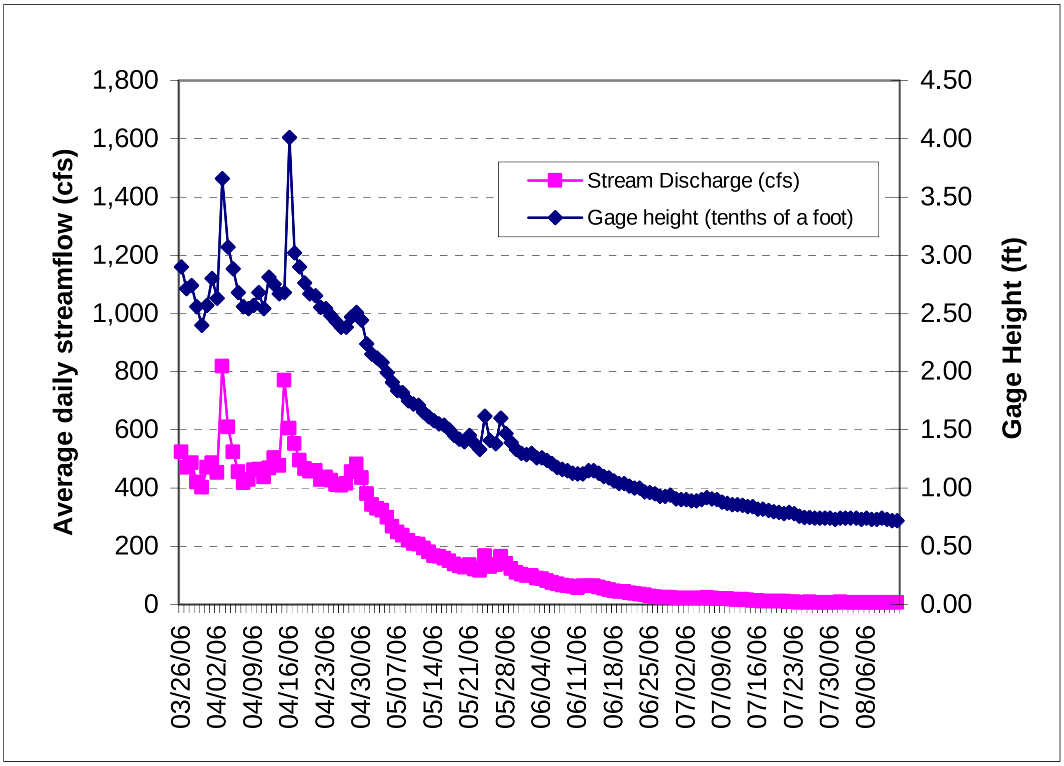
Appendix 2. Comparison of 35 year average monthly discharge (cfs) with average of previous six water years and water year 2006, O'Kane gaging station, upper Redwood Creek, Humboldt County, CA. (USGS 2006).

	Annual Discharge* (cfs)		
Month	Historic Average	Average of previous 6 water years (2000-05)	Water Year 2006
Oct.	33	9	10
Nov.	220	41	156
Dec.	461	420	1030
Jan.	513	441	977
Feb.	558	450	719
Mar.	463	333	563
Apr.	307	291	491
May	163	189	191
June	67	57	55
July	21	18	14
Aug.	9	6	5
Sept.	8	4	3
Ave:	235	188	351

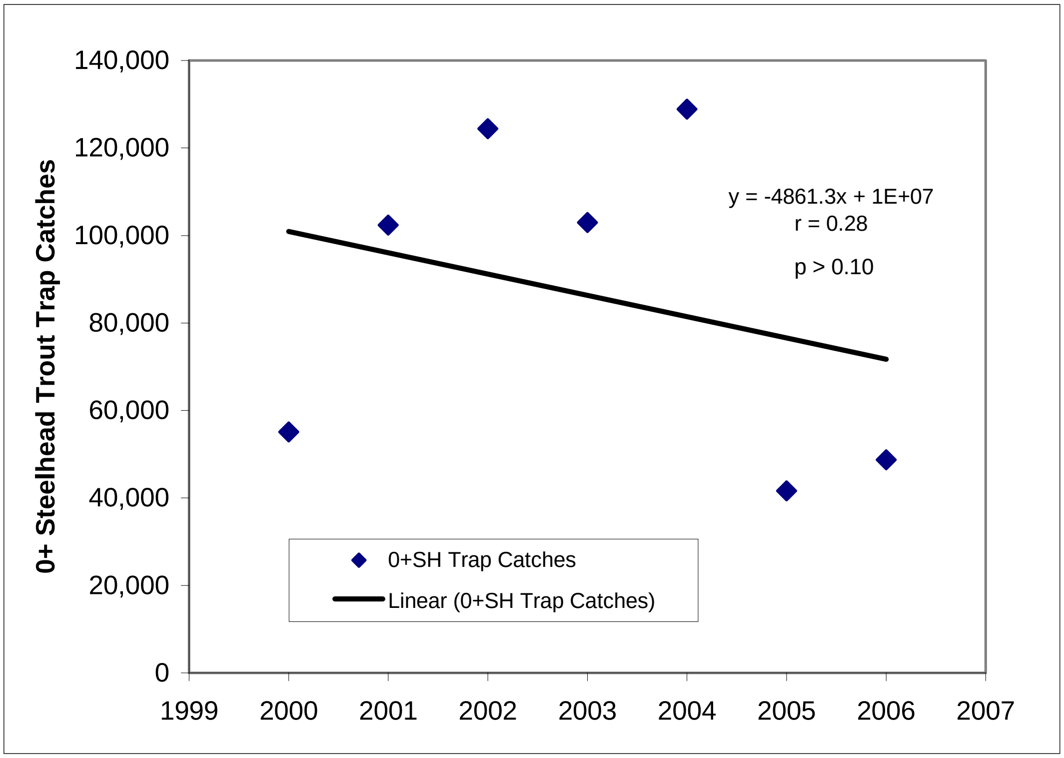
* Data courtesy of Chris O’Neil, pers. comm. 2006

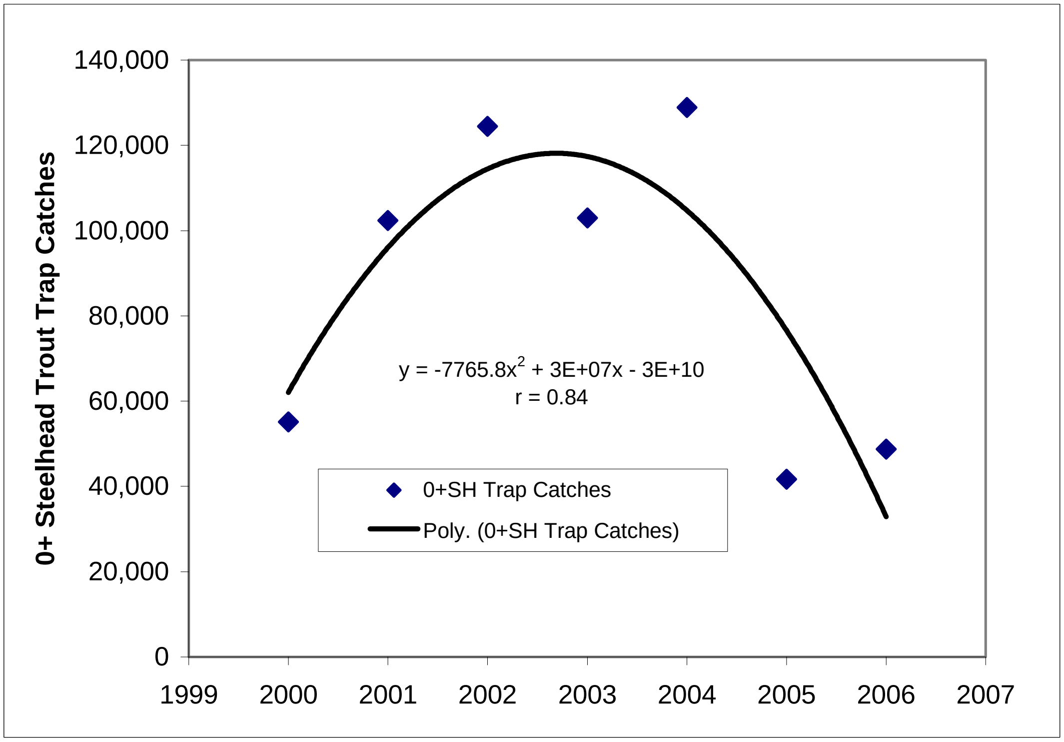


Appendix 3. Graphical representation of daily stream gage height (ft.) at trap site and average daily stream flow (cfs) measured at O'Kane gaging station (USGS 2006), upper Redwood Creek, Humboldt County, CA.



Appendix 4. Linear (top graph) and polynomial (bottom graph) trend lines for 0+ steelhead trout trap catches over seven study years, upper Redwood Creek, Humboldt County, CA.





Appendix 5. Regression and correlation results for tests of average weekly gage height (ft), stream discharge (cfs), stream temperature (^oC), and time (week number) on weekly 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 weekly catches, upper Redwood Creek, Humboldt County, CA., 2006.

Weekly Values		Regression Results			
Y variable (Catches)	X variable	p value	R^2 or r*	Slope Sign	Power of test
All spp.	Gage height	*0.047*	0.20	Negative	0.52
All spp.	Discharge	*0.02*	0.25	Negative	0.65
All spp.	Temperature	0.21	0.09	Positive	0.24
All spp.	Week number	0.31	0.06	Positive	0.17
0+ KS**	Gage height	0.06	0.18	Positive	0.47
0+ KS**	Discharge	0.13	0.12	Positive	0.33
0+ KS**	Temperature	*0.01*	0.30	Negative	0.76
0+ KS**	Week number	*0.003*	0.62*	Negative	0.89
0+ KS**	Trap efficiency	0.60	0.00	Positive	0.08
0+ SH	Gage height	*0.02*	0.25	Negative	0.63
0+ SH	Discharge	*0.01*	0.30	Negative	0.75
0+ SH	Temperature	0.12	0.13	Positive	0.33
0+SH	Week number	0.20	0.30*	Positive	0.24
1+ SH	Gage height	0.60	0.02	Positive	0.08
1+ SH	Discharge	0.77	0.00	Positive	0.06
1+ SH	Temperature	0.13	0.12	Negative	0.32
1+ SH	Week number	0.14	0.33*	Negative	0.31
1+ SH	Trap efficiency	0.30	0.08	Negative	0.17
2+ SH	Gage height	*0.0006*	0.49	Positive	0.97
2+ SH	Discharge	*0.0007*	0.48	Positive	0.80
2+ SH**	Temperature	*0.000001*	0.76	Negative	1.00
2+ SH**	Week number**	*0.0005*	0.71*	Negative	0.98
2+ SH**	Trap efficiency	0.36	0.08	Positive	0.14

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

Appendix 6. Regression and correlation results for tests of average weekly gage height (ft), stream discharge (cfs), and stream temperature (^{o}C) on weekly population emigration of 0+ Chinook salmon, 1+ steelhead trout, and 2+ steelhead trout in YR 2006, upper Redwood Creek, Humboldt County, CA.

Weekly Values		Regression Results			
Y variable (Population)	X variable	p value	R^2 or r*	Slope Sign	Power of test
0+ KS**	Gage height	*0.005*	0.36	Positive	0.85
0+ KS**	Discharge	*0.014*	0.29	Positive	0.73
0+ KS**	Temperature	*0.0007*	0.25	Negative	0.97
0+ KS**	Week number*	*0.0001*	0.76	Negative	1.00
1+ SH**	Gage height	Test assumptions not met, test not reliable			
1+ SH**	Discharge	0.08	0.16	Positive	0.43
1+ SH	Temperature	Test assumptions not met, test not reliable			
1+ SH	Week number*	*0.017*	0.32	Negative	0.27
2+ SH**	Gage height**	*0.008*	0.43	Positive	0.82
2+ SH**	Discharge**	*0.0005*	0.62	Positive	0.99
2+ SH**	Temperature	*0.003*	0.50	Negative	0.92
2+ SH**	Week number*	*0.005*	0.68	Negative	0.88

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

Appendix 7. 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., 2006.

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	74	Pit Tag	6/10/06	6/15/06	4.5	6.4
0+ KS	70	Pit Tag	6/10/06	6/16/06	5.5	5.3
0+ KS	73	Pit Tag	6/10/06	6/17/06	6.5	4.5
0+ KS	77	Pit Tag	6/10/06	6/20/06	9.5	3.1
0+ KS	70	Pit Tag	6/10/06	6/25/06	14.5	2.0
0+ KS	71	Pit Tag	6/10/06	6/27/06	16.5	1.8
0+ KS	70	Pit Tag	6/10/06	6/29/06	18.5	1.6
0+ KS	69	Pit Tag	6/13/06	6/20/06	6.5	4.5
0+ KS	68	Pit Tag	6/13/06	6/25/06	11.5	2.5
0+ KS	74	Pit Tag	6/15/06	6/24/06	8.5	3.4
0+ KS	86	Pit Tag	6/18/06	6/21/06	2.5	11.6
0+ KS	76	Pit Tag	6/18/06	6/22/06	3.5	8.3
0+ KS	76	Pit Tag	6/18/06	6/23/06	4.5	6.4
0+ KS	72	Pit Tag	6/20/06	6/23/06	2.5	11.6
0+ KS	75	Pit Tag	6/20/06	6/24/06	3.5	8.3
0+ KS	72	Pit Tag	6/20/06	6/24/06	3.5	8.3
0+ KS	74	Pit Tag	6/20/06	6/24/06	3.5	8.3
0+ KS	71	Pit Tag	6/20/06	6/24/06	3.5	8.3
0+ KS	71	Pit Tag	6/20/06	6/24/06	3.5	8.3
0+ KS	71	Pit Tag	6/20/06	6/24/06	3.5	8.3
0+ KS	72	Pit Tag	6/20/06	6/29/06	8.5	3.4
0+ KS	78	Pit Tag	6/22/06	6/25/06	2.5	11.6
0+ KS	72	Pit Tag	6/22/06	7/02/06	9.5	3.1
0+ KS	75	Pit Tag	6/22/06	7/06/06	13.5	2.1
0+ KS	76	Pit Tag	7/01/06	7/08/06	6.5	4.5
0+ KS	78	Pit Tag	7/01/06	7/09/06	7.5	3.9
0+ KS	73	Pit Tag	7/01/06	7/21/06	19.5	1.5
0+ KS	72	Pit Tag	7/01/06	7/22/06	20.5	1.4
Ave:	73 (SD =3.6)				8.0 (SD = 5.5)	5.5 (SD = 3.3)

* Released at upper trap site (RM33) at night (2100).
** Recaptured at lower trap (RM4) by 0900.

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 = 28) at the lower trap in Redwood Creek in YR 2006, Humboldt County, CA.

	Descriptive Statistics			
Variable	Min.	Max.	Avg. (median)	SD**
Size at T1				
FL mm	68	86	73.4 (72.5)	3.6
Wt g	3.3	6.2	4.29 (4.10)	0.64
Size at T2				
FL mm	71	87	76.5 (76.5)	3.8
Wt g	3.5	6.5	4.71 (4.66)	0.73
% change in				
FL mm	0.00	12.68	3.87 (2.82)	4.31
Wt g	0.00	39.74	10.64 (6.71)	12.70
AGR*				
FL mm	0.00	0.74	0.24 (0.31)	0.234
Wt g	0.00	0.20	0.05 (0.04)	0.052
RGR*				
FL mm	0.000	0.010	0.003 (0.004)	0.003
Wt g	0.000	0.051	0.012 (0.010)	0.012
SGR*				
FL mm	0.000	0.920	0.323 (0.395)	0.310
Wt g	0.000	4.800	1.056 (0.905)	1.153

* Abbreviations are the same as in Table 24.
** SD = standard deviation of mean.

Appendix 9. Results of linear regressions using travel time (d), travel rate (mi/d), average water temperature (^{o}C), average stream discharge (cfs), and average lunar phase on various growth indices for pit tagged 0+ Chinook salmon recaptured at the lower trap in Redwood Creek, Humboldt County, CA., YR 2006.

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*	0.72	Negative	1.00
% Change FL	Water Temperature	0.94	0.00	Positive	0.05
% Change FL	Stream Discharge	0.88	0.00	Negative	0.05
% Change FL	Lunar Phase	*0.04*	0.15	Positive	0.54
% Change Wt	Travel Time	*0.000001*	0.60	Positive	1.00
% Change Wt	Lunar Phase	0.18	0.07	Positive	0.26
% Change Wt	Travel Rate	*0.0003*	0.39	Negative	0.98
% Change Wt	Water Temperature	Test assumptions not met, test not reliable.			
% Change Wt	Stream Discharge	Test assumptions not met, test not reliable.			
% Change Wt	Lunar Phase	Test assumptions not met, test not reliable.			
AGR FL	Travel Time	*0.00004*	0.48	Positive	1.00
AGR FL	Travel Rate	*0.000001*	0.72	Negative	1.00
AGR FL	Water Temperature	Test assumptions not met, test not reliable.			
AGR FL	Stream Discharge	Test assumptions not met, test not reliable.			
AGR FL	Lunar Phase	*0.003*	0.29	Positive	0.88
AGR Wt	Travel Time	Test assumptions not met, test not reliable.			
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.			
AGR Wt	Lunar Phase	Test assumptions not met, test not reliable.			
SGRsc FL	Travel Time	*0.00008*	0.46	Positive	0.99
SGRsc FL	Travel Rate	*0.000001*	0.69	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 FL	Lunar Phase	*0.003*	0.28	Positive	0.87
SGRsc Wt	Travel Time	*0.005*	0.39	Positive	0.97
SGRsc Wt**	Travel Rate	0.10	0.10	Negative	0.38
SGRsc Wt**	Water Temperature	0.54	0.01	Negative	0.09
SGRsc Wt**	Stream Discharge	0.36	0.03	Positive	0.15
SGRsc Wt	Lunar Phase	0.67	0.01	Positive	0.07
RGR FL	Travel Time	*0.00006*	0.47	Positive	1.00
RGR FL	Travel Rate	*0.000001*	0.68	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 FL	Lunar Phase	*0.005*	0.27	Positive	0.27
RGR Wt**	Travel Time	Test assumptions not met, test not reliable.			
RGR Wt**	Travel Rate	Test assumptions not met, test not reliable.			
RGR Wt**	Water Temperature	Test assumptions not met, test not reliable.			
RGR Wt**	Stream discharge	Test assumptions not met, test not reliable.			
RGR Wt**	Lunar Phase	Test assumptions not met, test not reliable.			

* Abbreviations are the same as in Table 24.

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

P values in italics indicates statistical significance for that test.

Appendix 10. 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 1+ steelhead trout recaptured (n = 6) at the lower trap in Redwood Creek in YR 2006, Humboldt County, CA.

	Descriptive Statistics			
Variable	Min.	Max.	Avg. (median)	SD**
Size at T1				
FL mm	67	107	87.3 (85.0)	14.7
Wt g	3.2	13.0	7.92 (6.60)	3.93
Size at T2				
FL mm	77	118	97.5 (96.5)	14.5
Wt g	4.9	17.8	10.24 (9.71)	4.50
% change in				
FL mm	0.00	42.17	12.6 (9.19)	16.0
Wt g	-9.6	196.8	10.64 (46.54)	78.4
AGR*				
FL mm	0.00	0.61	0.31 (0.32)	0.269
Wt g	-0.48	0.21	-0.05 (0.04)	0.257
RGR*				
FL mm	0.000	0.007	-0.004 (0.004)	0.003
Wt g	-0.038	0.034	-0.004 (0.010)	0.003
SGRsc*				
FL mm	0.000	0.690	0.350 (0.400)	0.298
Wt g	-4.036	1.892	-0.098 (0.905)	2.406

* Abbreviations are the same as in Table 24.

Appendix 11. Results of linear regressions using travel time (d), travel rate (mi/d), average water temperature (^{o}C), average stream discharge (cfs), and average lunar phase on various growth indices for pit tagged 1+ steelhead trout recaptured (n = 6) at the lower trap in Redwood Creek, Humboldt County, CA., YR 2006.

Variables		Regression Output (Results)			
Dependent (Y)*	Independent (X)	p value	Adj. or R2	Slope Sign	Power of test
% Change FL	Travel Time	*0.0002*	0.97	Positive	1.00
% Change FL	Travel Rate	0.1440	0.45	Negative	0.29
% Change FL	Water Temperature	0.211	0.36	Negative	0.21
% Change FL	Stream Discharge	0.313	0.25	Positive	0.15
% Change FL	Lunar Phase	0.35	0.22	Positive	0.13
% Change Wt	Travel Time	*0.0004*	0.97	Positive	1.00
% Change Wt	Travel Rate	0.19	0.38	Negative	0.23
% Change Wt	Lunar Phase	0.43	0.16	Positive	0.11
% Change Wt	Water Temperature	0.26	0.30	Negative	0.18
% Change Wt	Stream Discharge	0.35	0.22	Positive	0.13
AGR FL	Travel Time	*0.06*	0.63	Positive	0.52
AGR FL	Travel Rate	*0.03*	0.73	Negative	0.69
AGR FL	Water Temperature	0.11	0.50	Negative	0.34
AGR FL	Stream Discharge	0.33	0.23	Positive	0.14
AGR FL	Lunar Phase	*0.03*	0.72	Positive	0.67
AGR FL	Lun. Ph., Trav. time	*0.03*	0.84	Pos, Pos.	0.51
AGR Wt	Travel Time	*0.07*	0.60	Positive	0.46
AGR Wt	Travel Rate	*0.0004*	0.99	Negative	1.00
AGR Wt	Water Temperature	*0.06*	0.64	Negative	0.52
AGR Wt	Stream Discharge	0.20	0.38	Positive	0.22
AGR Wt	Lunar Phase	0.02	0.76	Positive	0.76
SGRsc FL	Travel Time	*0.09*	0.56	Positive	0.40
SGRsc FL	Travel Rate	*0.02*	0.77	Negative	0.77
SGRsc FL	Water Temperature	*0.07*	0.60	Negative	0.46
SGRsc FL	Stream Discharge	0.23	0.32	Positive	0.19
SGRsc FL	Lunar Phase	*0.02*	0.76	Positive	0.77
SGRsc Wt	Travel Time	*0.09*	0.55	Positive	0.40
SGRsc Wt	Travel Rate	*0.0002*	0.98	Negative	1.00
SGRsc Wt	Water Temperature	*0.04*	0.70	Negative	0.64
SGRsc Wt	Stream Discharge	0.14	0.45	Positive	0.29
SGRsc Wt	Lunar Phase	*0.02*	0.77	Positive	0.77
RGR FL	Travel Time	*0.05*	0.65	Positive	0.54
RGR FL	Travel Rate	*0.02*	0.76	Negative	0.76
RGR FL	Water Temperature	*0.07*	0.60	Negative	0.46
RGR FL	Stream Discharge	0.22	0.34	Positive	0.20
RGR FL	Lunar Phase	*0.04*	0.70	Positive	0.62
RGR Wt	Travel Time	*0.03*	0.72	Positive	0.67
RGR Wt	Travel Rate	*0.002*	0.93	Negative	1.00
RGR Wt	Water Temperature	*0.04*	0.68	Negative	0.60
RGR Wt	Stream discharge	0.15	0.44	Positive	0.28
RGR Wt	Lunar Phase	*0.04*	0.68	Positive	0.60

* Abbreviations are the same as in Table 24. *P values* in italics indicates statistical significance for that test.

Appendix 12. 0+ Chinook salmon delayed mortality test results, upper Redwood Creek, Humboldt County, CA., 2006.

Age / spp.	Date	(n)	Water Temp (C)	Fin Clipping (24 hr) Morts./ Total	Fin Clipping (24 hr) Percent Mortality	Handling (24 hr) Morts./ Total	Handling (24 hr) Percent Mortality	Pit Tagging (34 hr) Morts./ Total	Pit Tagging (34 hr) Percent Mortality
0+KS	3/30 – 3/31	10	7.5	0/10	0.00				
0+KS	4/04 - 4/05	21	7.6	0/21	0.00				
0+KS	4/13 – 4/14	18	9.6	0/18	0.00				
0+KS	4/14 – 4/15	16	8.8	0/16	0.00				
0+KS	4/22 – 4/23	23	10.1	0/23	0.00				
0+KS	4/25 – 4/26	10	10.0	0/10	0.00				
0+KS	4/28 – 4/29	10	11.4	0/10	0.00				
0+KS	5/04 – 5/05	3	11.6	0/3	0.00				
0+KS	5/06 – 5/07	5	11.0	0/5	0.00				
0+KS	5/31 – 6/01	38	13.2	0/38	0.00				
0+KS	6/07 – 6/08	5	16.6			0/5	0.00		
0+KS	6/08 – 6/09	5	16.3			0/5	0.00		
0+KS	6/09 – 6/10	22	16.9					0/22	0.00
0+KS	6/12 – 6/13	15	14.8					0/15	0.00
0+KS	6/14 – 6/15	13	15.0					0/13	0.00
0+KS	6/18 – 6/19	17	18.2					0/17	0.00
0+KS	6/20 – 6/21	18	18.3					0/18	0.00
0+KS	6/20 – 6/22	21	18.3					0/21	0.00
0+KS	6/29 – 6/30	4	21.0	0/4	0.00				
0+KS	6/30 – 7/01	12	21.5					0/12	0.00
0+KS	7/02 – 7/03	2	20.4			0/2	0.00		
0+KS	7/03 – 7/04	3	20.0					0/3	0.00

Appendix 13. 1+ steelhead trout delayed mortality test results, upper Redwood Creek, Humboldt County, CA., 2006.

				Fin Clipping (24 - 48 hr)		Handling (24 hr)		Pit Tagging (34 hr)	
Age/ spp.	Date	(n)	Average Water Temp (^{o}C)	Morts./ Total	Percent Mortality	Morts./ Total	Percent Mortality	Morts./ Total	Percent Mortality
1+SH	4/02-4/03	5	7.3	0/5	0.00				
1+SH	4/04-4/05	3	7.6	0/3	0.00				
1+SH	4/08-4/10	6	8.0	0/6	0.00				
1+SH	4/09-4/10	4	7.9	0/4	0.00				
1+SH	4/14-4/16	8	7.7	0/8	0.00				
1+SH	4/15-4/16	4	6.6	0/4	0.00				
1+SH	4/22-4/23	1	10.5					0/1	0.00
1+SH	4/25-4/26	34	10.2					0/34	0.00
1+SH	4/28-4/29	51	11.4					0/51	0.00
1+SH	4/29-4/30	22	11.0					0/22	0.00
1+SH	5/05-5/06	25	11.5					1/25	4.00
1+SH	5/09-5/10	30	11.5			0/30	0.00		
1+SH	5/12-5/13	46	12.6					0/46	0.00
1+SH	5/24-5/25	25	12.5					0/25	0.00
1+SH	5/29-5/30	26	12.9					0/26	0.00
1+SH	5/30-5/31	39	13.5					0/39	0.00
1+SH	6/05-6/06	11*	18.4					0/10	0.00
1+SH	6/12-6/13	7	14.8					0/7	0.00
1+SH	6/14-6/15	5	15.0					0/5	0.00
1+SH	6/21-6/22	30	17.8			0/30	0.00		
1+SH	6/22-6/23	22	20.7					0/22	0.00
1+SH	6/30-7/01	8	21.5					0/8	0.00
1+SH	7/03-7/04	3	20.0					0/3	0.00
1+SH	7/06-7/07	2	18.3					0/2	0.00

* One fish died immediately (w/in 5 minutes after pit tag insertion).

Appendix 14. 2+ steelhead trout delayed mortality test results, upper Redwood Creek, Humboldt County, CA., 2006.

				Fin Clipping (24 hr)		Handling (24 hr)		Pit Tagging (34 hr)	
Age/ spp.	Date	(n)	Average Water Temp (°C)	Morts./ Total	Percent Mortality	Morts./ Total	Percent Mortality	Morts./ Total	Percent Mortality
2+SH	4/02-4/03	1	7.3	0/1	0.00				
2+SH	4/04-4/05	6	7.6	0/6	0.00				
2+SH	4/08-4/10	1	8.0	0/1	0.00				
2+SH	4/09-4/10	2	7.9	0/2	0.00				
2+SH	4/13-4/14	13	9.6					0/13	0.00
2+SH	4/14-4/15	5	8.8	0/5	0.00				
2+SH	4/22-4/23	2	10.5					0/2	0.00
2+SH	4/25-4/26	14	10.2					0/14	0.00
2+SH	5/05-5/06	6	11.5					0/6	0.00
2+SH	5/09-5/10	9	11.5			0/9	0.00		
2+SH	5/10-5/11	3	12.5	0/3	0.00				
2+SH	5/12-5/13	3	12.6					0/3	0.00
2+SH	5/15-5/16	1	14.0	0/1	0.00				
2+SH	5/30-5/31	3	13.3	0/3	0.00				
2+SH	6/13-6/14	1	13.9	0/1	0.00				
2+SH	6/21-6/22	2	17.8	0/2	0.00				
2+SH	8/22-8/23	1	21.3	0/1	0.00				