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2005 ANNUAL REPORT

LOWER REDWOOD CREEK
JUVENILE SALMONID (SMOLT) DOWNSTREAM MIGRATION STUDY
2004 – 2005 Seasons
PROJECT 2a7

Prepared by

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Anadromous Fisheries Resource Assessment and Monitoring Program

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ABSTRACT

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

A rotary screw trap was deployed on April 18th 2005 and trapped 118 d out of a possible 130 d. Days missed trapping were estimated to have negligible effects on trap captures and population estimates. The trap captured 10,827 0+ Chinook salmon, 11 1+ Chinook salmon, 1,345 0+ steelhead trout, 2,033 1+ steelhead trout, 417 2+ steelhead trout, 53 0+ coho salmon, 39 1+ coho salmon, 9 cutthroat trout, and 2 0+ pink salmon to total 14,736 individuals. Trap catches in YR 2005 were much lower (by 83%) than catches in YR 2004, with percent reductions ranging from 43 to 93% for a given species at age. Weekly trapping efficiencies averaged 11.7% for 0+ Chinook salmon, 4.4% for 1+ steelhead trout, 4.3% for 2+ steelhead trout, and 5.2% for 1+ coho salmon. The total population estimate with 95% confidence intervals was 131,164 (117,259 – 145,069) for 0+ Chinook salmon, 32,901 (24,967 – 40,835) for 1+ steelhead trout, 8,754 (4,975 – 12,533) for 2+ steelhead trout, and 183 (56 – 309) for 1+ coho salmon. Population estimates in YR 2005 were also much lower than estimates determined in YR 2004, with percent reductions ranging from 55 to 76%. The largest reduction occurred with 0+ Chinook salmon, which I attribute to: 1) high bedload mobilizing flows during egg incubation in spawning redds, 2) large decrease in adult spawners upstream of the trap site, or 3) a combination of the two factors. Peak population emigration in YR 2005 occurred during June-July for 0+ Chinook salmon, and April-May for 1+ steelhead trout, 2+ steelhead trout, and 1+ coho salmon. Weekly population emigration for each species at age followed trends of actual catches.

Twenty-seven pit tagged 0+ Chinook salmon fingerlings released at the upper trap site (RM 33) were recaptured 29 miles downstream at the second trap (RM 4) in lower Redwood Creek. Travel time ranged from 1.5 – 19.5 d and averaged 7.5 d, and travel rate ranged from 1.5 – 19.3 mi/d and averaged 8.2 mi/d. On average, 0+ Chinook salmon migrated 29 miles downstream faster than 1+ and 2+ steelhead trout did in YR 2004 and YR 2005. Fifty-two percent of the recaptured 0+ Chinook salmon fingerlings in YR 2005 showed positive growth in FL and Wt, 18% showed a decrease in Wt, 48% showed no change in FL, and 30% showed no change in Wt. Growth was positively related to travel time and travel time explained more of the variation in growth than any other variable tested. The percent change in FL ranged from 0.0 – 17.1 and averaged 3.6, and percent change in Wt ranged from - 7.7 – 46.0 and averaged 9.6. The final size of recaptured pit tagged 0+ Chinook salmon was positively related to the initial size at tagging and release.

[1/] This paper should be referenced as: Sparkman MD. 2006. Lower Redwood Creek juvenile salmonid (smolt) downstream migration study, study year 2005. CDFG, AFRAMP, Annual Report 2005 2a7: 105 p.

INTRODUCTION

This report presents results of the second consecutive year of juvenile salmonid downstream migration trapping in lower Redwood Creek, Orick, California during the spring/summer emigration period. The study was conducted by the California Department of Fish and Game's Anadromous Fisheries Resource Assessment and Monitoring Program (CDFG AFRAMP) in YRS 2004 and 2005. Funding for YR 2004 was provided by the department's Steelhead Report Card Program and AFRAMP, and in YR 2005 funding was provided by the Steelhead Report Card Program, AFRAMP, and the Federal Restoration Grant Program.

The initial impetus for this study was to determine how many wild salmon and steelhead smolts were emigrating from the majority of the Redwood Creek basin before entering the Redwood Creek estuary and Pacific Ocean. The 'majority' of the Redwood Creek basin includes all anadromous waters upstream of the first major tributary (Prairie Creek, river mile RM 3.7) to Redwood Creek. Areas downstream of Prairie Creek are generally not used for spawning by adult salmonids; thus, the only smolt production the trap will miss is from Prairie Creek. Prior to our trapping in lower Redwood Creek, Humboldt State University (YR 2001) and the United States Fish and Wildlife Service (USFWS) (YR 2003) operated a rotary screw trap in lower Redwood Creek nearby the present trapping site. Their efforts did not produce smolt population estimates but did collect data on species presence/absence, temporal distribution of out-migration, and fork lengths and weights of captured fish. In YR 2004, CDFG AFRAMP was able to successfully determine juvenile Chinook salmon and steelhead trout emigrant smolt population estimates from the majority of Redwood Creek for the first time in Redwood Creek's anadromous salmonid monitoring history. Additionally, AFRAMP and the Redwood Creek Landowners Association (RCLA) have successfully determined smolt population estimates for juvenile Chinook salmon and steelhead trout emigrating from upper Redwood Creek for the past six consecutive years (Sparkman 2005). Prior to our studies on juvenile salmonid downstream migration and smolt abundance in Redwood Creek, scientific studies which quantified anadromous salmonids within the Redwood Creek watershed were primarily limited to the estuary (juveniles) and Prairie Creek (adults and juveniles).

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

Determining and tracking smolt numbers over time is an acceptable, useful, and quantifiable measure of salmonid populations which many agencies (both state and federal), universities, consultants, tribal entities, and timber companies perform each year. Juvenile salmonid out-migration can be used to assess: 1) the number of parents that produced the cohort (Roper and Scarnecchia 1999, Ward 2000, Sharma and Hilborn 2001, Ward et al. 2002, Bill Chesney pers. comm. 2005), 2) redd gravel conditions (Cederholm et al. 1981, Holtby and Healey 1986, Hartman and Scrivener 1990), 3) in-stream habitat quality and watershed health (Tripp and Poulan 1986, Hartman and Scrivener 1990, Hicks et al. 1991, Bradford et al. 2000, Sharma and Hilborn 2001, Ward et al. 2002), 4) restoration activities (Everest et al. 1987 *in* Hicks et al. 1991, Slaney et al. 1986, Tripp 1986, McCubbing and Ward 1997, Solazzi et al. 2000, Cleary 2001, Ward et al 2002, McCubbing 2002, Ward et al. 2003), 5) over-winter survival (Scrivener and Brown 1993 *in* McCubbing and Ward 1997, Quinn and Peterson 1996, Solazzi et al. 2000, McCubbing 2002, Ward et al. 2002, Giannico and Hinch 2003), and 6) future recruitment to adult populations (Holtby and Healey 1986, Nickelson 1986, Ward and Slaney 1988, Ward et al. 1989, Unwin 1997, Ward 2000).

Site Description

Redwood Creek lies within the Northern Coast Range of California, and flows 67 miles through Humboldt County before reaching the Pacific Ocean (Figure 1). Headwaters originate at an elevation of about 5,000 ft and converge to form the main channel at about 3,200 feet. Redwood Creek flows north to northwest to the Pacific Ocean, and bisects the town of Orick in Northern California. The basin of Redwood Creek is 179,151 acres, and about 49.7 miles long and 6.2 miles wide (Cashman et. al 1995).

Geology

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

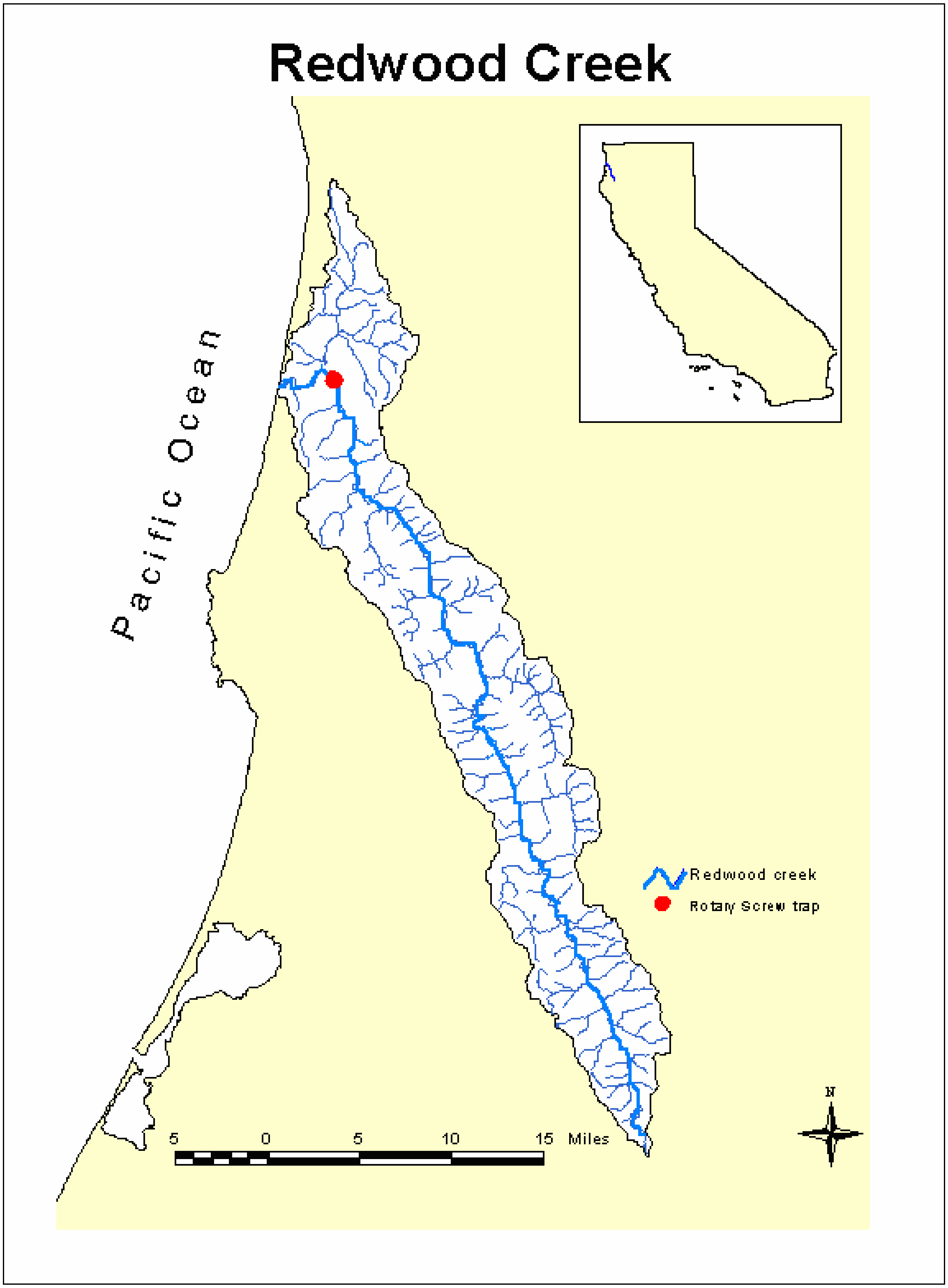

Figure 1. Redwood Creek watershed with rotary screw trap location (RM 4), Humboldt County, CA. (scale is slightly inaccurate due to reproduction process, Charlotte Peters pers. com. 2001).

The geology of the Redwood Creek basin has been well-studied and mapped (Cashman et. al 1995).

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

Climate and Annual Precipitation

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

The United States Geological Survey (USGS) operates a rain gage in lower Redwood Creek, about 850 m downstream of the current trapping site. Rainfall records cover the periods of 1987 – 2005 to total 19 years (Redwood National Park, in house data, 2005; Vicki Ozaki pers. comm. 2005). Annual precipitation ranges from 77 cm (30 in.) to 204 cm (80 in.), and averages 137 cm (54 in.). Most (91%) of the rainfall in Redwood Creek occurs from November through May, with peak monthly rainfall occurring in December and January (Appendix 1). However, in some years relatively large amounts of rainfall may occur in November, February, March (as in YR 2005), April, and May as well. Rainfall in WY 2005 (118.8 cm or 46.8 in.) was nearly equal to rainfall in WY 2004, and about 14% less than the 19 year average (Appendix 1).

The 19 year average monthly rainfall during the majority of the trapping season (April – July) totaled 24.2 cm (9.5 in.) (Table 1). Total monthly rainfall during this period of trapping in YR 2005 (39.9 cm or 15.7 in.) was 1.7 times greater than rainfall for the 19 year average, and 3.9 times greater than rainfall during the trapping season in YR 2004 (Table 1). Rainfall in April, 2005 was 1.4 times greater than the 19 year average for April; and rainfall in June 2005 was 2.1 times greater than the historic average for June (Table 1). Rainfall in May, 2005 was 6.4 times greater than rainfall in May, 2004; and rainfall in June, 2005 was 14 times greater than rainfall in June, 2004.

Table 1. Comparison of 19 year average monthly rainfall with average monthly rainfall in YR 2004 and YR 2005 during the majority of the trapping period, lower Redwood Creek, Orick, California (USGS 2005).

	Monthly Precipitation (cm)		
Month	Historic	YR 2004	YR 2005
April	12.6	7.1	17.6
May	7.8	2.4	15.3
June	3.3	0.5	7.0
July	0.4	0.1	0.0
Total:	24.2	10.2	39.9
Average:	6.0	2.5	10.0

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

Stream Discharge

A USGS gauging station (#11482500) is located about 850 m downstream of the trap site in lower Redwood Creek. The gauging station is downstream of the confluence of Prairie Creek with Redwood Creek, thus the station is influenced by Prairie Creek stream flow. Stream flow records for the Orick gage cover the periods of 1911 – 1913, 1953 – 2005, and total 54 years (Thomas C Haltom pers. comm. 2005; USGS 2005). High stream flows usually occur from November through May, and typically peak in January (Appendix 2). However, the months of December, February, March, and April can experience high flows as well. Using all years' data, mean monthly discharge is 1,007 cfs, and ranges from 37 – 2,496 cfs (Thomas C Haltom pers. comm. 2005, USGS 2005) (Appendix 2). Preliminary data for water year 2005 show that the average monthly discharge was 800 cfs, and ranged from 25 – 2,138 cfs. The highest average monthly discharge in WY 2005 occurred in April. Average stream discharge in WY 2005 was about 21% less than the 54 year historic average and 6% less than the average for WY 2004.

The 54 year average monthly flow during the majority of the trapping season (April – July) equaled 550 cfs, and ranged from 86 – 1,223 cfs (Thomas C Haltom pers. comm. 2005, USGS 2005) (Table 2). Average monthly discharge from April – July, 2005 (1,087 cfs) was higher than the historic average by a factor of 1.98, and higher than the average for YR 2004 by a factor of 4.25 (Table 2, data from USGS 2005). The probability of the average flow during the trapping period being greater than 1,087 cfs (based upon the 54 years of record) equaled 5.6% (USGS 2005).

Table 2. Comparison of 54 year average monthly stream discharge with average monthly discharge in WY 2004 and WY 2005 during the majority of the trapping period in lower Redwood Creek, Orick, California (USGS 2005).

	Monthly Stream Discharge (cfs)		
Month	Historic	WY 2004	WY 2005
April	1,223	602	2,138
May	636	271	1,400
June	254	109	613
July	86	41	195
Average:	550	256	1,087

Overstory

The overstory of Redwood Creek is predominately second and third growth Redwood (*Sequoia sempervirens*) and Douglas Fir (*Pseudotsuga menziesii*), mixed with Big Leaf Maple (*Acer macrophyllum*), California Bay Laurel (*Umbellularia californica*), Incense Cedar (*Calocedrus decurrens*), Cottonwood (*Populus spp*.), Manzanita (*Arctostaphylos spp*.), Oak (*Quercus spp*.), Tan Oak (*Lithocarpus densiflorus*), Pacific Madrone (*Arbutus menziesii*), and Red Alder (*Alnus rubra*). The lower portion of Redwood Creek (ie within Redwood National Park boundaries) contains old growth Redwood, mixed with second growth redwood and other tree species.

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 about 200 m upstream 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. The downstream migrant trap in lower Redwood Creek is located in an area of gravel aggredation.

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

Federal ESA Species Status

Chinook (King) salmon (*Oncorhynchus tshawytscha*), coho (Silver) salmon (*O. kisutch*), steelhead trout (*O. mykiss*), and cutthroat trout (*O. clarki clarki*) are known to inhabit Redwood Creek. This study and the study in upper Redwood Creek also show that pink salmon (*O. gorbuscha*) are present in Redwood Creek. Chinook salmon (KS) of Redwood Creek belong to the California Coastal Chinook Salmon Evolutionarily Significant Unit (ESU), and are listed as “threatened” under the Federal Endangered Species Act (Federal Register 1999a). The definition of threatened as used by National Oceanic and Atmospheric Administration (NOAA) and the National Marine Fisheries Service (NMFS) is “likely to become endangered in the foreseeable future throughout all or a significant portion of their range” (NOAA 1999). Coho salmon (CO) belong to the Southern Oregon/Northern California Coasts ESU and were classified as “threatened” (Federal Register 1997) prior to the Chinook salmon listing. Steelhead trout (SH) fall within the Northern California Steelhead ESU, and are also listed as a “threatened” species (Federal Register 2000). Coastal cutthroat trout (CT) of Redwood Creek fall within the Southern Oregon/California Coasts Coastal Cutthroat Trout ESU, and were determined “not warranted” for ESA listing (Federal Register 1999b). Despite ESU listings of Redwood Creek anadromous salmonid populations, relatively little data exists concerning abundance and population sizes, particularly for juvenile (and adult) life history stages. Historically, the most prolific species was most likely the fall/early winter-run Chinook salmon.

Purpose

The purpose of this project is to describe juvenile salmonid downstream migration from the majority of the Redwood Creek basin, and to determine emigrant population sizes for wild 0+ (young-of-year) Chinook salmon (Ocean type), 1+ (between 1 and 2 years old) steelhead, 2+ (2 years old and greater) steelhead, and 1+ coho salmon smolts. The primary long term goal is to monitor the status and trends of out-migrating juvenile salmonid smolts in Redwood Creek in relation to watershed condition and restoration activities in the basin; and to provide data needed for Viable Salmonid Population

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

1) Determine the species composition and temporal pattern of downstream migrating juvenile salmonids.
2) Enumerate species out-migration.
3) Determine population estimates for downstream migrating 0+ Chinook salmon, 1+ steelhead trout, 2+ steelhead trout, and 1+ coho salmon.
4) Record fork length (mm) and weight (g) of captured fish.
5) 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).
6) Collect and handle fish in a manner that minimizes mortality.
7) Statistically analyze data for significance and trends.
8) Compare data between study years.
9) Link data collected from the lower trap, upper trap, and estuary (Redwood National Park) to provide a more complete study on the life history and abundance of emigrating juvenile salmonids (smolts) in Redwood Creek.

METHODS AND MATERIALS

Trap Operations

A stock E.G. Solutions (5 foot diameter cone) rotary screw trap was set in lower Redwood Creek (RM 4) on April 18, 2005 at the same location as in YR 2004. The trap's livebox was slightly modified by adding perforated plates (2 mm diameter) on the sides and bottom of the livebox to dissipate livebox water velocities. The debris wheel at the downstream end of the trap was made non-operational to prevent the smaller fry from being transported back into the river. The trap was located about 1/3 mile upstream of the confluence of Prairie Creek with Redwood Creek, and positioned in a run habitat type just downstream of a low gradient riffle. The trap was scheduled to be set on April 1st (same time the trap was set in YR 2004), however, continuous high stream flows precluded trap placement and deployment. The rotary screw trap was set on April 18th, and operated continually (24 hrs/day, 7 days a week) through August 26th except for 12 days (May 9, 10, 17 - 22, and June 18 - 21) due to high flow events. Trapping methods were nearly identical to those used for the upper trap (RM 33) (Sparkman 2005). During periods of high flows and debris loading in the livebox, we moved the trap to the side of the stream and raised the cone. The trap was re-set as soon as possible into the thalweg of the stream, and every attempt was made to maintain the trap's position in the thalweg. On one particular high flow event (May 17th – 22nd), the average daily stream discharge rose from 1,670 cfs to 3,530 cfs. The trap's cone was raised the previous day (May 16th) after removing fish from the livebox. Between the evening of May 18th and the morning of May 19th, a large tree (about 60 ft long) floated downstream and snagged one of the steel cables which connected the trap to the anchor (fence posts for the left side of the river). The trap, facing upstream, spun to the right and was diagonal to the current (Appendix 3). The water level was so high that the tops of the fence posts were nearly underwater. We pulled the trap to the side of the stream using a winch, and then disconnected the cable from the pontoon of the rotary screw trap. The cable then slid around the tree, and the tree floated downstream. Although the fence posts were under high pressure (from the trap and tree) and nearly underwater, they held and didn't excessively bend, break, or dislodge.

During periods of lesser stream flows, weir panels were used with the rotary screw to: 1) keep the trap's cone revolutions relatively high, and 2) maintain good trap efficiencies by directing fish into the cone area. The weir panels were set to fall down under any unexpected, high stream flows. Weir panels were first installed on July 17th, and positioned at an angle to each of the trap's pontoons. Rock weirs were used with the weir panels for the right side of the stream. Additional weir panels were later added to increase the overall length, and by August 12th, the weir panels were 66 ft long on the right bank side (includes rock weir), and 60 ft long on the left bank side (Appendix 4). Prior to the end of the study, plastic drop cloths were fastened to the weir panels to force more water into the cone area; this increased the cone revolutions greatly, and enabled trapping to the end of the catch distribution and study period.

The trapping season in YR 2005 was extended (to August 26th) compared to YR 2004 because: 1) stream flow was adequate for operating the trap, and 2) juvenile salmonids were emigrating beyond July 27th. The end date for trapping is determined by examining the catch distribution (when the right tail of the distribution nears zero), and in the case for lower Redwood Creek, stream flow. Lower Redwood Creek at the trapping site can become completely dry near the end of July or the beginning of August, thus preventing any remaining smolts from entering the estuary until rains occur. However, in YR 2005, Redwood Creek had relatively good stream flow well beyond the middle of August.

To summarize, the YR 2005 trapping season, particularly March - May, can be characterized as working in and out of high flow events and handling large amounts of debris in the livebox; and towards the end of the study, weir panels were extensively used.

Biometric Data Collection

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

Random samples of each species at age (eg 0+ KS, 0+ SH, etc.) were netted from the ice chest for examination, enumeration, and biometric data collection. Each individual fish was counted by species at age, and observed for trap efficiency trial marks. Marked fish from the upper trap were tallied separately from the marked fish used to determine trap efficiencies for the lower trap. Every 1+ and 2+ steelhead trout captured were scanned for pit tags and observed for elastomer marks. 0+ Chinook salmon with upper caudal fin clips (secondary mark for the pit tag) were also scanned (interrogated) for pit tags.

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), 2+ and greater steelhead trout (2+ SH), 0+ coho salmon (0+ CO), and 1+ coho salmon (1+ CO). Only fork lengths were taken from 0+ steelhead trout (0+ SH). A 350 mm measuring board (± 1 mm) and an Ohaus Scout ll digital scale (± 0.1 g) were used in the study. Fork lengths were taken every day of trap operation, and fork length frequencies of 0+ and older steelhead trout coho salmon, and Chinook salmon were used to determine age-length relationships at various times throughout the trapping period. Scales were occasionally read to verify age class cutoffs. 0+ Chinook salmon and 1+ steelhead trout weights were taken 2 - 4 times per week. 0+ and 1+ coho salmon and 2+ steelhead trout weights were taken nearly every day of trap operation and collection due to expected, low sample sizes. Individuals were weighed in a tared plastic pan (containing water) on the electronic scale. The scale was 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 80 m downstream of the trap site and released in the margin of the stream; and aged 1 and older fish were transported 125 m downstream of the trap site and released near the middle of the stream.

Developmental Stages

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

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

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

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

Discerning developmental stages is subjective; however, I attempted to minimize observer bias by individually training (and checking) each crew member and having 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, 2+ steelhead trout, and 1+ coho salmon using mark-recapture methodology described by Carlson et al. (1998). The population estimate for 2+ steelhead trout in YR 2004 was re-calculated on a weekly basis to compare with the estimate in YR 2005. The new point estimate fell within the 95% confidence interval for the original estimate, and is considered more realistic and less biased (with few recaptures population models may overestimate population size).

The approximately unbiased estimate equation for a 1-site study was used to determine total population size (U_h) in a given capture and trapping efficiency period (h). Variance was computed, and the value was used to calculate 95% confidence intervals (CI) for each weekly population estimate. The weekly population estimate (U_h) does not include catches of marked releases in the “C” component (or ‘u_h’) of the equation, and any short term handling mortality was subtracted (Carlson et al. 1998). Trap efficiency trials were conducted one to six times a week for 0+ Chinook salmon, 1+ Chinook salmon, 1+ steelhead trout, 2+ steelhead trout, and 1+ coho salmon. Data was combined and run through the equation to determine the weekly estimate (for a complete description of estimation methods and model assumptions see Sparkman 2004a). The Carlson et al. (1998) model and my methods were (favorably) peer reviewed in 2003 (Phil Law, CDFG Biometrician, pers. comm. 2003).

Partial fin clips were used to identify trap efficiency trial fish by squaring the round edge (or tip) of a given fin (caudal, pectoral) with scissors. Fish used in efficiency trials were given partial fin clips while under anesthesia (MS-222), and recovered in 5 g buckets which received fresh stream water (via the plumbing system). Clip types for 0+ Chinook salmon, 1+ steelhead trout and 2+ steelhead trout were different than those used at the upper trap. Clips for 2+ steelhead trout were stratified by week such that marked fish of one group (or week) would not be included in the following weekly calculation (however, no out of strata captures occurred in YR 2004, nor in YR 2005). I did not stratify clips for 0+ Chinook and 1+ steelhead trout because four years of data (when I did stratify clips) at the upper trap showed that nearly all of the recaptures (99.4%) occurred in the correct strata. The few fish that were recaptured out of strata had little to no effect on the weekly and total population estimates (Phil Law, personal comm. 2003). 0+ Chinook salmon, 1+ Chinook salmon, 1+ steelhead trout, and 1+ coho salmon were given lower caudal partial fin clips, and 2+ steelhead trout were given right or left pectoral partial fin clips. Once recovered from anesthesia, the fish were placed in mesh cages in the stream for at least 1 - 2 hrs to test for short term delayed mortality (Carlson et al. 1998). Fin clipped 0+ Chinook salmon were released in fry habitat 183 m upstream of the trap, and clipped 1+ and 2+ steelhead trout, 1+ coho salmon and 1+ Chinook salmon were released into a pool (with woody debris) 152 m upstream of the trap. Fin clipped fish were released upstream of the trap after the livebox was emptied (eg 1300 – 1800), and in some instances, the fish were manually released at night. Night releases were conducted to possibly increase the catch of efficiency trial marked fish, however, trap efficiencies for night releases did not significantly vary from day releases.

Additional Experiments

Re-migration

In YR 2004, we marked and released 223 2+ steelhead trout and 577 1+ steelhead trout at the upper trap site 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 the marked fish residualized in the stream in YR 2004 to be later caught as 2 or 3 year old fish migrating downstream in YR 2005. Every 1+ and 2+ steelhead trout captured at the lower trap in YR 2005 were examined for elastomer marks. Mark retention was assumed to be nearly 90% within 16 months (Fitzgerald et al. 2004).

Travel Time and Growth

We marked 37 2+ steelhead trout and 146 1+ steelhead trout at the upper trap site with plastic elastomer in YR 2005 to investigate travel time from the upper trap to the lower trap (a distance of 29 miles). We applied the elastomer marks subdermally using a hypodermic needle on the underside of both lower jaws while fish were under anesthesia (MS-222). 0+ Chinook salmon were generally too small to safely mark. Marked fish were treated as batches, with a unique color combination for each week of release. Partial fin clips (upper caudal) were applied to each elastomer marked fish in order to discern elastomer mark releases in YR 2004 from YR 2005. Although some of the YR 2004 elastomer marked juveniles also had partial upper caudal fin clips, the fins should have regenerated by YR 2005. Each batch of marked fish was held in the stream for 24 hours (at the upper trap site) to test for any delayed mortality prior to release, and released into the stream at the upper trap's downstream release site.

Plastic elastomer has limitations because individual fish cannot be uniquely identified when marks are used for batches of fish, and the mark is rather difficult to apply for fish under 80 mm (FL). Pit tags offer the ability of individual recognition by using numbers unique to each tag (and marked fish). In YR 2005 we used Pit Tags to investigate both travel time and growth of tagged fish as they migrated downstream from the upper trap and captured at the lower trap or estuary (David Anderson, pers. comm. 2005). We found pit tagging to be easier and faster than applying elastomer. A more thorough examination of the pit tag data and subsequent results is forthcoming (Sparkman, In progress).

Pit tags used in the study were 11.5 mm long x 2 mm wide, and weighed 0.09 g (ALLFLEX USA, Inc., PO BOX 612266, Dallas/Ft Worth Airport, Texas). Pit tags were applied to randomly selected 1+ steelhead trout (n = 147), 2+ steelhead trout (n = 46) and 0+ Chinook salmon smolts (FL $\geq$ 70 mm**,** n = 555) using techniques shown by Seth Ricker (CDFG, pers. comm. 2005). The number of pit tag groups released downstream was 21 for 0+ Chinook salmon, 13 for 1+ steelhead trout, and 17 for 2+ steelhead trout. Fish were anesthetized with MS-222, and measured for FL (mm) and Wt (g) prior to tagging. A scalpel (sterilized with a 10:1 solution of water to Argentyne; Argent Chemical Laboratories, 8702 152nd Ave. N.E., Redmond, WA, 98052) was used to make a small incision (2 - 3 mm long) into the body cavity just posterior (about 3 - 5 mm) to a pectoral fin. The incision was dorsal to the ventral most region of the fish to help prevent the tag from exiting the incision. Tags were also sterilized with Argentyne, and then inserted by hand into the body cavity via the incision. Glue was not used to close the incision after tag placement because previous experience with tagging showed it was unnecessary (Seth Ricker, pers. comm. 2005). Pit tagged 0+ Chinook salmon were also given a small partial upper caudal fin clip to aid in recognizing a tagged fish so that technicians at the lower trap and estuary did not have scan every 0+ Chinook salmon they captured. Some of the 1+ and 2+ steelhead trout also had partial fin clips because we tagged recaptures from trap efficiency trials to increase sample size. After tag application, fish were held in a livecar in the stream for a period of 34 hrs to test for delayed mortality. 0+ Chinook salmon were kept separately from 1+ and 2+ steelhead trout. All pit tagged fish were manually released at night downstream of the upper trap site. Field crews at the upper trap, lower trap, and estuary had hand held pit tag readers (ALLFLEX USA, Inc., PO BOX 612266, Dallas/Ft Worth Airport, Texas) so that they could scan and identify pit tagged fish; and perform necessary fork length and weight measurements.

Physical Data Collection

A staff gage with increments in hundredths of a foot was used to measure the relative stream surface elevation (hydrograph) at the trap site from April 19th – August 26th, 2005. The gage was read every morning at 0900 to the nearest one-hundredth of a foot prior to biometric data collection. A graphical representation of the data, along with average daily stream discharge data from the O'Kane gaging station (USGS 2005), is given in Appendix 5.

Stream temperatures were recorded with an Optic StowAway® Temp data logger (Onset Computer Corporation, 470 MacArthur Blvd. Bourne, MA 02532) placed behind the rotary screw trap. A second probe was deployed at the same location for comparison. Both probes gave similar results (Ave. = 14.7 ^{o}C), therefore only data from one probe is reported. The probes were placed into a PVC cylinder with holes to ensure adequate ventilation and to prevent influences from direct sunlight. Probes were set to record stream temperatures (^{o}C) every 60 minutes and recorded about 3,700 measurements per probe over the course of the study. The shallowest stream depth during which measurements were taken (in August) was about three feet. The maximum weekly average temperature (MWAT) and maximum weekly maximum temperature (MWMT) for YRS 2001 - 2005 were determined following methods described by Madej et al. (2005). MWAT is defined as the maximum value of a 7-day moving average of daily average stream temperatures, and MWMT is the maximum value of a 7-day moving average of daily maximum stream temperatures (Madej et al. 2005).

Statistical Analyses

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

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

Linear correlation 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. Regression and correlation models did not include any combination of the independent variables (eg average temperature, average daily discharge, gage height, and trapping week number) in a given model or test because they were highly correlated with one-another (Correlation, $p < 0.00005$, r ranged from 0.79 – 0.95).

The 0+ Chinook salmon population estimate was partitioned into classes of fry (newly emerged and post-emergent fry, FL < 45 mm) and fingerlings (FL > 44 mm) each week of a given year using fork lengths and weekly population estimates. The percentage of juvenile Chinook salmon per size class each week was then multiplied by the corresponding weekly population estimate (which included recaptures of marked 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 six years of trapping in upper Redwood Creek (FL nadir ranged from 42 – 45 mm, mean = 44 mm) and two years of trapping in lower Redwood Creek (FL nadirs = 43 and 44mm, mean = 43.5 mm), from trapping Chinook salmon redds in Prairie Creek (emergent fry fork length per redd (n = 4) ranged from 35 – 43, and averaged 39 mm) (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, Bendock (1995) used a FL < 40 mm for fry, and Seiler et al. (2004) used a fry cutoff of 40 mm FL. Therefore, the 45 mm FL cutoff for fry in Redwood Creek was similar to that used in other studies.

Regression and correlation were also used to test for influences of average weekly stream temperature, stream discharge, gage height, and trapping week number on population emigration by week for 0+ Chinook salmon, 1+ steelhead trout, 2+ steelhead trout, and 1+ coho salmon. As in previous tests, combinations of independent variables were not included in the model due to high correlations.

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 the average weekly FL and Wt of each species at age increased, decreased or didn't change over the study period in YR 2004 and YR 2005 (excluding 0+ steelhead weight). The lack of data in any given week was due to: 1) differences in trap deployment time among study years, 2) no catches occurred, or 3) sample size was too low to generate a reliable average. Single factor ANOVA (or non-parametric equivalent, Kruskal-Wallis One-Way ANOVA on Ranks) was used to test for significant variation in weekly FL's and Wt's among study years 2004 and 2005.

I determined a ' rough' estimate of growth rate in FL and Wt for 0+ Chinook salmon and 0+ steelhead trout in YR 2004 and YR 2005 generally following methods by Bendock (1995). I used the first weekly average in FL and Wt with a sample size ≥ 25 and the last weekly average in the season with a sample size greater than ≥ 25. The first average was subtracted from the last average, and divided by the number of days from the first day after the weekly average to the last day of the last weekly average. For example, in YR 2005 growth in FL was calculated by subtracting 49.1 mm (Ave. for 4/16 – 4/22) from 95.3 mm (Ave. for 8/20 – 8/26) and then dividing by 126 days. Thus, the growth rate would cover the period of 4/23 – 8/26. 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.

Chi-square was used to test for differences in the proportions of pre-smolt and smolt designations for captured 1+ steelhead trout and 2+ steelhead trout in YR 2005 with captures in YR 2004. Parr stage was not included in the tests because at least one of the values in the contingency tables was less than 5, which can cause the tests to be inaccurate (NCSS 97).

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

Travel time is defined as the difference (in days) from the recapture date to initial release date, and equals the period of growth for recaptured individuals. Since pit tagged fish were released at night (eg 2100) and recaptured at some date in the morning by the lower trap (when the crew checks the trap at 0900) the earliest recorded travel time could be 0.5 days (or 12 hours). Travel rate is the travel time divided by 29 miles (the distance between the upper and lower traps). For the following equations, t_1 is the initial date, t_2 is the ending or recapture date, Y_1 is fish size at t_1, and Y_2 is the fish size at t_2 (Busacker et al. 1990).

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

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

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

2) Absolute growth rate = $(Y_2 - Y_1)/(t_2 - t_1)$

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

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

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

Specific growth rate is expressed as a scaled number (by multiplying specific growth by 100). Thus, if the specific growth rate scaled equaled 0.741 %(mm per day), the un-scaled value would equal 0.00741 mm per day.

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

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

Relative growth rate is a growth rate that is relative to the initial size of the fish, and units for FL are in mm/mm/d and for Wt are in g/g/d. Therefore, if the relative growth rate equaled 0.003 mm/mm/d, then we would say that the fish grew 0.003 mm per mm of fish per day.

Travel time, travel rate, and growth for all recaptured pit tagged 0+ Chinook salmon smolts (n = 27) were modeled using linear regression. These parameters for 1+ and 2+ steelhead trout could not be modeled due to low recaptures. Independent variables for travel time and travel rate (dependent variables in this case) included fish size at time 1 or time 2, water temperature during a specific migration period (average of data from both traps), and stream discharge during a specific migration period (average of data from both traps). Independent variables for modeling growth (dependent variable) included travel time, travel rate, average water temperature, and average stream discharge. Stream temperature and stream discharge were not included together in any regression models because they were highly correlated ($p < 0.001$). During the travel time and growth experiments (6/3 – 8/10), average daily stream temperatures at the upper trap site ranged from 11.0 – 22.4 ^{o}C (51.8 – 72.3 ^{o}F) and average daily stream discharge ranged from 13 - 309 cfs. Average daily stream temperatures at the lower trap site ranged from 12.2 – 20.0 ^{o}C (54.0 – 68.0 ^{o}F) and average daily stream discharge ranged from 63 - 1,620 cfs. Thus, the experiments were conducted over a fairly wide range in values for discharge and stream temperature.

Minimum, average, and maximum stream temperatures for each day during the trapping period were determined from data collected by the temperature probes. Descriptive statistics were used to determine the average stream temperature during the course of the study. Single factor ANOVA was used to test for significant variation in average monthly stream temperature among YR 2004 and YR 2005; and for variation among average daily stream temperature among study years. Tests utilized truncated and non-truncated data. Data was truncated to match the period (dates) of measurements each year for a more equivalent comparison. Linear correlations were used to test if the average daily (24 hour) stream temperature increased or decreased over the study period in YRS 2004 and 2005. Regression was used to examine the relationship of the daily stream gage height on average daily stream temperature in YR 2005.

If data violated tests of statistical assumptions, data was transformed with Log (x+1) to approximate normality (Zar 1999). For tests involving ANOVA, the non-parametric equivalent was used (Kruskal-Wallis One-Way ANOVA on Ranks). Power is defined as the probability of correctly rejecting the null hypothesis when it is false (Zar 1999). The level of significance (Alpha) for each statistical test was set at 0.05.

RESULTS

The rotary screw trap could not be deployed on April 1st as in study YR 2004 because of continuous high flow events (Appendix 5). The rotary screw trap was set on April 18th, operated from 4/18/05 - 8/26/05, and trapped 118 nights out of a possible 130. Excluding the initial 17 days of missed trapping, the trapping rate in YR 2005 was 91% compared to 97% for YR 2004. Days missed trapping in YR 2005 occurred in May (n = 8), and June (n = 4).

Species Captured

Juvenile Salmonids

Species captured in YR 2005 included: juvenile Chinook salmon (*Oncorhynchus tshawytscha*), juvenile coho salmon (*O. kisutch*), juvenile steelhead trout (*O. mykiss*), coastal cutthroat trout (*O. clarki clarki*), and juvenile pink salmon (*O. gorbuscha*). A total of 14,746 juvenile salmonids were captured in YR 2005 (Figure 2).

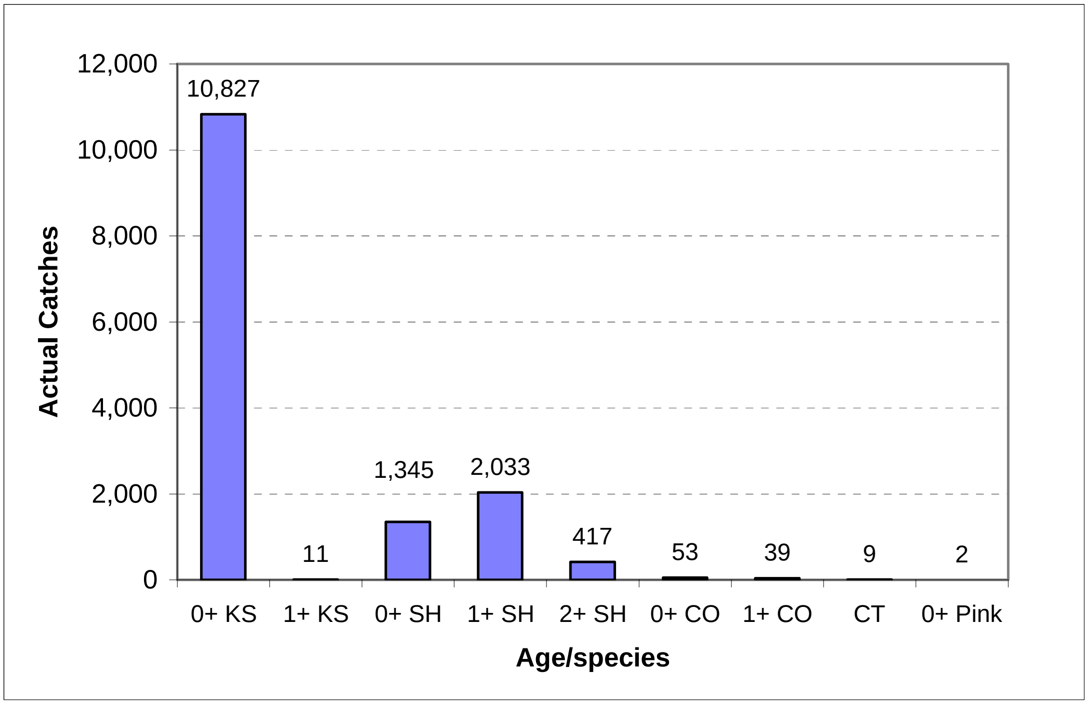

Figure 2. Total juvenile salmonid trap catches (n = 14,746) from April 19th through August 26th, 2005, lower Redwood Creek, Humboldt County, CA. Numeric values above columns represent actual catches. 0+ KS = young-of-year Chinook salmon, 1+ KS = age 1 Chinook salmon, 0+ SH = young-of-year steelhead trout, 1+ SH = age 1 and older steelhead trout, 2+ SH = age 2 and older steelhead trout, CT = cutthroat trout, 0+ Pink = young-of-year pink salmon.

Trap catches of juvenile salmonids in YR 2005 were much less (83%) than trap catches in YR 2004 (Table 3). The greatest reduction in catches in YR 2005 occurred with 0+ steelhead trout (93%) and 0+ Chinook salmon (82%). 1+ Chinook salmon trap catches in YR 2005 was 5.5 times greater than in YR 2004.

Table 3. Comparison of juvenile salmonid trap catches in YR 2004 with YR 2005, lower Redwood Creek, Humboldt County, CA.

	Actual Catches		
Age/species*	YR 2004	YR 2005	Percent reduction in YR 2005
0+ KS	61,778	10,827	82.5
1+ KS	2	11	-
0+ SH**	18,642	1,345	92.8
1+ SH	6,371	2,033	68.1
2+ SH	907	417	54.0
0+ CO	202	53	73.8
1+ CO	69	39	43.5
CT	37	9	75.7
0+ Pink	NC***	2	-
Total:	88,088	14,736	83.3

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

Miscellaneous Species

The trap caught numerous species besides juvenile anadromous salmonids in YR 2005, 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 included coastal (Pacific) giant salamander (*Dicamptodon tenebrosus*), rough skinned newt (*Taricha granulosa granulosa*), red legged frog (*Rana aurora draytonii*), and tailed frog tadpole (*Ascaphus truei*) (Table 4). Numerous aquatic and semi-aquatic invertebrates were also captured in the trap.

Table 4. Comparison of miscellaneous species captured in YR 2004 with catches in YR 2005, lower Redwood Creek, Humboldt County, CA.

	Number Captured	
Species Captured	YR 2004	YR 2005
Prickly Sculpin	68	140
Coast Range Sculpin	502	212
Sucker	156	89
3-Spined Stickleback	7,225	215
Adult Pac. Lamprey	13	3
Juvenile Lamprey	154	84
Possible River Lamprey	0	0
Pac. Giant Salamander	4	8
Painted Salamander	0	0
Rough Skinned Newt	2	3
Red-Legged Frog	0	2
Yellow-Legged Frog	0	0
Tailed Frog	0	1

Juvenile Salmonid Captures

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

0+ Chinook salmon daily catches in YR 2005 (Total = 10,827) ranged from 0 - 581 individuals, and averaged 91 fish per day. Daily catches in YR 2004 (Total = 61,778) ranged from 0 – 2,196 and averaged 547 per day. Daily 0+ Chinook salmon captures in YR 2005 expressed as a percentage of total 0+ Chinook salmon catch in YR 2005 ranged from 0.0 – 5.4%, and averaged 0.8%. The peak catch in YR 2005 occurred on 7/18/05 compared to 6/17/04 in YR 2004.

0+ steelhead trout daily catches in YR 2005 (Total = 1,345) ranged from 0 - 119 individuals, and averaged 11 per day. Daily catches in YR 2004 (Total = 18,642) ranged from 0 – 639 and averaged 154 per day. Daily 0+ steelhead captures in YR 2005 expressed as a percentage of total 0+ steelhead catch in YR 2005 ranged from 0.0 – 8.8% and averaged 0.8%. The peak catch in YR 2005 occurred 5/08/05 compared to 6/11/04 in YR 2004.

1+ steelhead trout daily catches in YR 2005 (Total = 2,033) ranged from 0 - 94, and averaged 17 per day. Daily catches in YR 2004 (Total = 6,371) ranged from 0 – 213 and averaged 56 per day. Daily 1+ steelhead trout captures in YR 2005 expressed as a percentage of total 1+ steelhead trout catch in YR 2005 ranged from 0.0 - 4.6% and averaged 0.8%. The peak catch in YR 2005 occurred on 5/3/05 compared to 5/29/04 in YR 2004.

2+ steelhead trout daily catches in YR 2005 (Total = 417) ranged from 0 - 27, and averaged three individuals per day. Daily catches in YR 2004 (Total = 907) ranged from 0 – 39 and averaged eight per day. Daily 2+ steelhead trout captures in YR 2005 expressed as a percentage of total 2+ steelhead trout catches in YR 2005 ranged from 0.0 – 6.5%, and averaged 0.8%. The peak catch in YR 2005 occurred on 5/03/05 compared to 5/16/04 in YR 2004.

0+ coho salmon daily catches in YR 2005 (Total = 53) ranged from 0 - 3 individuals, and averaged 0.4 fish per day. Daily catches in YR 2004 (Total = 202) ranged from 0 – 15 and averaged 2 per day. Daily 0+ coho salmon captures in YR 2005 expressed as a percentage of total 0+ coho salmon catch in YR 2005 ranged from 0.0 – 5.7% and averaged 0.8%. Peak catches in YR 2005 occurred 6/24/05, 7/19/05 and 7/27/05 compared to 7/18/04 in YR 2004.

1+ coho salmon daily catches in YR 2005 (Total = 39) ranged from 0 - 7 individuals, and averaged 0.3 fish per day. Daily catches in YR 2004 (Total = 69) ranged from 0 – 7 and averaged 0.6 fish per day. Daily 1+ coho salmon captures in YR 2005 expressed as a percentage of total 1+ coho salmon catch in YR 2005 ranged from 0.0 – 18.0% and averaged 0.8%. Peak catches in YR 2005 occurred 5/06/05 compared to 4/16/04 in YR 2004.

Days Missed Trapping

The trap was not set on April 1st (as in YR 2004) and therefore initially lacked 17 days of trapping. In YR 2004, trap catches during these 17 days equaled 12% of the total catch for 0+ Chinook salmon, 0% for 1+ Chinook salmon, 3% for 0+ steelhead trout, 7% for 1+ steelhead trout, 11% for 2+ steelhead trout, 3% for 0+ coho salmon, 26% for 1+ coho salmon, and 5% for cutthroat trout. At the population level in YR 2004, trap catches during the 17 days expanded to 10% of the total population estimate for 0+ Chinook salmon, 3.4% for 1+ steelhead trout, 11% for 2+ steelhead trout, and 13% for 1+ coho salmon.

Twelve days were not trapped (after trap deployment) in YR 2005 due to high flow events and high debris loads in the livebox. Days missed trapping did not appear to influence the total catch or population estimate of 0+ Chinook salmon, 1+ steelhead trout and 2+ steelhead trout to any large degree (Table 5). However, an estimated 14% of the 1+ coho salmon population and 15% of the 0+ steelhead trout catch would have been missed if the estimated catches were not added to the known or actual catches in the population model.

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 = 12 d) during the emigration period of April 19th through August 26th (as a percentage of total without missed days in parentheses), lower Redwood Creek, Humboldt County, CA., 2005.

Age/spp.*	Catch	Population Level
0+KS	466 (4.3%)	3,815 (3.0%)
1+KS	0 (0.0%)	-
0+ SH	204 (15.1%)	-
1+ SH	100 (4.9%)	1,222 (3.9%)
2+ SH	30 (7.2%)	351 (4.0%)
0+CO	4 (7.5%)	-
1+CO	5 (12.8%)	40 (21.9%)
CT	0 (0.0%)	-

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

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

0+ Chinook salmon

0+ Chinook salmon were captured in each week during the trapping period in YR 2005 (Figure 3). Peak catches in YR 2005 occurred during the week of 7/16 – 7/22, with a smaller peak occurring 6/4 – 6/10; peak catches in YR 2004 occurred during 6/18 – 6/24 and 4/9 – 4/15. The pattern of catches over time showed emigration in YR 2005 was extended beyond the ending date for YR 2004.

Catches by month (not shown) also show the between-year variation in the catch distribution; the highest percentage of the total catch in YR 2005 occurred in July (61%) compared to June (47%) in YR 2004. The months of June and July accounted for 83% of the total catch in YR 2005, compared to May and June, 2004 which accounted for 79% of the total catch.

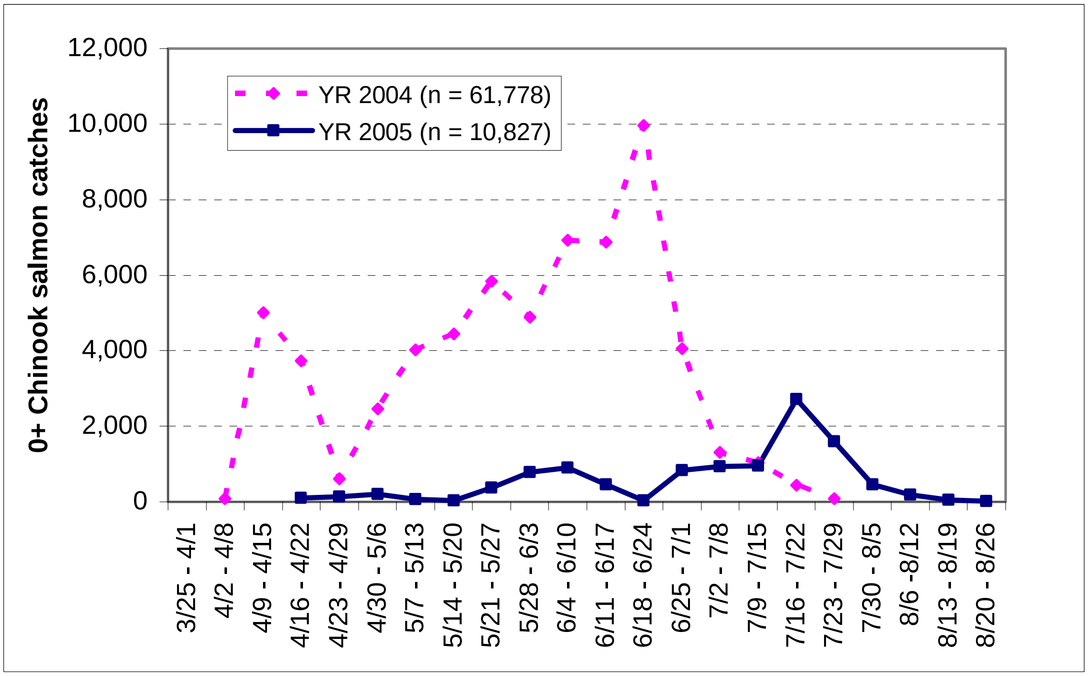

Figure 3. Comparison of 0+ Chinook salmon captures by week in YR 2005 with catches in YR 2004, lower Redwood Creek, Humboldt County, CA.

1+ Chinook salmon

1+ Chinook salmon catches were low in each study year, however catches in YR 2005 were much higher than in YR 2004 (Figure 4). 1+ Chinook salmon were captured in four of the 19 weeks of trap operation in YR 2005. Peak catches in YR 2005 occurred during 4/30 – 5/6, compared to 5/7 – 5/14 in YR 2004. 1+ Chinook salmon were captured in April and May in YR 2005, and May in YR 2004.

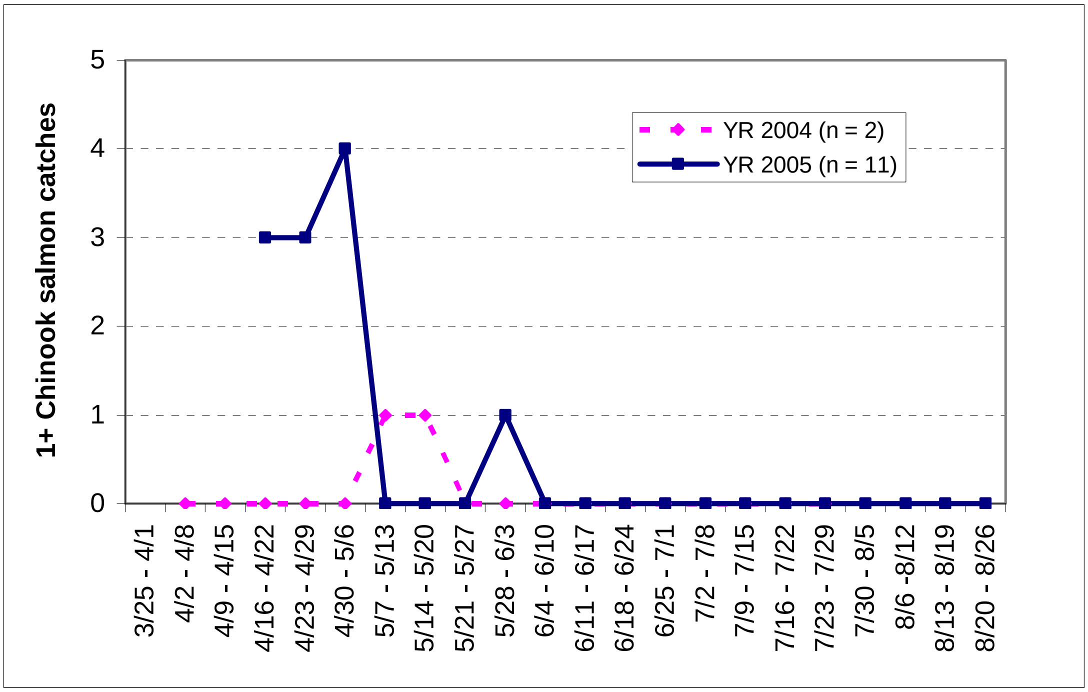

Figure 4. Comparison of 1+ Chinook salmon catches in YR 2005 with catches in YR 2004, lower Redwood Creek, Humboldt County, CA.

0+ Steelhead trout

0+ steelhead trout were captured in each week during the trapping period in YR 2005 (Figure 5). Trap catches peaked during 5/7 – 5/13 in YR 2005 and 6/11 – 6/17 in YR 2004. On a monthly basis, the greatest number of catches occurred in May (n = 515 or 38% of total) in YR 2005, and June (n = 9,947 or 53% of total) in YR 2004. The months of May and July accounted for 65% of the total catch in YR 2005, compared to June and July, 2004, which accounted for 80% of the total catch.

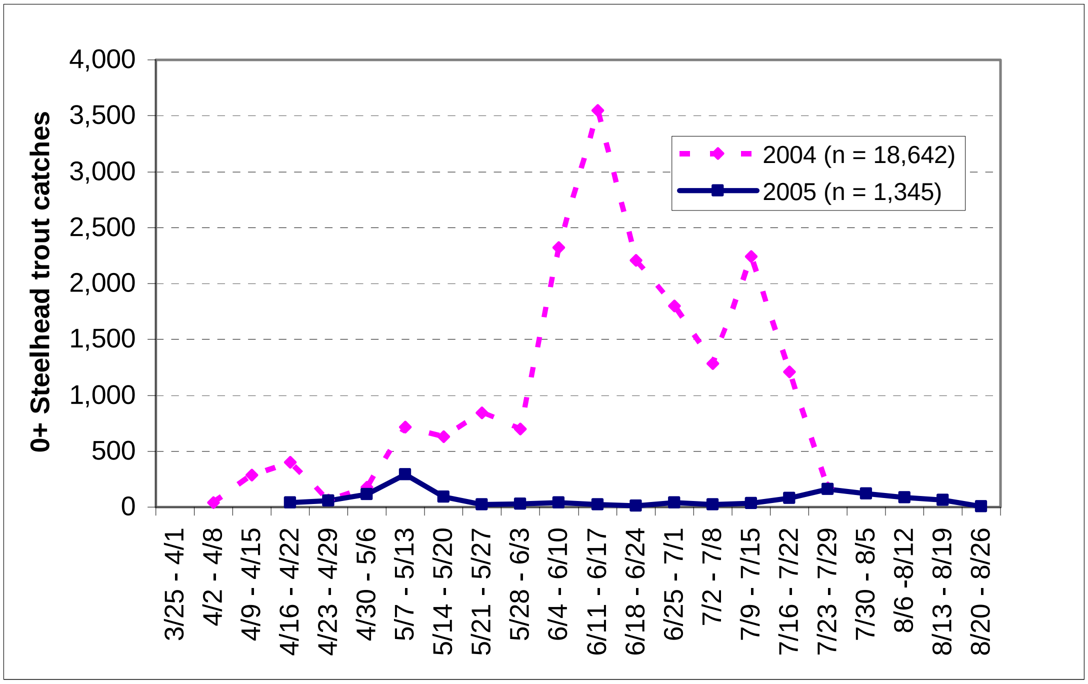

Figure 5. Comparison of 0+ steelhead trout captures in YR 2005 with catches in YR 2004, lower Redwood Creek, Humboldt County, CA.

1+ Steelhead trout

1+ steelhead trout were captured in each week during the trapping period in YR 2005 (Figure 6). Trap catches peaked during 4/23 – 5/6 in YR 2005, with smaller peaks occurring 5/28 – 6/3 and 7/30 – 8/5; in YR 2004, trap catches peaked during 5/14 – 5/20. Catches in four weeks in YR 2005 matched weekly catches in YR 2004 (Figure 6). The pattern of catches over time showed emigration in YR 2005 was extended beyond the ending date for YR 2004.

On a monthly basis, the greatest number of catches occurred in April (n = 690 or 34% of total) in YR 2005, and May (n = 3,004 or 47% of total) in YR 2004. The months of April and May accounted for 63% of the total catch in YR 2005, compared to May and June, 2004 which accounted for 75% of the total catch.

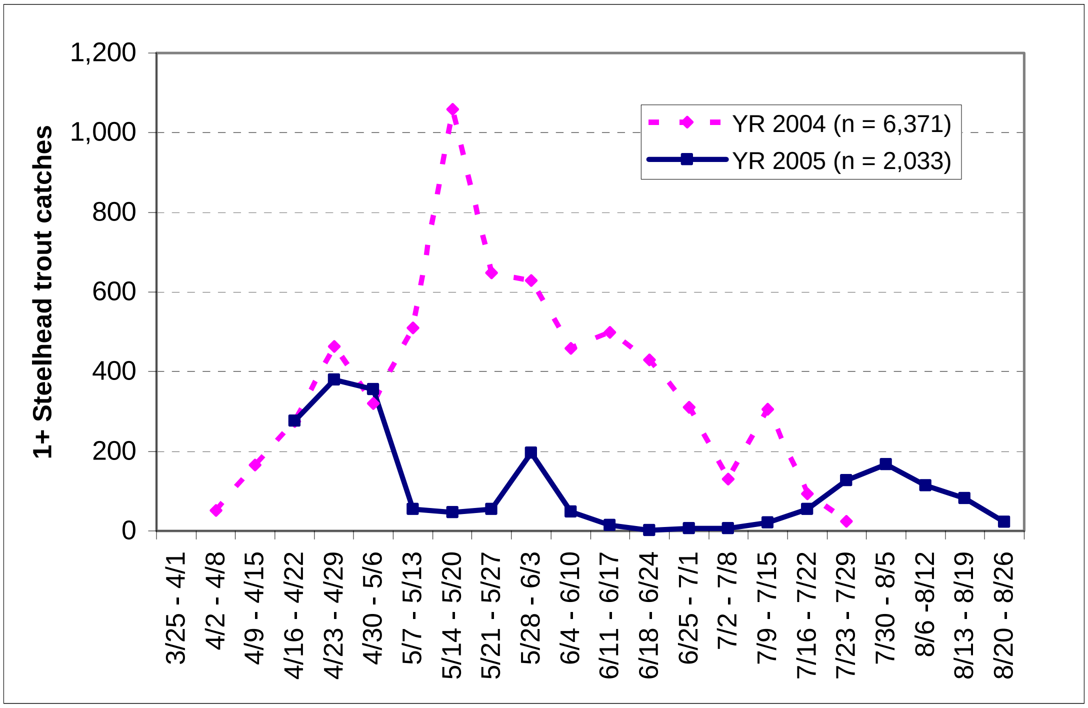

Figure 6. Comparison of 1+ steelhead trout catches in YR 2005 with catches in YR 2004, lower Redwood Creek, Humboldt County, CA.

2+ Steelhead trout

2+ steelhead trout were captured in each week during the trapping period in YR 2005 (Figure 7). Trap catches peaked during 4/30 – 5/6 in YR 2005, with a smaller peak occurring 5/28 – 6/3; in YR 2004, trap catches peaked during 5/14 – 5/20. In only a few weeks were catches comparable among study years. The pattern of catches over time showed emigration in YR 2005 was extended beyond the ending date for YR 2004.

On a monthly basis, the greatest number of catches for both trapping years occurred in May (n = 169 or 40% of total in YR 2005; n = 515 or 57% of total in YR 2004). The months of April and May accounted for 70% of the total catch in YR 2005, compared to May and June, 2004 which accounted for 78% of the total catch.

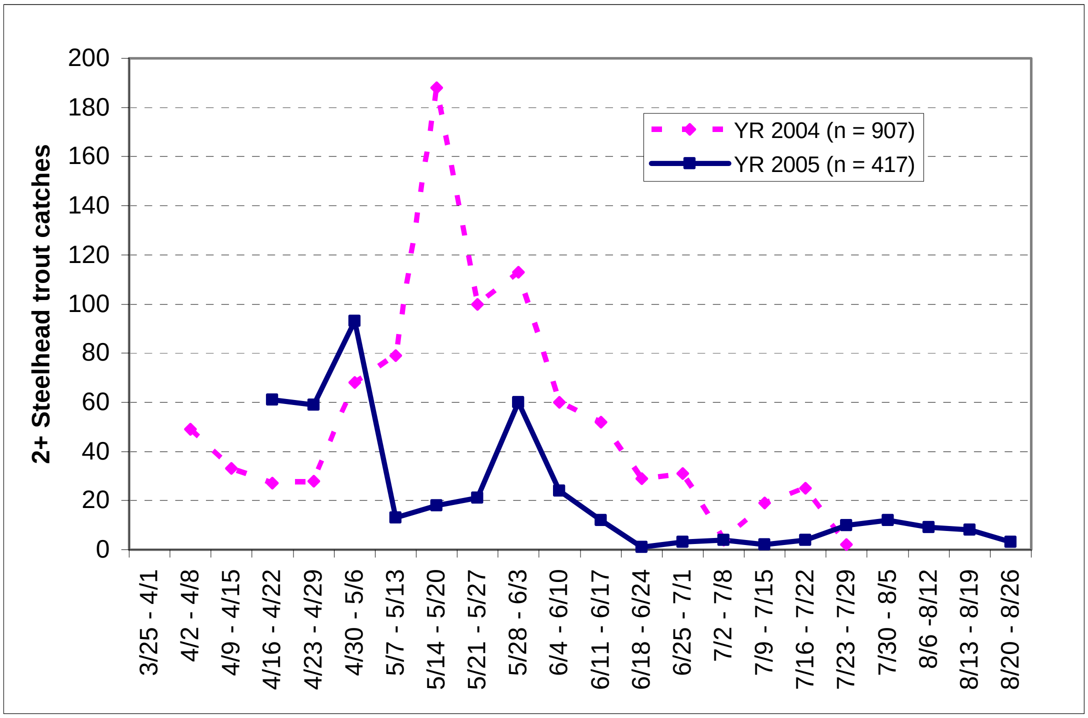

Figure 7. Comparison of 2+ steelhead trout catches in YR 2005 with catches in YR 2004, lower Redwood Creek, Humboldt County, CA.

0+ Coho salmon

0+ coho salmon were captured in 15 of 19 weeks of trap operation in YR 2005 (Figure 8). Peak catches occurred during 7/16 – 7/29 in YR 2005, and 5/14 – 5/20 and 7/16 – 7/22 in YR 2004 (Figure 8). The pattern of catches over time showed emigration in YR 2005 was extended beyond the ending date for YR 2004.

On a monthly basis, the greatest number of catches for both study years occurred in July (n = 20 or 38% of the total in YR 2005; n = 71 or 35% of the total in YR 2004). The months of June and July accounted for 58% of the total catch in YR 2005, compared to May and July, 2004 which accounted for 67% of the total catch.

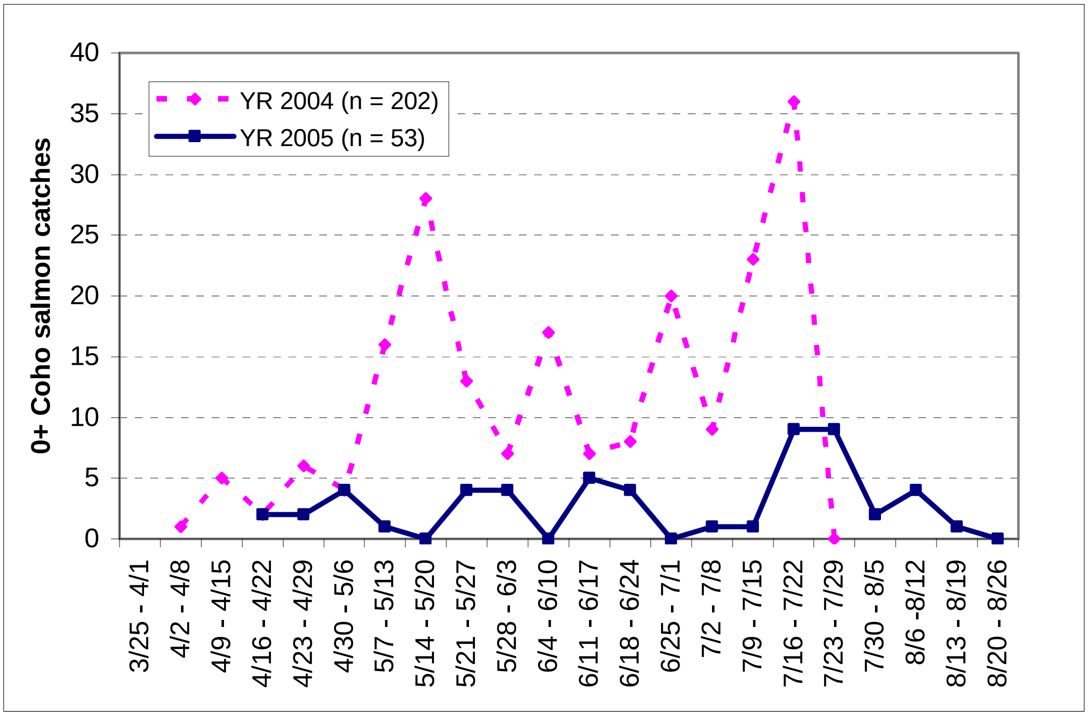

Figure 8. Comparison of 0+ coho salmon catches in YR 2005 with catches in YR 2004, lower Redwood Creek, Humboldt County, CA.

1+ Coho salmon

1+ coho salmon were caught nearly each week prior to week 6/4 – 6/10 in YR 2005 (Figure 9). Peak catches in YR 2005 occurred during 4/30 – 5/6, with a smaller peak occurring 5/21 – 5/27; in YR 2004, peak catches occurred 4/30 – 5/6, with smaller peaks occurring 4/16 – 4/22 and 5/28 – 6/3 (Figure 9).

On a monthly basis, the greatest number of catches for both study years occurred in May (n = 21 or 54% of the total catch in YR 2005; n = 43 or 62% of the total catch in YR 2004). The months of April and May accounted for 100% of the total catch in YR 2005, and 97% of the total catch in YR 2004.

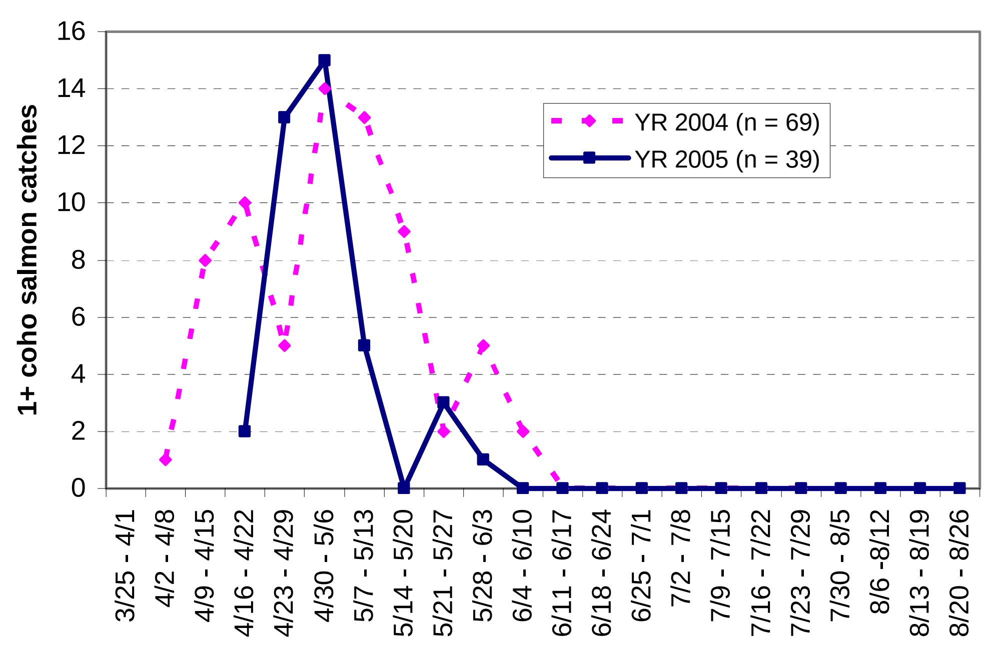

Figure 9. Comparison of 1+ coho salmon catches in YR 2005 with catches in YR 2004, lower Redwood Creek, Humboldt County, CA.

Cutthroat trout

Cutthroat trout catches were low in each study year, however catches in YR 2004 were much higher than catches in YR 2005 (Figure 10). Cutthroat trout were captured in six of 19 weeks of trap operation in YR 2005. No definitive peak in catches occurred in YR 2005, however, in YR 2004 a peak in catch occurred during 5/14 – 5/20 (Figure 10).

Catches of cutthroat trout by month were low in YR 2005. In YR 2004, May accounted for 49% of the total catch.

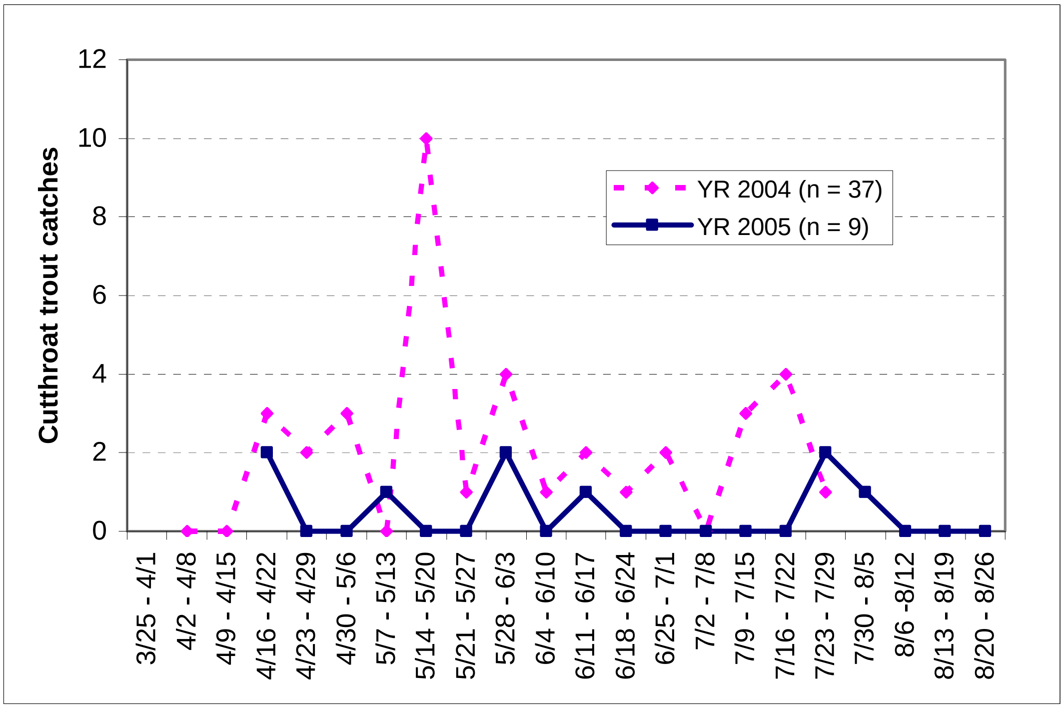

Figure 10. Comparison of cutthroat trout catches in YR 2005 with catches in YR 2004, lower Redwood Creek, Humboldt County, CA.

Trapping Efficiencies

0+ Chinook salmon

We fin clipped and released 5,150 young-of-year Chinook salmon upstream of the trap site during 85 efficiency trials over the course of trapping in YR 2005. The average number used in our weekly trials (includes 2- 6 efficiency trials) was 271, and ranged from 11 – 600 per week. Weekly trapping efficiencies in YR 2005 ranged from 5.0 – 31.4%, and averaged 11.7% (Table 6). Average trapping efficiencies among study years were similar.

0+ Chinook salmon weekly trap efficiencies in YR 2005 significantly increased over time (Correlation, $p = 0.002$, $r = 0.66$, positive slope, power = 0.93), and were negatively related to gage height (Regression, $p = 0.005$, $R^2 = 0.38$, negative slope, power = 0.86) and stream discharge (log x+1 transformation) (Regression, $p = 0.0006$, $R^2 = 0.51$, negative slope, power = 0.98).

Table 6. 0+ Chinook salmon trapping efficiency in YR 2004 and YR 2005, lower Redwood Creek, Humboldt County, CA.

	0+ Chinook salmon trap efficiency (percentage)		
	Weekly trapping efficiency		
Study Year	Range	Average	Seasonal
2004	7.3 - 20.7	11.9	11.9
2005	5.0 - 31.4	11.7	9.6

1+ Steelhead trout

We fin clipped and released 1,127 one-year-old steelhead trout upstream of the trap site during 70 efficiency trials over the course of trapping in YR 2005. The average number used in our weekly trials (includes 2 - 6 efficiency trials) was 59, and ranged from 2 – 189 individuals per week. Weekly trapping efficiencies in YR 2005 ranged from 0.0 – 7.7%, and averaged 4.4% (Table 7). The average trapping efficiency in YR 2005 was about 53% less than the average for YR 2004 (Table 7).

1+ steelhead trout weekly trap efficiencies in YR 2005 did not significantly change over time (Correlation, $p = 0.87$, $r = 0.04$, positive slope, power = 0.05). Weekly trap efficiencies were also not related to gage height (Regression, $p = 0.63$, $R^2 = 0.01$, negative slope, power = 0.07) or stream discharge (Regression, $p = 0.97$, $R^2 = 0.00$, positive slope, power = 0.05).

Table 7. 1+ steelhead trout trapping efficiency in YR 2004 and YR 2005, lower Redwood Creek, Humboldt County, CA.

	1+ steelhead trout trap efficiency (percentage)		
	Weekly trapping efficiency		
Study Year	Range	Average	Seasonal
2004	4.8 – 37.5	9.4	7.9
2005	0.0 – 7.7	4.4	4.6

2+ Steelhead trout

We fin clipped and released 306 two-year-old steelhead trout upstream of the trap site during 58 efficiency trials over the course of trapping in YR 2005. The average number used in our weekly trials (includes 1 - 5 efficiency trials) was 16, and ranged from 1 – 48 individuals per week. Weekly trapping efficiencies in YR 2005 ranged from 0.0 – 33.3%, and averaged 4.3% (Table 8). The average trapping efficiency in YR 2005 was about 25% less than the average for YR 2004 (Table 8).

The correlation of week number on 2+ steelhead trout weekly trap efficiencies, and the regressions of gage height and stream discharge on 2+ steelhead trout weekly trap efficiencies did not pass statistical assumptions (even with transformation), and results were not valid.

Table 8. 2+ steelhead trout trapping efficiency in YR 2004 and YR 2005, lower Redwood Creek, Humboldt County, CA.

	2+ steelhead trout trap efficiency (percentage)		
	Weekly trapping efficiency		
Study Year	Range	Average	Seasonal
2004	0.0 – 25.0	5.8	3.6
2005	0.0 – 33.3	4.3	2.3

1+ Coho salmon

We fin clipped and released 22 one plus-year-old coho salmon upstream of the trap site during 12 efficiency trials over the course of trapping in YR 2005. The average number used in our weekly trials (includes 1 - 4 efficiency trials) was 3, and ranged from 1 – 7 individuals per week. Weekly trapping efficiencies in YR 2005 ranged from 0.0 – 20.0%, and averaged 5.2% (Table 9). The average weekly trapping efficiency in YR 2005 was 1.4 times greater than the average for YR 2004 (Table 9).

Table 9. 1+ coho salmon trapping efficiency in YR 2004 and YR 2005, lower Redwood Creek, Humboldt County, CA.

	1+ coho salmon trap efficiency (percentage)		
	Weekly trapping efficiency		
Study Year	Range	Average	Seasonal
2004	0.0 – 25.0	3.7	3.6
2005	0.0 – 20.0	5.2	9.1

Population Estimates

0+ Chinook salmon

The population estimate (or production) of 0+ Chinook salmon emigrating past the trap in lower Redwood Creek in YR 2005 equaled 131,164 individuals with a 95% CI of 117,259 – 145,069 (Table 10). Population estimate error (or uncertainty) equaled ± 10.6%. Population emigration in YR 2005 was markedly lower than emigration in YR 2004 (N = 554,890; 95%CI 493,160 – 616,620) by 76% (Table 10).

Monthly population emigration peaked in July (N = 77,386 or 59% of total) in YR 2005 compared to June (N = 292,155 or 53% of total) in YR 2004. The two most important months for emigration in YR 2005 were June and July (N = 108,597 or 83% of total) compared to May and June (N = 431,623 or 78% of total) in YR 2004.

Table 10. 0+ Chinook salmon population estimates in YR 2004 and YR 2005, lower Redwood Creek, Humboldt County, CA.

Study Year	0+ Chinook salmon
2004	554,890 (± 11.1%)
2005	131,164 (± 10.6%)

Population emigration on a weekly basis shows the decrease in abundance in YR 2005 and differences in the migration pattern among study years (Figure 11). The greatest peak in weekly migration in YR 2005 occurred during 7/16 – 7/22 (N = 29,766), compared to 6/18 – 6/24 (N = 110,980) in YR 2004. The pattern of population emigration (similar to the catch distribution) over time showed emigration in YR 2005 was extended beyond the ending date for YR 2004 (7/29).

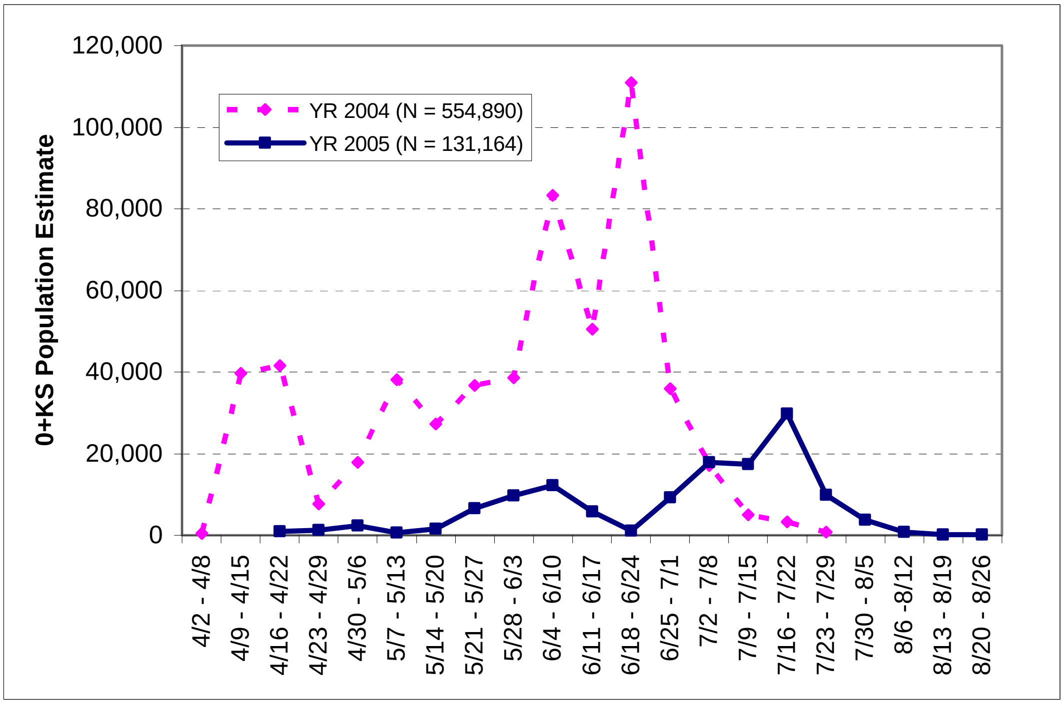

Figure 11. 0+ Chinook salmon population emigration by week in YR 2004 and YR 2005, lower Redwood Creek, Humboldt County, CA. Age/species abbreviation is the same as in Figure 2.

The population of 0+ Chinook salmon emigrants consisted of both fry (FL < 45 mm) and fingerlings (FL > 44 mm) in YR 2004 and YR 2005 (Figure 12). The number (and percentage) of fry in YR 2005 (N = 2,052 or 1.6% of total population) was much less than in YR 2004 (N = 82,854 or 15% of total population). The migration of fry in YR 2005 peaked 4/30 – 5/6 (N = 739), compared to 4/9 – 4/15 (N = 37,972) in YR 2004. The last fry to migrate past the trap site in YR 2005 occurred on 5/28, compared to 5/21 in YR 2004.

Fingerling migration was low in the beginning of trapping each study year, increased over time each year, and peaked during 7/16 – 7/22 (N = 29,766) in YR 2005 and 6/18 – 6/24 (N = 110,980) in YR 2004 (Figure 12). The total number of fingerlings in YR 2005 equaled 129,113 (or 98.4% of total population estimate) compared to 472,306 (or 85% of total population estimate) in YR 2004.

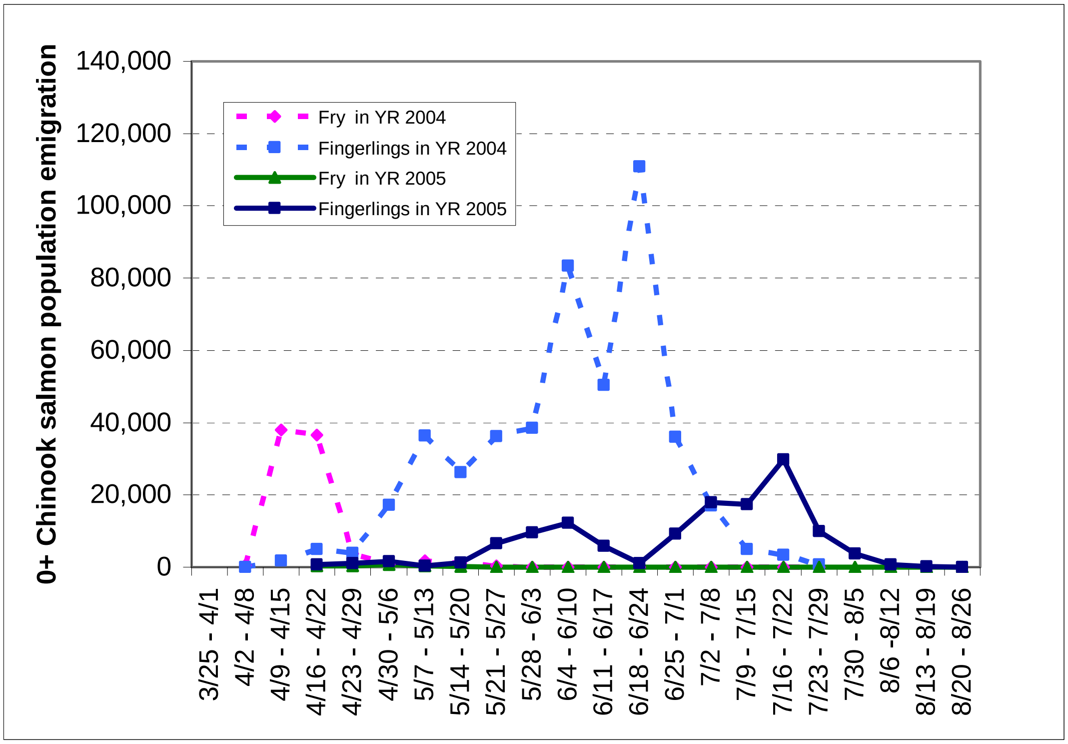

Figure 12. Estimated 0+ Chinook salmon fry and fingerling abundance and migration timing in YR 2004 and YR 2005, lower Redwood Creek, Humboldt County, CA.

1+ Steelhead trout

The population estimate (or production) of 1+ steelhead trout emigrating past the trap in lower Redwood Creek in YR 2005 equaled 32,901 individuals with a 95% CI of 24,967 – 40,835. Population estimate error (or uncertainty) equaled ± 24.1%. Population emigration in YR 2005 was 57% lower than emigration in YR 2004 (N = 77,221; 95% CI = 64,649 – 89,792) (Table 11).

Monthly population emigration peaked in April (N = 11,192 or 34% of total) in YR 2005 compared to May (N = 32,926 or 43% of total) in YR 2004. The two most important months for emigration in YR 2005 were April and May (N = 22,238 or 68% of total) compared to May and June (N = 58,680 or 76% of total) in YR 2004.

Table 11. 1+ steelhead trout population estimates in YR 2004 and YR 2005, lower Redwood Creek, Humboldt County, CA.

Study Year	1+ steelhead trout
2004	77,221 (± 16.3%)
2005	32,901 (± 24.1%)

Population emigration on a weekly basis shows the decrease in abundance in YR 2005 compared with YR 2004 (Figure 13). The greatest peak in weekly migration occurred during 4/30 – 5/6 (N = 7,494) in YR 2005, compared to 5/14 – 5/20 (N = 9,985) in YR 2004. Emigration during 6/11 – 7/15 in YR 2005 was much lower than emigration during the same time period in YR 2004 (Figure 13). The pattern of population emigration over time showed emigration in YR 2005 was extended beyond the ending date for YR 2004 (7/29) (Figure 13).

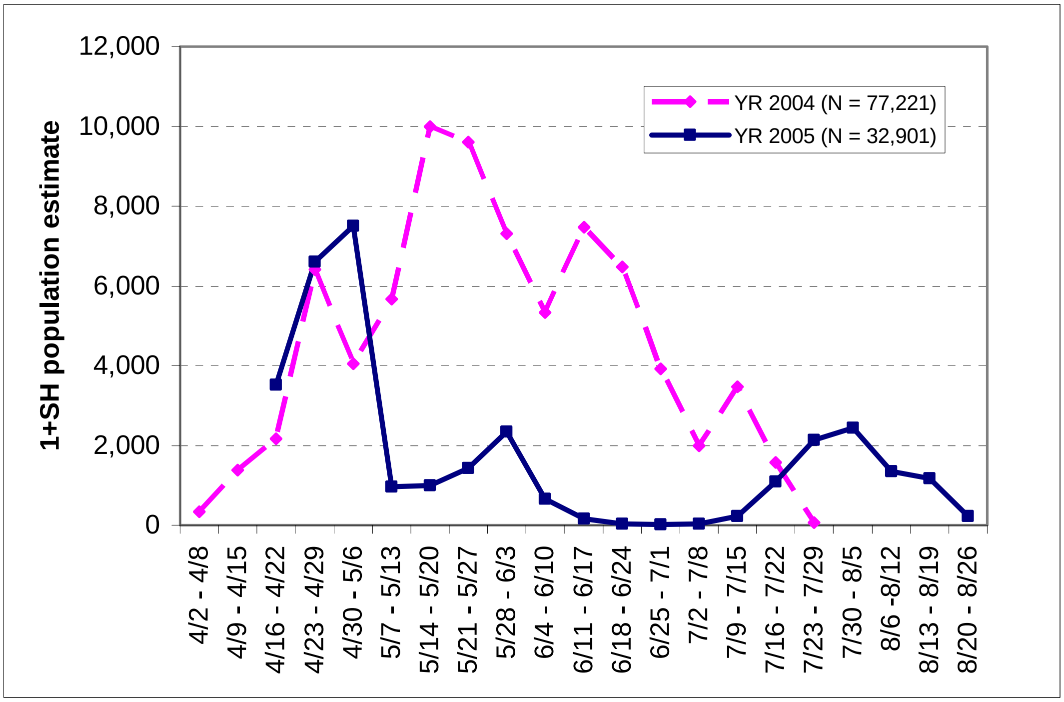

Figure 13. 1+ steelhead trout population emigration by week in YR 2004 and YR 2005, lower Redwood Creek, Humboldt County, CA. Age/species abbreviation is the same as in Figure 2.

2+ Steelhead trout

The population estimate (or production) of 2+ steelhead trout emigrating past the trap in lower Redwood Creek in YR 2005 equaled 8,754 individuals with a 95% CI of 4,975 – 12,533. Population estimate error (or uncertainty) equaled ± 43.2%. Using point estimates, population emigration in YR 2005 was 55% lower than emigration in YR 2004 (N = 19,353; 95% CI = 11,918 – 26,788) (Table 12).

Monthly population emigration peaked in May for both study years (N = 3,738 or 43% of total in YR 2005; N = 11,956 or 62% of total in YR 2004). The two most important months for emigration in YR 2005 were April and May (N = 6,391 or 73% of total) compared to May and June (N = 15,688 or 81% of total) in YR 2004.

Table 12. 2+ steelhead trout population estimates in YR 2004 and YR 2005, lower Redwood Creek, Humboldt County, CA.

Study Year	2+ steelhead trout
2004	19,353 (± 38.4%)
2005	8,754 (± 43.2%)

Population emigration on a weekly basis shows the decrease in abundance in YR 2005 compared with YR 2004 (Figure 14). The greatest peak in weekly migration occurred during 4/30 – 5/6 for both study years (N = 2,232 in YR 2005; N = 3,604 in YR 2004) (Figure 14). The pattern of population emigration over time showed emigration in YR 2005 was extended beyond the ending date for YR 2004 (Figure 14).

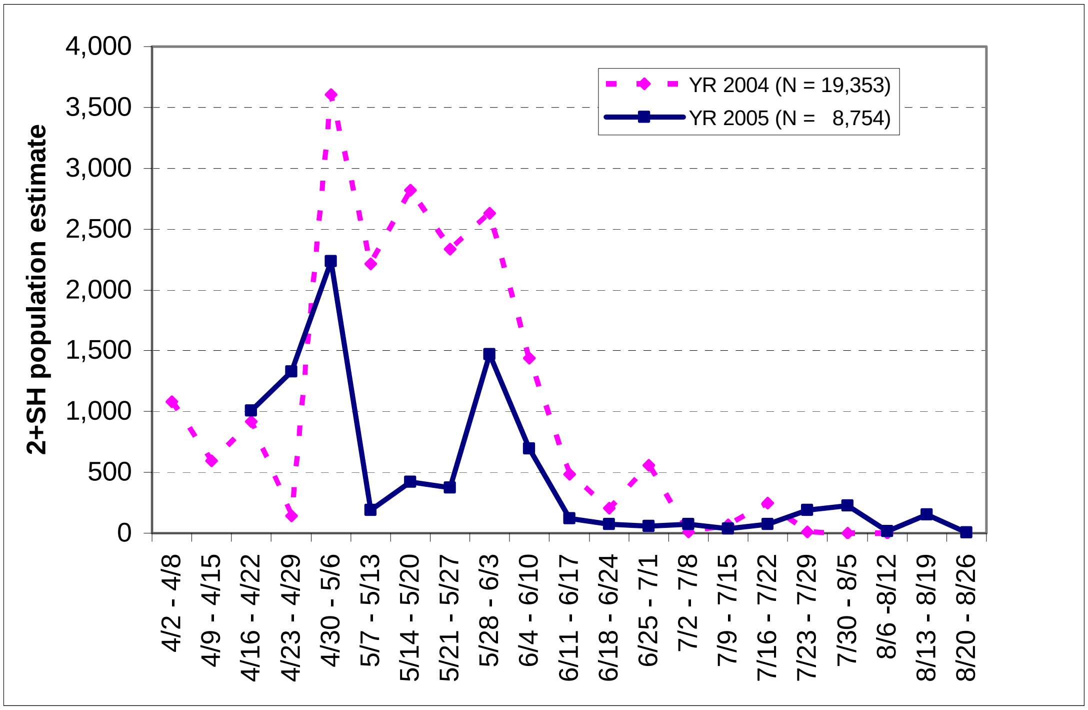

Figure 14. 2+ steelhead trout population emigration by week in YR 2004 and YR 2005, lower Redwood Creek, Humboldt County, CA. Age/species abbreviation is the same as in Figure 2.

1+ Coho salmon

The population estimate (or production) of 1+ coho salmon emigrating past the trap in lower Redwood Creek in YR 2005 equaled 183 individuals with a 95% CI of 56 – 309. Population estimate error (or uncertainty) equaled ± 69.3%. Using point estimates, population emigration in YR 2005 was 66% lower than emigration in YR 2004 (N = 535; 95% CI = 197 – 872) (Table 13).

Monthly population emigration peaked in May for both study years (N = 126 or 69% of total in YR 2005; N = 373 or 70% of total in YR 2004). The two most important months for emigration in both study years were April and May (N = 182 or 99% of total in YR 2005; N = 525 or 98% of total in YR 2004).

Table 13. 1+ coho salmon population estimates in YR 2004 and YR 2005, lower Redwood Creek, Humboldt County, CA.

Study Year	1+ coho salmon
2004	535 (± 63.2%)
2005	183 (± 69.3%)

Population emigration on a weekly basis shows the decrease in abundance in YR 2005 compared with YR 2004 (Figure 15). The majority of migration during both study years occurred prior to the end of May. The greatest peak in weekly migration occurred during 5/7 – 5/13 (N = 80) in YR 2005 and 4/30 – 5/6 (N = 182) in YR 2004 (Figure 15).

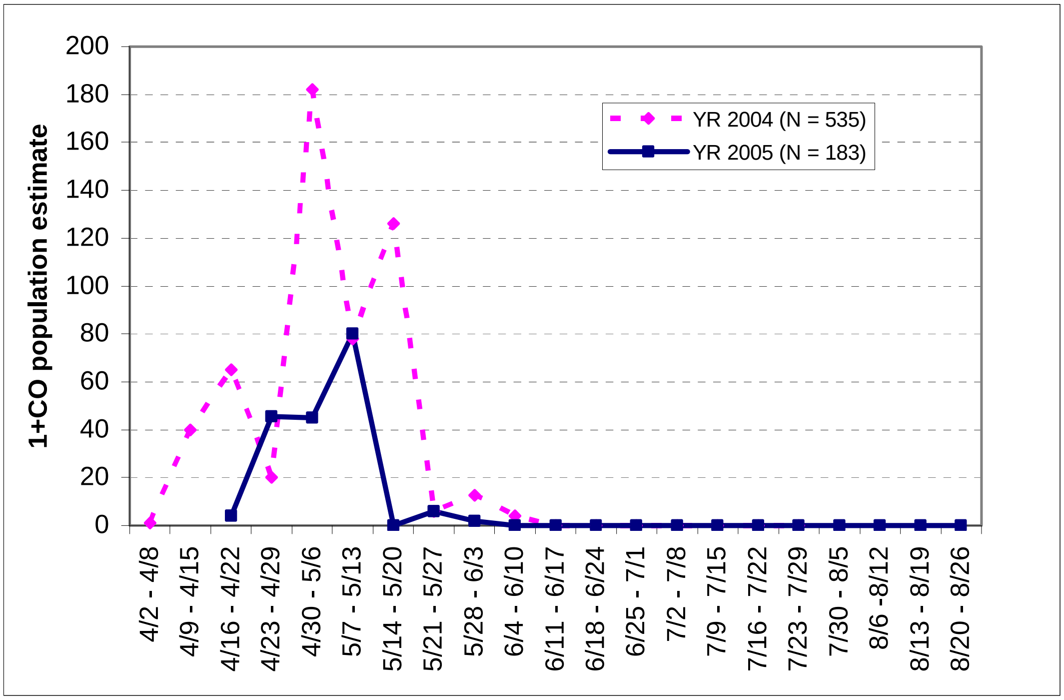

Figure 15. 1+ coho salmon population emigration in YR 2004 and YR 2005, lower Redwood Creek, Humboldt County, CA. Age/species abbreviation is the same as in Figure 2.

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

0+ Chinook salmon weekly population emigration [transformed with log(x+1)] in YR 2005 was not statistically related to the stream gage height, stream discharge, or stream temperature (Regression, $p > 0.05$ for each test); and was also not related to week number (Correlation, $p > 0.05$).

1+ steelhead trout weekly population emigration [transformed with log(x+1)] in YR 2005 was not statistically related to the stream gage height, stream discharge, or stream temperature (Regression, $p > 0.05$ for each test); however, 1+ steelhead trout weekly population emigration (not transformed) was negatively related to the trapping week number (Correlation, $r = 0.52$, $p = 0.023$, slope is negative, power = 0.65). The correlation of week number with emigration showed that 52% of the variation in emigration can be associated with trapping week number.

2+ steelhead trout weekly population emigration [transformed with log(x+1)] in YR 2005 was positively related to the stream gage height (Regression, $R^2 = 0.36$, $p = 0.007$, slope is positive, power = 0.83) and stream discharge (Regression, $R^2 = 0.23$, $p = 0.04$, slope is positive, power = 0.56), and negatively related to stream temperature (Regression, $R^2 = 0.44$, $p = 0.002$, slope is negative, power = 0.93). Weekly population emigration was also negatively related to trapping week number (Correlation, $r = 0.77$, $p = 0.0001$, slope is negative, power = 1.0).

1+ coho salmon weekly population emigration [transformed with log(x+1)] in YR 2005 was positively related to stream gage height (Regression, $R^2 = 0.31$, $p = 0.01$, slope is positive, power = 0.75), and stream discharge (Regression, $R^2 = 0.26$, $p = 0.03$, slope is positive, power = 0.63), and negatively related to stream temperature (Regression, $R^2 = 0.44$, $p = 0.002$, slope is negative, power = 0.93). The weekly population estimates were also negatively related to trapping week number (Correlation, $r = 0.71$, $p = 0.0006$, slope is negative, power = 0.97).

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 emigration). Far more 1+ steelhead trout migrated downstream than either 0+ or 2+ steelhead trout each study year (Table 14). Using catch and population data, the ratio of 0+ steelhead trout to 1+ steelhead trout to 2+ steelhead trout equaled 0.2:4:1 compared to 1:4:1 in YR 2004. Combining both years, the ratio equaled 0.7:4:1. The ratio of 1+ steelhead trout to 2+ steelhead trout equaled 4:1 for both study years.

Table 14. Comparison of 0+ steelhead trout, 1+ steelhead trout, and 2+ steelhead trout percent composition of total juvenile steelhead trout downstream migration in YR 2004 and YR 2005, lower Redwood Creek, Humboldt County, CA.

	Percent composition of total juvenile steelhead trout emigration		
Study Year	0+ steelhead*	1+ steelhead	2+ steelhead
2004	16.2	67.0	16.8
2005	3.1	76.5	20.4
Combined	12.6	69.6	17.8

* Uses actual catches instead of population estimate.

Fork Lengths and Weights

0+ Chinook Salmon

We measured (FL mm) 2,723 and weighed (g) 1,284 0+ Chinook salmon in YR 2005 (Table 15). Average FL (74.3 mm) and Wt (5.17 g) in YR 2005 was greater than the average FL (59.8 mm) and Wt (2.55 g) in YR 2004. Standard error of the mean was 0.3 mm and 0.09 g for FL and Wt in YR 2005, and 0.2 mm and 0.04 g for FL and Wt in YR 2004. The average size of fry (FL < 45 mm) was 40.6 mm in YR 2005, and 39.9 mm in YR 2004; average size of fingerlings was 76.4 mm in YR 2005 and 63.5 mm in YR 2004.

Table 15. 0+ Chinook salmon average and median fork length (mm) and weight (g) in YR 2004 and YR 2005, lower Redwood Creek, Humboldt County, CA.

		0+ Chinook Salmon					
		Fork Length (mm)			Weight (g)		
YR	(N)	n	Ave.	Median	n	Ave.	Median
2004	554,890	3,192	59.8	61.0	1,429	2.55	2.4
2005	131,164	2,723	74.3	80.0	1,284	5.17	5.6

Average weekly FL (mm) significantly increased over time (weeks) in YRS 2004 and 2005 (Correlation, $p = 0.000001$, $r = 0.97$, power = 1.0 for each test) (Figure 16). The increases in average FL over time show growth was taking place, and from 4/23 – 8/26 0+ Chinook salmon grew 0.37 mm/d in YR 2005 compared to 0.30 mm/d from 4/9 – 7/29 in YR 2004. The average weekly FL (mm) in both study years was positively related to the percentage of fingerlings each week (Regression, YR 2005, $R^2 = 0.55$, $p = 0.0003$, power = 0.99; YR 2004, $R^2 = 0.77$, $p = 0.000003$, power = 1.0). Kruskal-Wallis One-Way ANOVA on Ranks showed that the median weekly FL (79.2 mm) in YR 2005 was significantly greater than the median weekly FL (63.0 mm) in YR 2004 ($p = 0.03$).

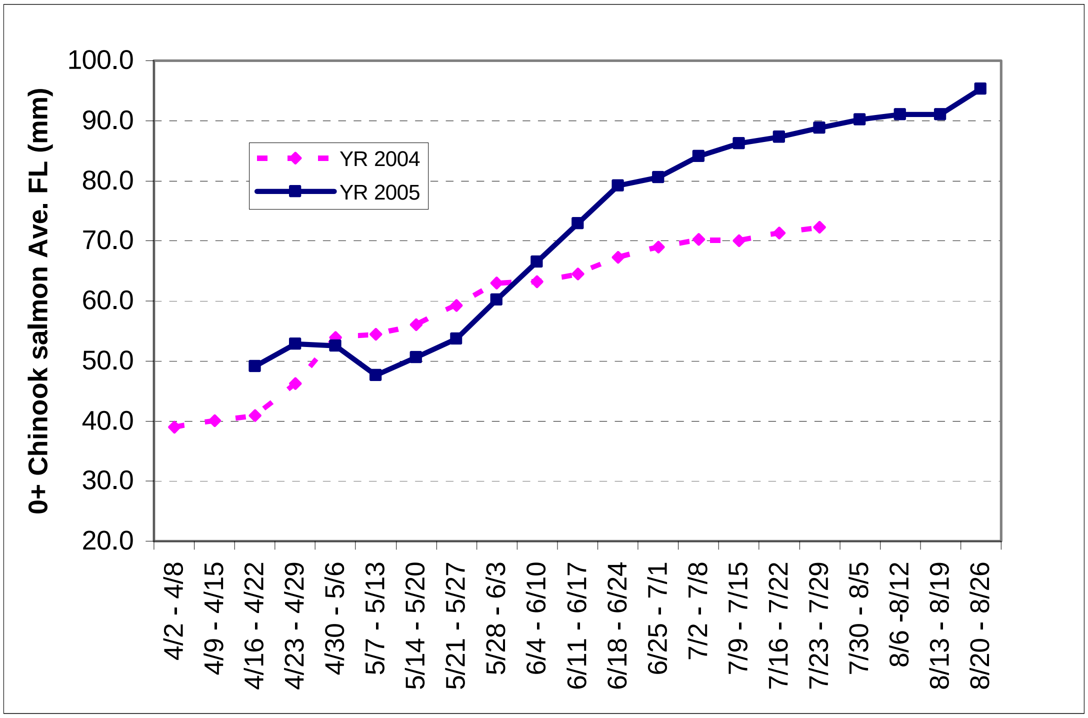

Figure 16. 0+ Chinook salmon average weekly fork length (mm) in YR 2004 and YR 2005, lower Redwood Creek, Humboldt County, CA.

Average weekly Wt (g) significantly increased over time (weeks) in YRS 2004 and 2005 (Correlation, p = 0.000001, r = 0.97 and 0.98, power = 1.0) (Figure 17). The increases in average Wt over time show growth was taking place, and from 4/30 – 8/26 0+ Chinook salmon grew 0.07 g/d in YR 2005 compared to 0.03 g/d from 4/9 – 7/29 in YR 2004. The average weekly Wt (g) in both study years was positively related to the percentage of fingerlings each week (Regression, YR 2005, $R^2 = 0.55$, p = 0.0003, power = 0.99; YR 2004, $R^2 = 0.63$, p = 0.0001, power = 1.0). The median weekly Wt (g) (5.53 g) in YR 2005 was significantly greater than the median weekly Wt (2.84 g) in YR 2004 (Kruskal-Wallace One-Way ANOVA on Ranks, p = 0.02).

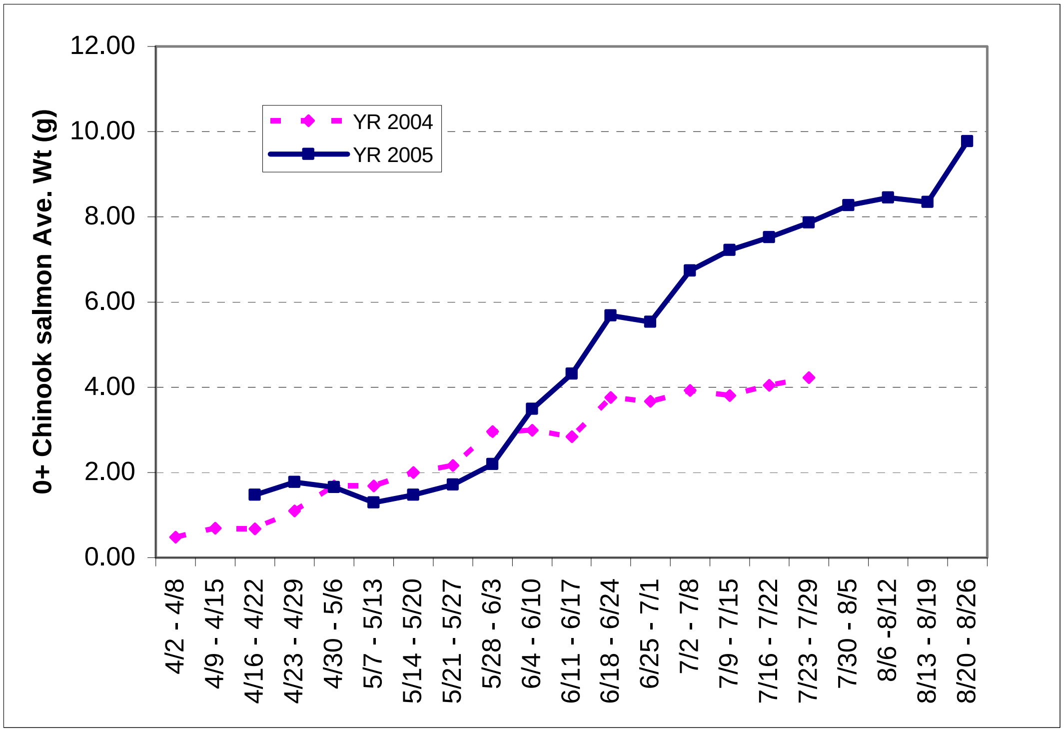

Figure 17. 0+ Chinook salmon average weekly weight (g) in YR 2004 and YR 2005, lower Redwood Creek, Humboldt County, CA.

1+ Chinook Salmon

We measured (FL mm) and weighed (g) 11 1+ Chinook salmon in YR 2005 (Table 16). Average FL (109 mm) and Wt (13.60 g) in YR 2005 was greater than the average FL and Wt in YR 2004.

Table 16. 1+ Chinook salmon average and median fork length (mm) and weight (g) in YR 2004 and YR 2005, lower Redwood Creek, Humboldt County, CA.

		0+ Chinook Salmon					
		Fork Length (mm)			Weight (g)		
YR	(N)	n	Ave.	Median	n	Ave.	Median
2004	> 2	2	101.0	101.0	2	11.25	11.25
2005	> 11	11	109.2	111.0	11	13.60	13.50

0+ Steelhead Trout

We measured (FL mm) 1,099 0+ steelhead trout in YR 2005 (Table 17). Average FL (51.1 mm) in YR 2005 was greater than the average fork length (49.6 mm) in YR 2004. Standard error of the mean was 0.6 mm in YR 2005 and 0.2 mm in YR 2004.

Table 17. 0+ steelhead trout average and median fork length (mm) in YR 2004 and YR 2005, lower Redwood Creek, Humboldt County, CA.

		0+ Steelhead Trout					
		Fork Length (mm)			Weight (g)		
YR	(N)	n	Ave.	Median	n	Ave.	Median
2004	> 18,642	2,939	49.6	52.0	-	-	-
2005	> 1,345	1,099	51.1	53.5	-	-	-

The first three average weekly FL's in YR 2004 were dominated by fry compared to the first five weeks in YR 2005 (Figure 18). Average weekly FL (mm) significantly increased over time (weeks) in YRS 2004 and 2005 (Correlation, $p = 0.000001$, $r = 0.98$, power = 1.0 for each test) (Figure 18). The increases in average FL over time show growth was taking place, and from 4/23 – 8/19 0+ steelhead trout grew 0.34 mm/d in YR 2005 compared to 0.29 mm/d from 4/9 – 7/29 in YR 2004.

Kruskal-Wallis One-Way ANOVA on Ranks showed that the median weekly FL (45.9 mm) in YR 2005 was not significantly different than the median weekly FL (50.3 mm) in YR 2004 ($p > 0.05$).

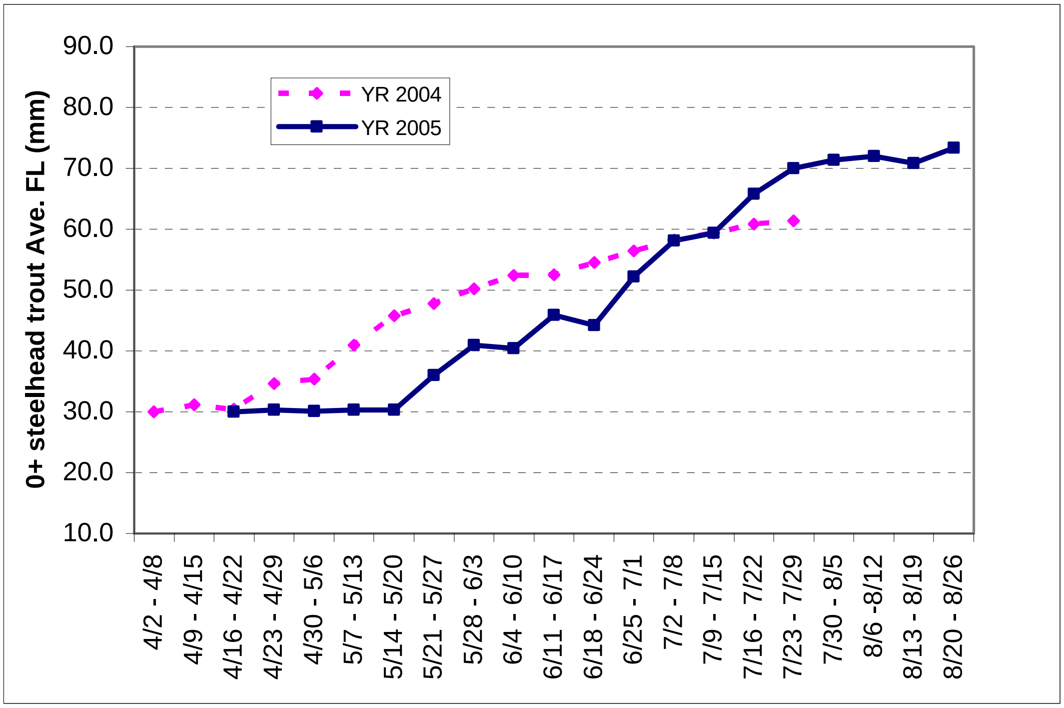

Figure 18. 0+ steelhead trout average weekly fork length (mm) in YR 2004 and YR 2005, lower Redwood Creek, Humboldt County, CA.

1+ Steelhead Trout

We measured (FL mm) 1,442 and weighed (g) 919 1+ steelhead trout in YR 2005 (Table 18). Average FL (90.8 mm) and Wt (8.31 g) in YR 2005 was greater than the average FL (84.4 mm) and Wt (7.04 g) in YR 2004. Standard error of the mean was 0.3 mm and 0.10 g for FL and Wt in YR 2005, and 0.3 mm and 0.11 g for FL and Wt in YR 2004.

Table 18. 1+ steelhead trout average and median fork length (mm) and weight (g), lower Redwood Creek, Humboldt County, CA.

		1+ Steelhead Trout					
		Fork Length (mm)			Weight (g)		
YR	(N)	n	Ave.	Median	n	Ave.	Median
2004	77,221	2,713	84.4	81.0	1,201	7.04	5.80
2005	32,901	1,442	90.8	89.0	919	8.31	7.40

Average weekly FL (mm) did not significantly change over time (weeks) in YRS 2004 and 2005 (Correlation, $p > 0.05$ for each test) (Figure 19). Average weekly fork length in YR 2005 (91.8 mm) was significantly greater than the average in YR 2004 (84.1 mm) (ANOVA, $p = 0.0007$, power = 0.95).

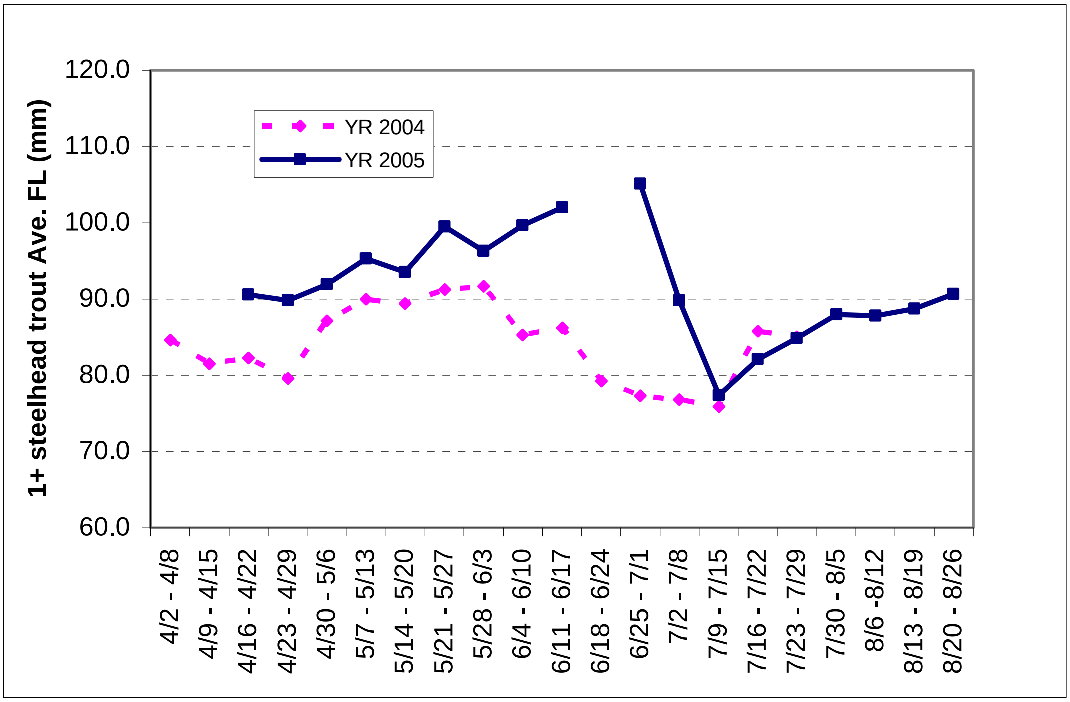

Figure 19. 1+ steelhead trout average weekly fork length (mm) in YR 2004 and YR 2005, lower Redwood Creek, Humboldt County, CA.

1+ steelhead trout average weekly Wt (g) did not significantly change over time (weeks) in YRS 2004 and 2005 (Correlation, $p > 0.05$ for each test) (Figure 20). Average weekly weight in YR 2005 (8.66 g) was significantly greater than the average in YR 2004 (6.95 g) (ANOVA, $p = 0.005$, power = 0.84).

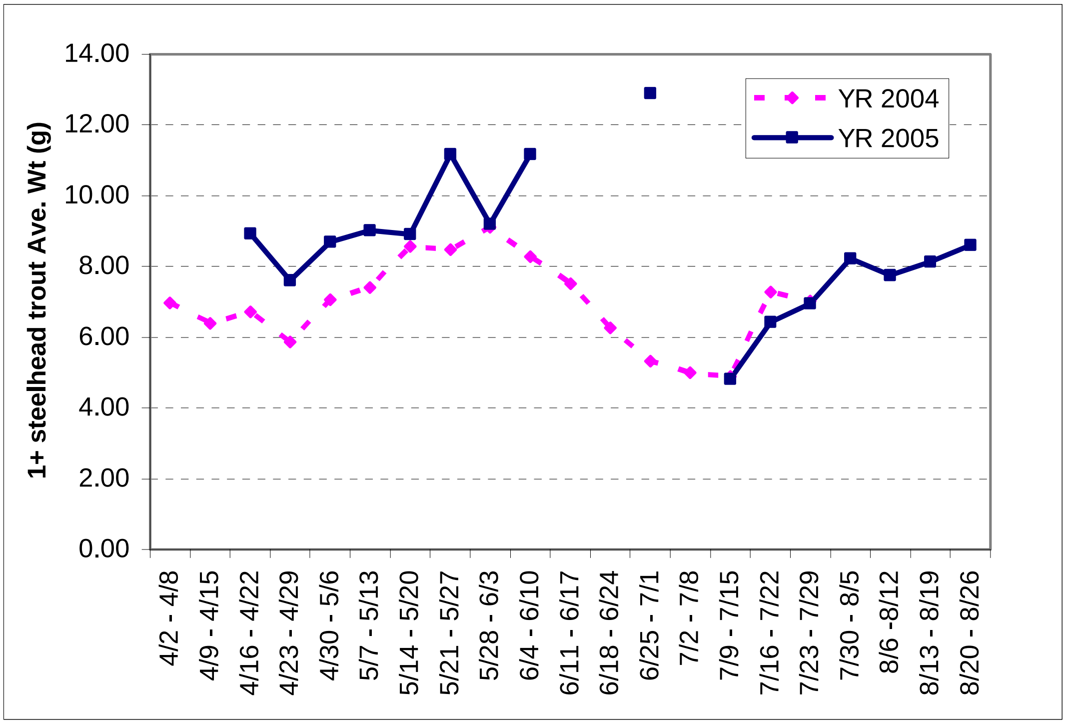

Figure 20. 1+ steelhead trout average weekly weight (g) in YR 2004 and YR 2005, lower Redwood Creek, Humboldt County, CA.

2+ Steelhead Trout

We measured (FL mm) 413 and weighed (g) 412 2+ steelhead trout in YR 2005 (Table 19). Average FL (143.2 mm) and Wt (31.25 g) in YR 2005 was greater than the average FL (141.9 mm) and Wt (30.69 g) in YR 2004. Standard error of the mean was 1.0 mm and 0.65 g for FL and Wt in YR 2005, and 0.7 mm and 0.44 g for FL and Wt in YR 2004.

Table 19. 2+ steelhead trout average and median fork length (mm) and weight (g) in YR 2004 and YR 2005, lower Redwood Creek, Humboldt County, CA.

		2+ Steelhead Trout					
		Fork Length (mm)			Weight (g)		
YR	(N)	n	Ave.	Median	n	Ave.	Median
2004	19,353	886	141.9	135.0	864	30.69	26.00
2005	8,754	413	143.2	139.0	412	31.25	27.05

The pattern of 2+ steelhead trout average weekly FL's (mm) over time in YRS 2004 and 2005 were similar (Figure 21). However, average weekly FL's in YR 2004 significantly decreased over time (Correlation, r = 0.79, p = 0.0002, slope is negative, power = 1.0); and in YR 2005, average weekly FL's did not significantly change over time (Correlation, p > 0.05). Average weekly fork length in YR 2005 (140.6 mm) was not significantly different than the average in YR 2004 (142.8 mm) (ANOVA, p > 0.05, power = 0.09).

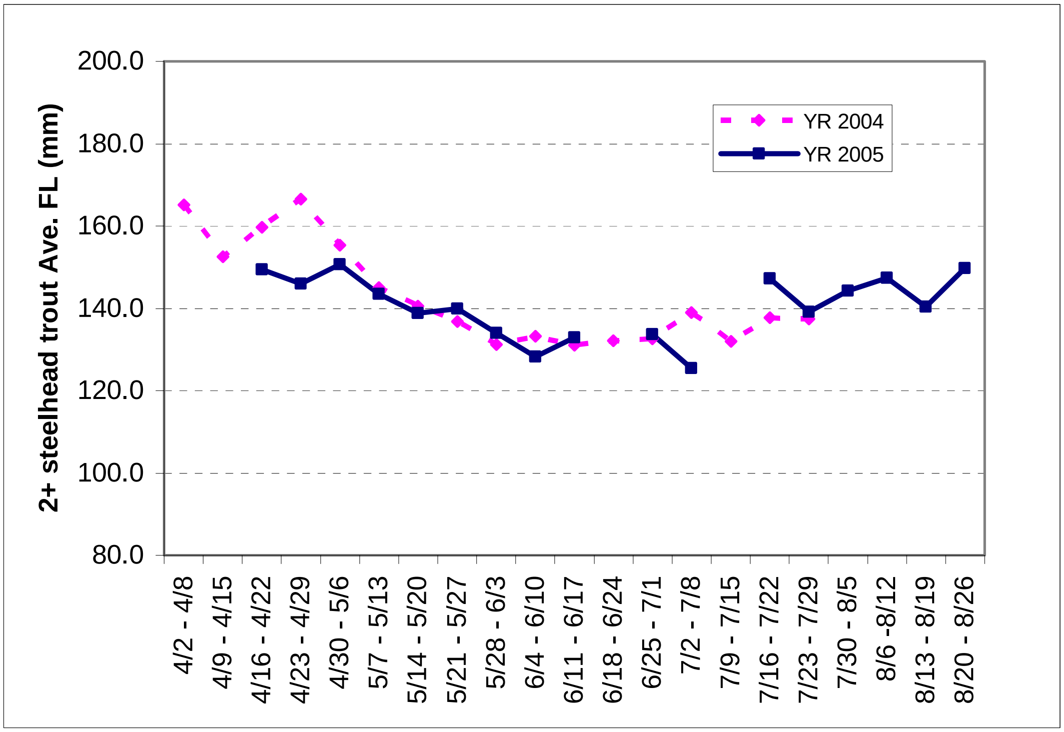

Figure 21. 2+ steelhead trout average weekly fork length (mm) in YR 2004 and YR 2005, lower Redwood Creek, Humboldt County, CA.

Similar to the FL measurements, 2+ steelhead trout average weekly Wt (g) in YR 2004 significantly decreased over time (Correlation, r = 0.80, p = 0.0001, slope is negative, power = 1.0); and in YR 2005, average weekly Wt's did not significantly change over time (Correlation, p > 0.05). Average weekly Wt (g) in YR 2005 (29.97 g) was not significantly different than the average in YR 2004 (31.51 g) (ANOVA, p > 0.05, power = 0.10).

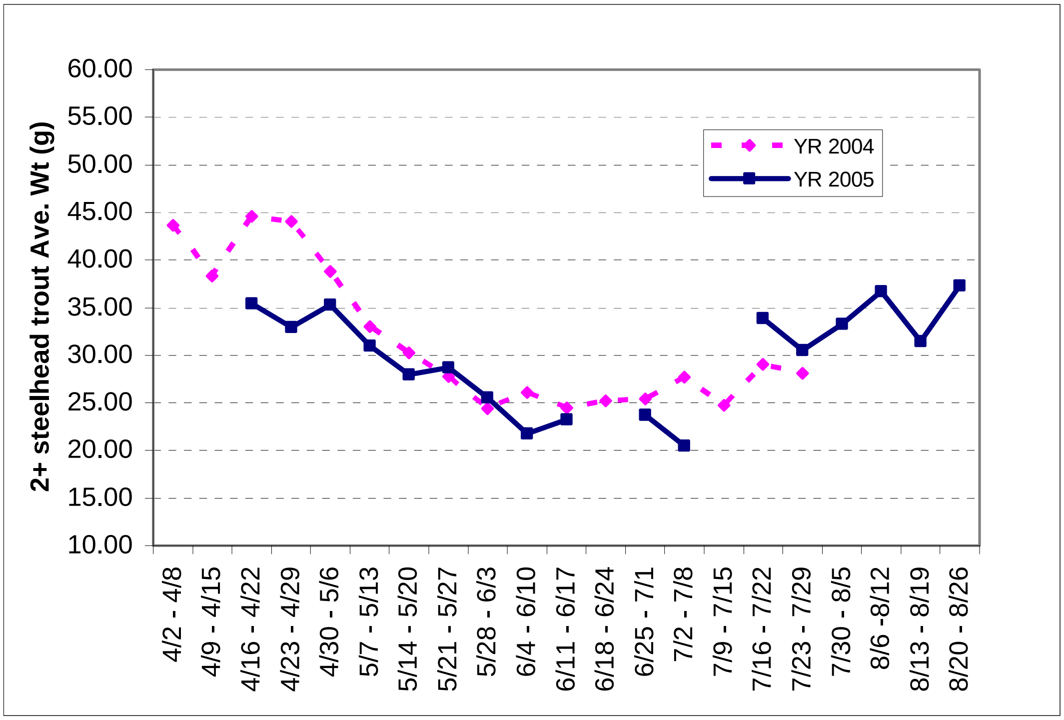

Figure 22. 2+ steelhead trout average weekly weight (g) in YR 2004 and YR 2005, lower Redwood Creek, Humboldt County, CA.

0+ Coho Salmon

We measured (FL mm) 53 and weighed (g) 50 0+ coho salmon in YR 2005 (Table 20). Average FL (61.8 mm) and Wt (3.38 g) in YR 2005 was less than the average FL (66.2 mm) and Wt (3.76 g) in YR 2004. Standard error of the mean was 2.0 mm and 0.30 g for FL and Wt in YR 2005, and 0.7 mm and 0.11 g for FL and Wt in YR 2004.

Table 20. 0+ coho salmon average and median fork length (mm) and weight (g) in YR 2004 and YR 2005, lower Redwood Creek, Humboldt County, CA.

		0+ Coho Salmon					
		Fork Length (mm)			Weight (g)		
YR	(N)	n	Ave.	Median	n	Ave.	Median
2004	> 202	202	66.2	66.0	198	3.76	3.50
2005	> 53	53	61.8	63.0	50	3.38	3.15

Data for average weekly FL's in YR 2004 failed correlation assumption tests, and results of the test of FL over time were not valid. However, average weekly FL's in YR 2005 passed assumption tests, and correlation showed a positive increase in FL over time (r = 0.97, p = 0.00006, slope is positive, power = 1.0) (Figure 23). Average weekly fork length in YR 2005 (60.7 mm) was not significantly different than the average in YR 2004 (63.4 mm) (ANOVA, p > 0.05, power = 0.08).

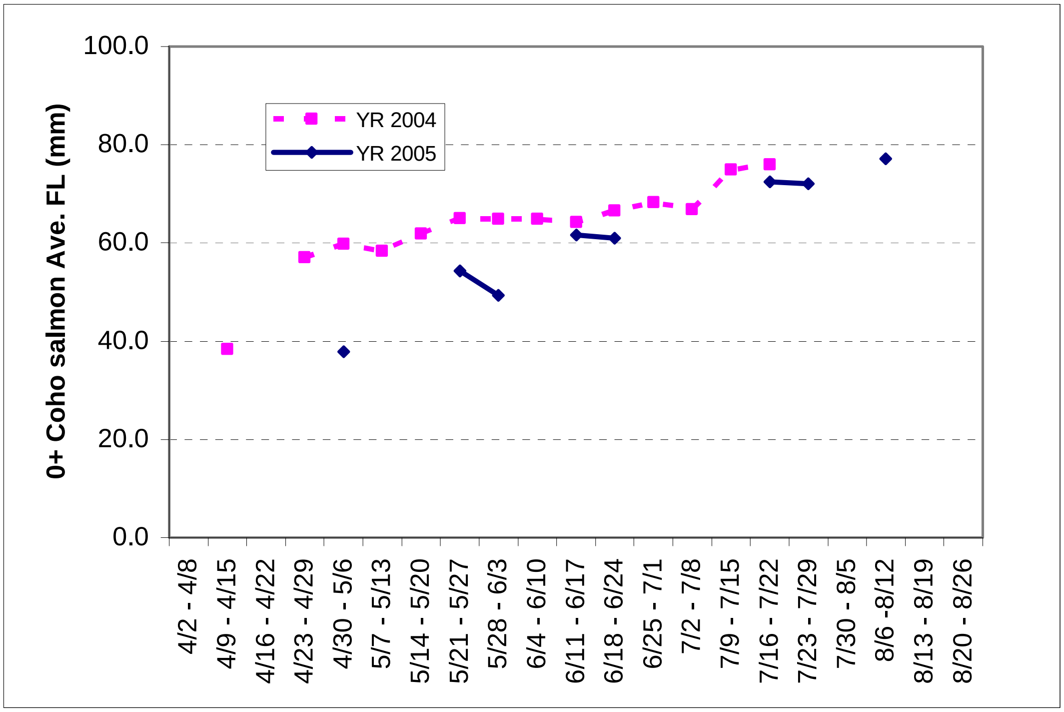

Figure 23. 0+ coho salmon average weekly fork length (mm) in YR 2004 and YR 2005, lower Redwood Creek, Humboldt County, CA.

0+ coho salmon average weekly Wt (g) in YR 2004 significantly increased over time (Correlation, r = 0.80, p = 0.000003, slope is positive, power = 1.0) as did the average for YR 2005 (Correlation, r = 0.98, p = 0.000008, slope is positive, power = 1.0) (Figure 24). Average weekly Wt (g) in YR 2005 (3.06 g) was not significantly different than the average in YR 2004 (3.44 g) (ANOVA, p > 0.05, power = 0.09).

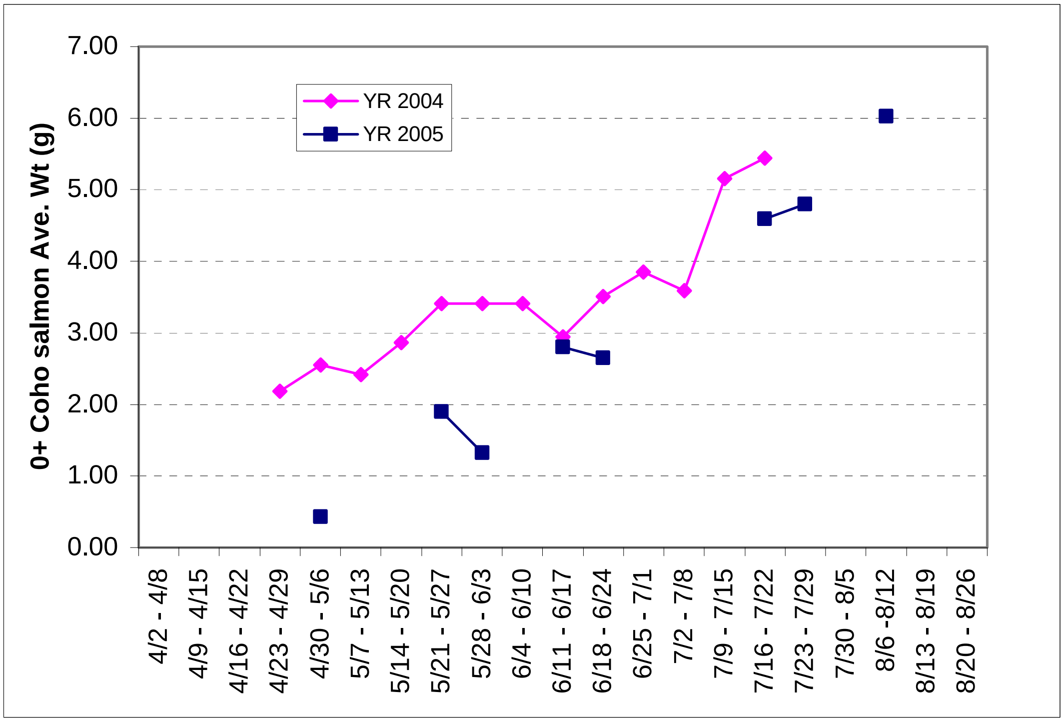

Figure 24. 0+ coho salmon average weekly weight (g) in YR 2004 and YR 2005, lower Redwood Creek, Humboldt County, CA.

1+ Coho Salmon

We measured (FL mm) 69 and weighed (g) 67 1+ coho salmon in YR 2005 (Table 21). Average FL (109.4 mm) and Wt (13.71 g) in YR 2005 was greater than the average FL (105.3 mm) and Wt (13.09 g) in YR 2004. Standard error of the mean was 1.3 mm and 0.48 g for FL and Wt in YR 2005, and 1.0 mm and 0.37 g for FL and Wt in YR 2004.

Table 21. 1+ coho salmon average and median fork length (mm) and weight (g) in YR 2004 and YR 2005, lower Redwood Creek, Humboldt County, CA.

		1+ Coho Salmon					
		Fork Length (mm)			Weight (g)		
YR	(N)	n	Ave.	Median	n	Ave.	Median
2004	535	69	105.3	105.0	67	13.09	12.09
2005	183	39	109.4	110.0	39	13.71	13.40

Average weekly fork length in YR 2004 increased over time (Figure 25) and a statistical relationship with time (weeks) was detected (Correlation, r = 0.86, p = 0.006, slope is negative, power = 0.93). Average weekly fork length in YR 2005 (109.1 mm) was not significantly different than the average in YR 2004 (106.0 mm) (ANOVA, p > 0.05, power = 0.18).

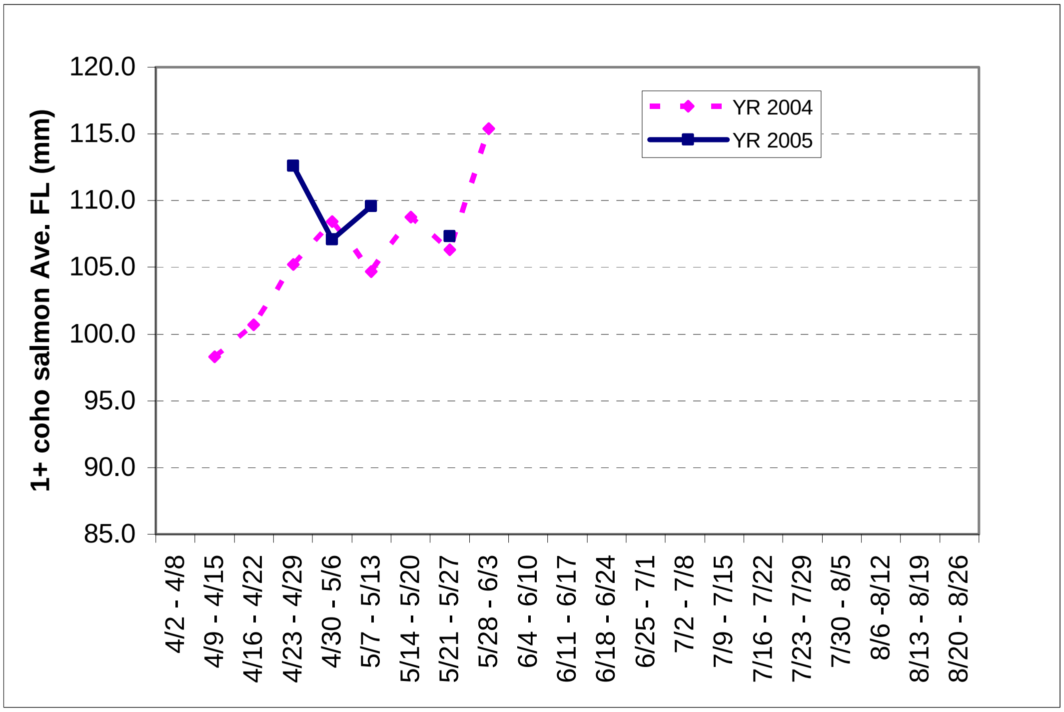

Figure 25. 1+ coho salmon average weekly fork length (mm) in YR 2004 and YR 2005, lower Redwood Creek, Humboldt County, CA.

Similar to average weekly FL data, 1+ coho salmon average weekly Wt (g) in YR 2004 significantly increased over time (Correlation, r = 0.80, p = 0.017, slope is positive, power = 0.77); and average Wt in YR 2005 did not significantly change over time (Correlation, p > 0.05, power = 0.09) (Figure 26).

Average weekly Wt (g) in YR 2005 (13.8 g) was not significantly different than the average in YR 2004 (13.3 g) (ANOVA, p > 0.05, power = 0.07).

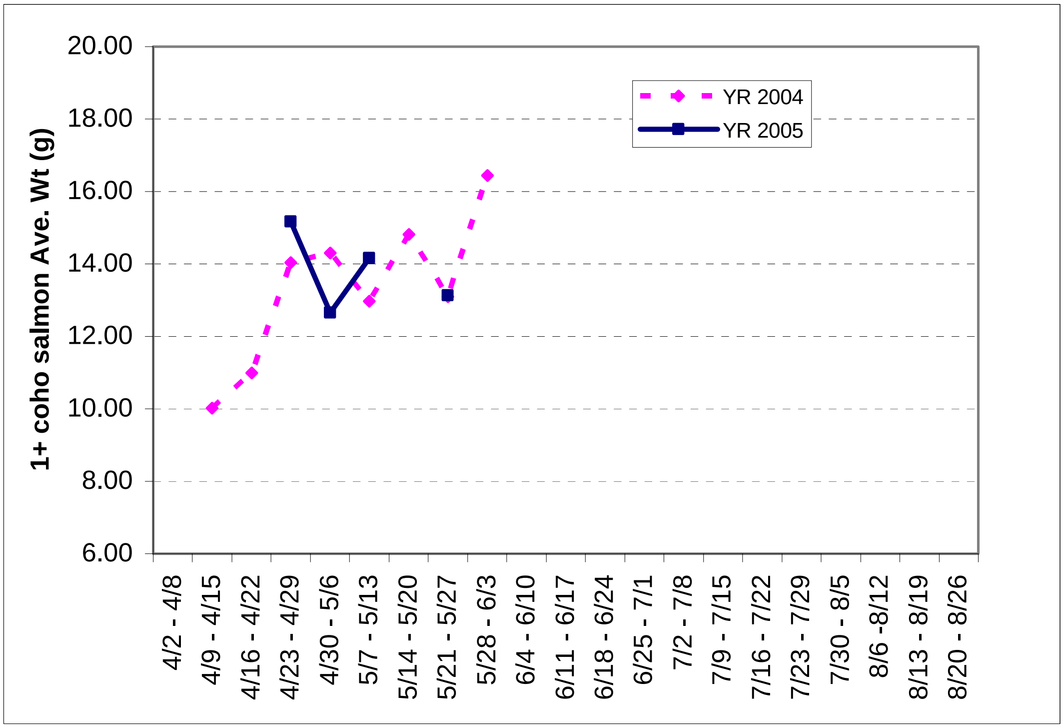

Figure 26. 1+ coho salmon average weekly weight (g) in YR 2004 and YR 2005, lower Redwood Creek, Humboldt County, CA.

Cutthroat Trout

We measured (FL mm) nine and weighed (g) seven cutthroat trout in YR 2005 (Table 22). Average FL (228.7 mm) and Wt (70.14 g) in YR 2005 was greater than the average FL (171.0 mm) and Wt (61.28 g) in YR 2004. Standard error of the mean was 34.2 mm and 16.2 g for FL and Wt in YR 2005, and 5.4 mm and 7.1 g for FL and Wt in YR 2004.

The FL's of cutthroat trout in YR 2004 ranged from 125 - 249 mm, compared to 144 - 450 mm in YR 2005.

Using FL measurements per day, the median FL in YR 2005 was significantly greater than the median in YR 2004 (Kruskal-Wallis One-Way ANOVA on Ranks, $p = 0.006$). No significant difference in median Wt among study years was detected (Kruskal-Wallis One-Way ANOVA on Ranks, $p > 0.05$).

Table 22. Cutthroat trout average and median fork length (mm) and weight (g) in YR 2004 and YR 2005, lower Redwood Creek, Humboldt County, CA.

		Cutthroat Trout					
		Fork Length (mm)			Weight (g)		
YR	(N)	n	Ave.	Median	n	Ave.	Median
2004	> 37	36	171.0	161.5	36	61.28	43.15
2005	> 9	9	228.7	185.0	7	70.14	64.80

0+ Pink Salmon

The two 0+ pink salmon captured on 4/29/05 had FL's of 38 and 39 mm.

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 2004 and YR 2005 (Table 23). Contingency tests (2x2) showed significant differences in the proportions of pre-smolt and smolt designations for 1+ steelhead trout and 2+ steelhead trout captured in YR 2005 with captures in YR 2004 (1+ SH, Chi-square, $p < 0.000001$; 2+SH, Chi-square, $p < 0.0009$). For both tests (1+SH and 2+SH) there were comparatively more smolt designations in YR 2005. The combined percentage of pre-smolts and smolts for 1+ steelhead trout and 2+ steelhead trout in YR 2004 and YR 2005 was nearly 100% (Table 23).

Table 23. Developmental stages of captured 1+ and 2+ steelhead trout in YR 2004 and YR 2005, lower Redwood Creek, Humboldt County, CA.

	Developmental Stage (as percentage of total catch)					
	1+ Steelhead Trout			2+ Steelhead Trout		
Year	Parr	Pre-smolt	Smolt	Parr	Pre-smolt	Smolt
2004	0.2	31.5	68.3	0.0	5.7	94.3
2005	0.2	13.6	86.2	0.0	1.7	98.3

Additional Experiments

Re-migration

We did not recapture any of the 1+ and 2+ steelhead trout marked and released with elastomer (n = 800) at the upper trap in YR 2004 at the lower trap in YR 2005. Thus, we have found no evidence of downstream migrating 1+ and 2+ steelhead trout holding over for another year to migrate downstream. This test also served to show that marked fish which passed the lower trap in YR 2004 did not migrate back upstream to later re-migrate downstream in YR 2005.

Travel Time and Growth

0+ Chinook Salmon

We recaptured 27 pit tagged 0+ Chinook salmon smolts at the lower trap out of 555 released from the upper trap site (Sparkman In progress). The lower trap caught pit tagged individuals from 16 of the 21 (or 76%) tagging groups released. The percentage recaptured per tagging group ranged from 0.0 – 20.0% and averaged 5.3%.

Initial fork lengths of recaptured fish ranged from 70 - 90 mm and averaged 80 mm (Appendix 6). Time to travel the 29 miles between traps ranged from 1.5 - 19.5 d and averaged 7.5 d (median = 5.5 d). Travel time was not significantly related to FL or Wt at time 1 or time 2, stream temperature, or stream discharge (Regression, $p > 0.05$ for all tests, n = 27). Travel rate ranged from 1.5 - 19.3 mi/d (2.4 – 31.1 km/d) and averaged 8.2 mi/d (13.2 km/d) (median = 5.3 mi/d or 8.5 km/d) (Appendix 6). Travel rate was weakly related to FL at time 1 (Regression, p = 0.01, $R^2 = 0.24$, slope is positive, power = 0.76, n = 27) and Wt at time 1 (Regression, p = 0.006, $R^2 = 0.27$, slope is positive, power = 0.83); no significant relationships were found with stream temperature, stream discharge or fish size at time 2 (Regression, $p > 0.05$ for each test).

Multiple fish released at the same time were occasionally recaptured at the lower trap on the same day (n = 5 recaptures). In contrast, most fish that were released at the same time (as a group) were recaptured on varying dates, and travel time for recaptured individuals (n = 5) for the 7/21/05 release group ranged from 4.5 - 19.5 days (Appendix 6).

The size of recaptured pit tagged 0+ Chinook salmon at time 2 (recapture day) was positively related to initial size at release (Regression, FL: p = 0.000001, $R^2 = 0.67$, power = 1.0; Wt: p = 0.00001, $R^2 = 0.62$, power = 1.0).

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

mm/mm/d), and specific growth rate scaled [Ave. = 0.279 %(mm/d)] (Appendix 8). The 0+ Chinook salmon averaged an absolute growth rate in Wt of 0.00 g/d, a relative growth rate of 0.001 g/g/d and a specific growth rate scaled of 0.003 %(g/d) (Appendix 8).

The relationship of travel time on various FL and Wt growth indices was significant and positive (Appendix 9). Travel time explained more of the variation in growth than any other variable tested (Appendix 9 and Figure 27).

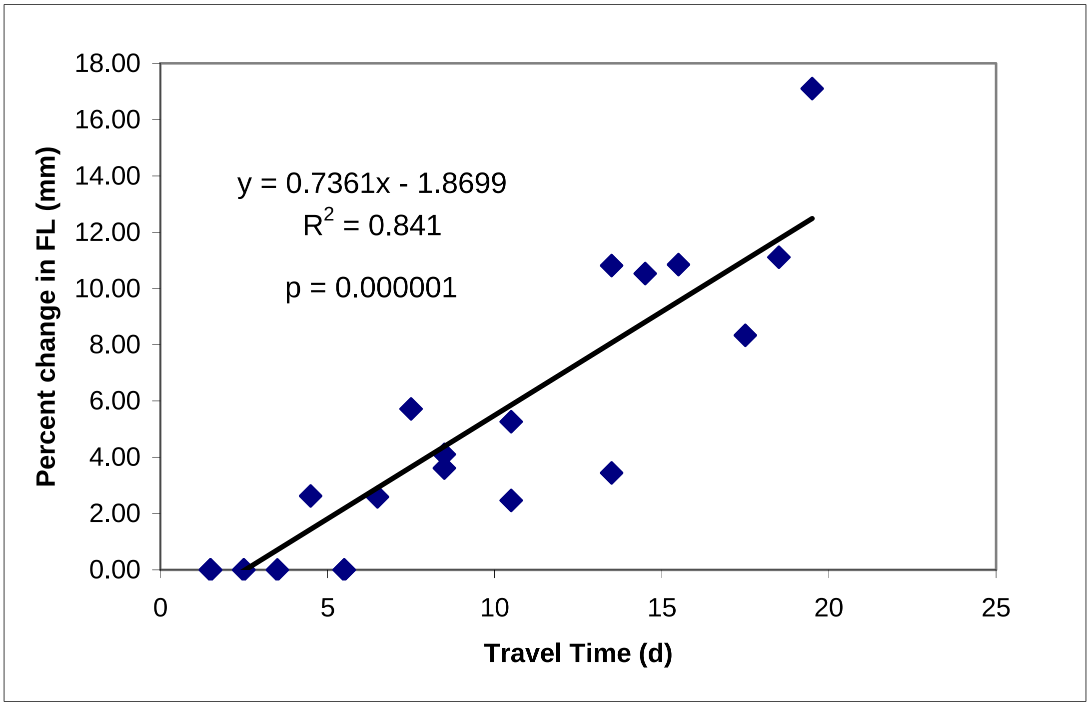

Figure 27. Linear regression of travel time (d) on percent change in FL (mm) for pit tagged 0+ Chinook salmon released at the upper trap site and recaptured at the lower trap (a distance of 29 mi) in Redwood Creek, Humboldt County, CA., 2005. Although 27 data points were used in the regression, only 18 are visible due to symbol overlap.

Separate growth statistics were determined for recaptured pit tagged 0+ Chinook salmon individuals showing either positive (n = 14) or negative growth (n = 5) (Table 22). On average, the pit tagged Chinook salmon absolute growth rate equaled 0.428 mm per day for FL, and 0.094 g per day for Wt (Table 24).

Table 24. Growth statistics for recaptured pit tagged 0+ Chinook salmon that showed positive (n = 14) or negative (n = 5) growth, Redwood Creek, Humboldt County, CA., 2005.

Positive Growth

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

Negative Growth

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

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

1+ and 2+ Steelhead Trout

We recaptured one 2+ steelhead trout marked with elastomer (which also had a partial upper caudal fin clip), and three 1+ steelhead trout marked with elastomer in YR 2005 at the lower trap in YR 2005 (Table 25). The 2+ steelhead trout was not a re-migrating fish (1+SH) from YR 2004 because the partial fin clip was fresh, and showed no signs of regeneration. We also captured two pit tagged 1+ steelhead trout at the lower trap which were released at the upper trap (Table 25). Travel time for the single 2+ steelhead trout was 7 d, as compared to the average travel time for 1+ steelhead trout of 12 d (n = 5, SD = 13.3). Travel time for 1+ steelhead trout ranged from 2 - 35 d, and travel rate ranged from 0.8 - 14.5 miles per day (Table 25).

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

Table 25. Travel time (d) and travel rate (mi/d) for 2+ steelhead trout and 1+ steelhead trout released at the upper trap site and recaptured at the lower trap (distance of 29 miles) in Redwood Creek, Humboldt County, CA., 2005.

Travel Time Experiments

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

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

** Recapture at lower trap (RM 4).

Trapping Mortality

The mortality of fish that were captured in the trap and subsequently handled was closely monitored over the course of each trapping period. The trap mortality (includes handling mortality) for a given age/species in YR 2005 ranged from 0.00 – 1.56%, and using all data, was 1.00% of the total captured and handled (Table 26). Trapping mortality was probably higher in YR 2005 compared to YR 2004 because in YR 2005 we experienced much higher stream flow and debris loading in the trap’s livebox.

Table 26. Trapping mortality for juvenile salmonids captured in YR 2004 and YR 2005, lower Redwood Creek, Humboldt County, CA.

	Trapping Mortality					
	YR 2004			YR 2005		
Age/spp.*	No. Caught	No. of mortalities	% Mortality	No. Caught	No. of mortalities	% Mortality
0+ KS	61,778	121	0.20	10,827	101	0.93
1+ KS	2	0	0.00	11	0	0.00
0+ SH**	18,642	44	0.24	1,345	21	1.56
1+ SH	6,371	2	0.03	2,033	20	0.84
2+ SH	907	0	0.00	417	4	0.96
0+ CO	202	0	0.00	53	0	0.00
1+ CO	69	0	0.00	39	0	0.00
CT	37	0	0.00	9	0	0.00
Total:	88,088	167	0.19	14,734	146	1.00

* Age/spp abbreviation is the same as in Figure 2.

** Includes a small but unknown percentage of young-of-year cutthroat trout.

Stream Temperatures

The average daily (24 hr period) stream temperature from 4/19/05 – 8/26/05 was 15.58 ^{o}C (or 60.4 ^{o}F) (95% CI = 15.08 – 16.08 ^{o}C), with daily averages ranging from 9.98 – 19.85 ^{o}C (50.0 – 67.7 ^{o}F). Median stream temperature in YR 2005 was 15.08 ^{o}C (59.1 ^{o}F). The average daily (24 hr period) stream temperature from 4/04/04 – 7/27/04 was 15.50 ^{o}C (or 59.9 ^{o}F) (95% CI = 15.02 – 15.98 ^{o}C), with daily averages ranging from 10.16 – 19.47 ^{o}C (50.3 – 67.0 ^{o}F). Median stream temperature in YR 2004 was 15.79 ^{o}C (60.4 ^{o}F).

The average daily stream temperature in YR 2005 from 4/19/05 – 7/27/05 (truncated to compare with YR 2004) was 14.69 ^{o}C (58.4 ^{o}F); and the average daily stream temperature from 4/19/04 – 7/27/04 (truncated to compare with the truncated data of YR 2005) was 16.08 ^{o}C (60.9 ^{o}F). The median daily stream temperature (truncated) in YR 2005 (14.49 ^{o}C) was significantly lower than median daily stream temperature (truncated) in YR 2004 (16.19 ^{o}C) (Kruskal-Wallis One Way ANOVA on Ranks, p = 0.0001).

Average monthly stream temperatures during the majority of the trapping season (April – July) in YR 2005 ranged from 11.5 – 18.5 ^{o}C (52.7 – 65.3 ^{o}F) (Table 27). In YR 2004, average monthly stream temperatures during trapping ranged from 11.9 – 18.6 ^{o}C (53.4 – 65.5 ^{o}F) (Table 27). Highest stream temperatures occurred in the later part of the trapping season (July or August) each study year. When comparing the months of April – July or April – August among study years, no significant differences were detected (ANOVA, p > 0.05 for each test).

Table 27. Average monthly stream temperatures (^{o}C) during the majority of the trapping periods in YR 2004 and YR 2005, lower Redwood Creek, Humboldt County, CA.

	Average Stream Temperature (^{o}C)	
Month	YR 2004	YR 2005
April	11.92*	11.49*
May	14.66	12.82
June	16.78	14.55
July	18.62*	18.51
August	-	18.45*
Average:	15.50	15.16

* Measurements do not encompass entire month.

The maximum weekly average temperature (MWAT) and the maximum weekly maximum temperature occurred in July for both study years (Table 28). Truncated and non-truncated data gave similar values which were nearly equal among study years (Table 28).

Table 28. **Maximum weekly average temperature (MWAT) and maximum weekly maximum temperature (MWMT) for lower Redwood Creek stream temperatures ^{o}C (^{o}F in parentheses) in both study years, Humboldt County, CA.**

		MWAT**		MWMT***	
Year	Time period	Date occurred	^{o}C (^{o}F)	Date occurred	^{o}C (^{o}F)
2004	4/07 – 7/24	7/22	19.2 (66.6)	7/18	22.2 (72.0)
2004*	4/22 – 7/24	7/22	19.2 (66.6)	7/18	22.2 (72.0)
2005	4/22 – 8/23	7/17	19.3 (66.7)	7/17	22.1 (71.8)
2005*	4/22 – 7/24	7/17	19.3 (66.7)	7/17	22.1 (71.8)

* Data truncated to same period of measurements for equal comparison among 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 (not truncated) in lower Redwood Creek significantly increased over time (Correlation, r = 0.91, p = 0.000001, slope is positive, power = 1.0) (Figure 28). The minimum stream temperature (not truncated) in YR 2005 equaled 8.99 ^{o}C (48.2 ^{o}F) and occurred on 4/19/05; the maximum stream temperature equaled 22.6 ^{o}C (72.7 ^{o}F) and occurred on 7/18/05.

The average stream temperature during the study period in YR 2005 was inversely related to the gage height of the stream at the trapping site (Regression, R2 = 0.82, p = 0.0000001, slope is negative, power = 1.0).

The average stream temperature in YR 2004 also increased over time [time was transformed with log(x+1)] (Correlation, r = 0.88, p = 0.000001, power = 1.0) (Figure 29). Average daily stream temperatures in YR 2005 were lower than temperatures in YR 2004 from 4/27 – 6/29 (Figure 29); however, the median daily stream temperature during the study period in YR 2004 (15.8 ^{o}C or 60.4 ^{o}F) was not significantly different than the median in YR 2005 (15.1 ^{o}C or 59.2 ^{o}F) (non-truncated data, Kruskal-Wallis One-Way ANOVA on Ranks, p > 0.05). When using truncated data (to match measurement dates among years; 4/19 – 7/27) the median daily stream temperature in YR 2004 (16.2 ^{o}C or 61.2 ^{o}F was significantly greater than the median in YR 2005 (14.5 ^{o}C or 58.1 ^{o}F) (Kruskal-Wallis One-Way ANOVA on Ranks, p = 0.0001).

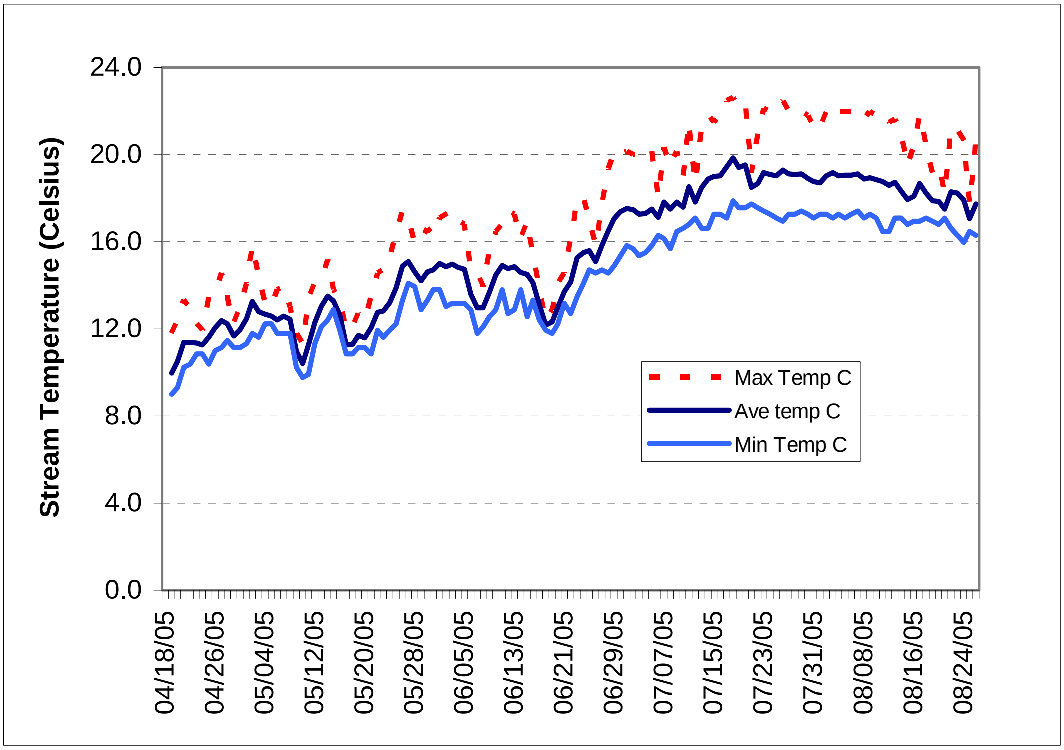

Figure 28. Average, minimum, and maximum stream temperatures (Celsius) at the trap site in lower Redwood Creek, Humboldt County, CA., 2005.

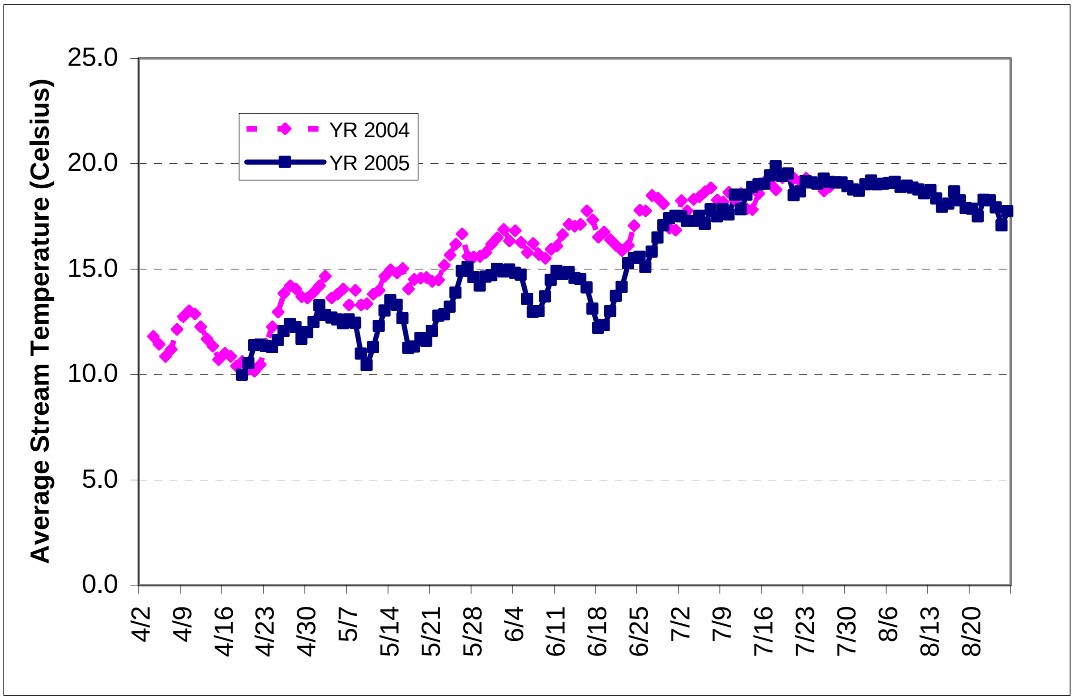

Figure 29. Average daily stream temperatures in YR 2004 and YR 2005, lower Redwood Creek, Humboldt County, CA.

DISCUSSION

The main goal of our downstream migration study in lower Redwood Creek is to estimate and monitor the production of Chinook salmon, steelhead trout, and coho salmon from the majority of the Redwood Creek watershed in a reliable, long-term manner. The long term goal is to monitor trends in smolt abundance and smolt size to detect positive or negative changes due to watershed conditions and restoration activities in the basin. Redwood Creek is a difficult, if not impossible stream to monitor for adult salmon and steelhead populations on a long term basis using traditional techniques (weirs and spawning ground surveys). 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 second consecutive year of trapping in lower Redwood Creek was a wet year, with average precipitation and stream flow during the trapping period greater than the historic and recent averages. Precipitation during the trapping period in YR 2005 (39.9 cm) was 1.7 times greater than the historic average, and 3.9 times greater than rainfall during YR 2004. In response, the average stream flow in which we operated the trap was about 2 times greater than the historic average, and 4.2 times greater than the average in YR 2004. Average stream flow from April – July 2005 was the fourth highest in the 54 years of record, and thus, the chance that a higher average flow will occur is about 5.6%. The increase in stream flow in YR 2005 probably led to cooler stream temperatures which in turn lowered the average stream temperature compared to YR 2004. High stream flow in YR 2005 also appeared to increase the summer base flow because we did not observe dry sections in lower Redwood Creek as in YR 2004.

Although conditions for trapping in YR 2005 were difficult, we were able to operate the trap and run multiple efficiency trials over a range of trapping conditions to produce a reliable catch and population estimate for most species at age. The 17 days we originally missed (from April 2nd to April 18th) prior to setting the trap in YR 2005 was estimated to equal 3.4 – 13.0% of a given population estimate based upon data collected in YR 2004. These percentages could be higher than what actually occurred during YR 2005 because at the more extreme flow conditions (unlike YR 2004) it appears that juvenile salmonids substantially decrease emigration as evidenced by trapping efforts in the upper basin. The population estimate least affected by the lack of trapping the initial 17 days (on a percent basis) was for 1+ steelhead trout, and the population estimate most affected was for 1+ coho salmon. The 12 days we missed trapping (after trap deployment) did not appear to greatly influence any total catch or population estimate except for 0+ steelhead trout and 1+ coho salmon. However, the catches during these 12 missed days were estimated using linear regression techniques, and then added to a given stratum for expansion to the population level (Roper and Scarnecchia 1999) to account for the (estimated) number of missed fish. The corrected population estimate for a given species at age fell within the 95% confidence interval for the uncorrected population point estimate; thus, the number of fish missed when the trap was inoperable would not have greatly impacted population estimates.

0+ Chinook Salmon

0+ Chinook salmon (ocean-type) were the most numerous migrant in both study years, however, the population emigrating in YR 2005 was much lower (by 76%) than the population emigrating in YR 2004. The reduction in population size we observed in YR 2005 could be due to: 1) decrease in the total number of spawners upstream of the trap site, 2) high bedload mobilizing flows in early December which scoured or jostled redd gravels, or 3) some combination of factors 1 and 2. Changes in spawner distributions are not likely responsible for the large decrease because Chinook salmon do not generally spawn in mainstem areas below the trap, and the number of spawners in Prairie Creek was not exceptionally large for that year. The large decrease in YR 2005 was probably not due to the lack of trapping from 4/2 – 4/18 because in YR 2004, only 10% of the juvenile Chinook salmon population emigrated during this time period. Additionally, few juveniles were captured from 4/19 – 4/31 in YR 2005.

Currently, we cannot separate effects of lower adult population size during years with high, bedload mobilizing flows on the subsequent production of juveniles because adult counts are not conducted. 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. 2003, Don Chapman pers. comm. 2003, Greene et al. 2005); and that estimates of mortality attributable to high flows and redd scour can reach 90% (Schuett-Hames et al. 2000). Greene et al. (2005) were able to show that the flood recurrence interval (and magnitude of floods) during Chinook salmon intragravel development was the second most important variable in their models used to predict the return rate of adult Chinook salmon. They further report that "large flow events may be a key factor in regulating Chinook salmon populations in the Skagit River basin, Washington" (Greene et al. 2005). High flows during December 8th (15,300 cfs) in Redwood Creek could have mobilized (or jostled) redd gravels (Mary Ann Madej pers. comm. 2006) which would then cause high egg mortality in the redd. This hypothesis is also relevant to populations upstream of the upper trap site (RM 33) because in two of the six study years, high bedload mobilizing flows occurred during the spawning season and subsequent juvenile production was severely reduced (Sparkman 2005). Adult Chinook salmon that spawned upstream of the lower trap after the high flow events in YR 2005 would not be subjected to the redd scour, and thus their progeny are more likely to be the survivors that made up the majority of the juvenile Chinook salmon population estimate for YR 2005.

0+ Chinook salmon population emigration in YR 2005 peaked in July, and lacked a large migration during June as in YR 2004 (N = 292,155). The two months within which the majority of emigration occurred was June and July in YR 2005, and May and June in YR 2004. Population emigration by week clearly showed that emigration in YR 2005 was delayed compared to YR 2004, with the peak in weekly emigration occurring four weeks later than the peak in YR 2004. Weekly population emigration in YR 2004 and YR 2005 closely resembled the catch distribution each year.

The 0+ Chinook salmon (ocean-type) emigrating from Redwood Creek exhibit two different juvenile life histories (fry and fingerling) based on size and time of downstream migration. The fry are migrating shortly after emergence from spawning redds, and therefore are much smaller than the fingerlings which have reared in the stream for a longer period of time. The emigration of 0+ Chinook salmon fry began near the onset of trapping in both study years, peaked during 4/30 – 5/6 in YR 2005 and 4/9 – 4/22 in YR 2004, and decreased to relatively low values by 5/21 in YR 2005, compared to 4/23 in YR 2004. Factors that can influence the temporal component to fry migration are: 1) time of adult spawning, 2) how far upstream of the trap the adults spawned, 3) time from egg deposition to fry emergence from redds, and 4) travel rate.

Post emergent fry migration is not unique to Redwood Creek, and many other streams experience migrations (sometimes in large numbers) 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, Meyer et al. 1998, Seiler et al. 2004, among others). Myers el al. (1998) summarized 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. The reasons why Chinook salmon fry migrate soon after emergence (or remain in the stream to grow into fingerlings) are elusive, difficult to prove, and generally unknown (Healey 1991). Healey (1991) covers the topic in much detail, and cites findings from authors who attributed (or speculated) fry dispersal to: 1) passive migration, 2) flow increases, 3) social interactions within species, 4) limits to rearing area (carrying capacity), 5) interactions with other species, and 6) genetics. In contrast, Healey (1991) also cites authors who reported no relationship between the number (or percentage) of fry and stream discharge, stream temperature, and rearing capacity. To summarize, Healey (1991) states that: 1) fry migration is a normal dispersal mechanism that helps re-distribute fry within the river, 2) estuaries can provide important rearing areas for fry, 3) fry are not ‘lost’ or surplus production, and 4) genotype may play an important role in fry migration. I used linear regression and six years of data from smolt trapping in upper Redwood Creek to investigate any relationship between stream flow (surrogate for habitat space), average stream temperature, and seasonal 0+ Chinook salmon population estimate on the percentage of emigrants each year that were fry (Sparkman 2005). None of the regression models were significant, and in fact, the regressions were highly non-significant ($p > 0.70$); therefore, no relationships between measured habitat variables or juvenile Chinook salmon population size on the percentage of fry in any given year were detected (ie no density-dependent relationship existed). Thus, the mechanism for fry dispersal from upper Redwood Creek was hypothesized to be largely genetic, and a normal component of diversity in the juvenile life history of ocean-type Chinook salmon in upper Redwood Creek.

Fingerlings have a much different migration pattern than fry as they migrate downstream through lower Redwood Creek. Fingerlings migrated in low numbers in April, increased in number over the emigration periods, and rather sharply decreased in number near the end of the emigration periods. The pattern of fingerling migration differed each year in that peak emigration in YR 2005 was four weeks later than the peak in YR 2004; and migration in YR 2005 reached low values in early August compared to mid July in YR 2004.

Fry and fingerlings also showed differences in the number and percent composition of total juvenile Chinook salmon emigration, which varied from year to year. For example, the percentage of juvenile Chinook salmon that migrated downstream as fry in YR 2004 (15%) and YR 2005 (1.6%) was much less than the percentage migrating downstream as fingerlings in YR 2004 (85%) and YR 2005 (98.4%). Fingerlings were far more abundant than fry each study year, with population abundance estimated as 427,306 in YR 2004 and 129,113 in YR 2005. Relatively larger numbers of fry were observed in YR 2004 (N = 82,854), compared to YR 2005 (N = 2,052); however, these numbers were still much less than the number of fingerlings.

The average size of 0+ Chinook salmon smolts in YR 2005 was markedly larger (by 14 mm and 2.6 g) than smolts in YR 2004, and may be related to a higher percentage of fingerlings or the smaller population size observed in YR 2005. However, in 2005 I found no statistical relationship between the overall percentage of fry or fingerlings in a given population estimate emigrating from upper Redwood Creek and average size (n = 6), but did detect a significant negative relationship of yearly 0+ Chinook salmon population emigration on average FL or Wt (Sparkman 2005). The negative relationship between population size and size of the emigrant may indicate a density-dependent relationship; with higher abundance and emigration, we see a decrease in the average FL or Wt. The density-dependent relationship may suggest that rearing space or carrying capacity (and food availability) upstream of the upper trap site was limiting the average size of Chinook salmon juveniles at higher population abundances. This same type of relationship could exist for juvenile Chinook salmon migrating through the majority of the Redwood Creek basin as well. Future trapping efforts in the lower basin should be able to detect such a relationship if it exists. If habitat is limiting the size of smolts at high abundances, successful watershed restoration in the basin should allow for the juvenile Chinook salmon to gain a larger size during years of higher abundance.

The larger average size observed in YR 2005 will most likely not compensate (as a compensatory, density-dependent effect) for the severe reduction in population emigration in YR 2005. One explanation for not compensating the low numbers with increased survival due to a larger average size (FL or Wt) for the 2005 cohort is found by examining the percentage of migrants in the fry and fingerling categories each study year. Although the population of smolts in YR 2005 was on a percentage basis mostly fingerlings, the number of fingerlings migrating in YR 2005 (N = 129,113) was much less than in YR 2004 (N = 472,306). Thus, the increase in the average size of fingerlings observed in YR 2005 would have to compensate for 343,193 less fingerlings migrating to the estuary and ocean compared to YR 2004.

Average weekly FL and Wt in YR 2005 and YR 2004 followed a similar pattern over time of starting out low and then increasing through the end of the study periods. The rather sharp increase in FL and Wt by week in YR 2004 and YR 2005 was influenced by the increasing percentage of fingerlings in the catch over time compared to fry. Unwin (1985) reported a similar finding in his trapping studies of ocean-type Chinook salmon juveniles in New Zealand. Average FL and Wt in YR 2005 from 6/10 onward was markedly higher than in YR 2004, and by the end of the emigration period, 0+ Chinook salmon were 23 mm and 5.6 g larger than emigrants at the end of the study in YR 2004. The increase in weekly FL's and Wt's over time indicate growth was taking place within the study periods. The rough or group estimate of growth in YR 2005 (0.37 mm/d and 0.07 g/d) was greater than growth in YR 2004 by about 0.07 mm/d and 0.04 g/d. The growth rate (FL) in both years fell 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.

Both fry and fingerlings from upper Redwood Creek are actively moving downstream to lower Redwood Creek and the estuary. In both study years, the lower trap in Redwood Creek has captured marked efficiency trial fry and fingerlings from upper Redwood Creek. In addition, Dave Anderson (pers. comm. 2005) has consistently captured marked 0+ Chinook salmon juveniles from upper and lower Redwood Creek in the estuary.

The estimates of travel time (in days) for recaptured pit tagged 0+ Chinook salmon smolts (n = 27) released at the upper trap site 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 and/or the salmon stock in Redwood Creek.

The travel time for 0+ Chinook salmon smolts to migrate 29 miles downstream ranged from 1.5 - 19.5 d, and averaged 7.5 d. On average, 0+ Chinook salmon moved downstream to the lower trap in fewer days than 2+ steelhead trout (n = 7, range = 2 to 35 d, ave. = 13 d) and 1+ steelhead trout (n = 9, range = 2 to 32 d, ave. = 15 d) in YR 2004

(Sparkman 2004c). The travel time for 0+ Chinook salmon fingerlings (n = 27) to reach the lower trap was not significantly related to: 1) the size of the migrant at time 1 or time 2, 2) stream temperature, or 3) stream discharge. The recapture of pit tagged 0+ Chinook salmon per release group in YR 2005 was variable. For one release group (6/30/05), five individuals were captured on the same day at the lower trap which suggests these fish traveled together as a group. In contrast, for five separate release groups, multiple recaptures from the same release group were captured on different days at the lower trap. For example, five individuals from the 7/21 release group were recaptured at the lower trap anywhere from 4.5 – 19.5 d after release from the upper trap; these fish did not travel as a group.

Travel rate ranged from 1.5 - 19.3 mi/d (2.4 – 31.1 km/d), and averaged 8.2 miles per day (13.2 km/d). Travel rate was weakly related to the size (FL or Wt) at time 1 (initial release), such that with a greater initial size we observed a higher travel rate. Similar to travel time, travel rate was not related to stream discharge, stream temperature, or fish size at time 2 ($p > 0.05$). Healey (1991) gives results from a study in the Rogue River, Oregon in which travel rate of spring Chinook salmon fingerlings was positively related to fish size and stream discharge in one year, and negatively related to stream discharge in the following year. Quinn (2005) reported that the rate at which 0+ Chinook salmon traveled downstream in the Columbia River was positively related to size. The upper range in travel rate (31.1 km/d) for Chinook salmon fingerlings in Redwood Creek was higher than that observed in the upper Rogue River (24.0 km/d) (Healey 1991). The average travel rate from upper Redwood Creek (13.2 km/d) was also higher than the average (1.6 km/d) put forward by Allen and Hassler (1986). Unfortunately, there appears to be a lack of data in the literature to compare individual travel time and travel rate with data collected on juvenile Chinook salmon in Redwood Creek. Many of the studies using pit tags with juvenile Chinook salmon are within the Columbia River system, which for the most part is not comparable to Redwood Creek because Redwood Creek is much smaller in size, does not have impoundments, and the stream flow is unregulated, among other differences.

Individual growth was expressed using a variety of indices and equations to facilitate comparisons with information found in the literature. The majority of studies appear to report growth using one index or another which makes comparisons difficult if that growth index is not used in a given study. Compounding the problem of comparing data is the difficulty in finding studies that determined individual growth rates for 0+ Chinook salmon fingerlings, and in un-regulated river systems (not counting estuarine studies). In YR 2005, 52% of the 27 recaptured 0+ Chinook salmon fingerling smolts showed positive growth in FL and Wt, 18% showed a decrease in Wt, 48% showed no change in FL and 30% did not show a change in Wt. Absolute growth rate (FL) ranged from 0 - 0.67 mm/d, and averaged 0.22 mm/d. The average value (0.22 mm/d) is comparable to the group growth rate for Chinook salmon fingerlings in the Nitinat River (0.21 mm/d), British Columbia and about 2/3 less than the group growth rate determined in the Cowichan River (0.62 mm/d), British Columbia (Healey 1991). The average value for recaptured pit tagged fingerlings (0.22 mm/d) in Redwood Creek in YR 2005 was about 41% less than that calculated for fry and fingerlings in YR 2005 using the average weekly FL data (0.37 mm/d). However, the latter estimate is a group estimate, includes fry (which may have a higher growth rate than fingerlings) and probably is not influenced by zero growth like the average for the individual growth rates were. For example, the absolute growth rate for Chinook salmon juveniles in Redwood Creek showing only positive growth ranged from 0.19 - 0.67 mm/d and averaged 0.43 mm/d, which is fairly close to the group estimate previously calculated (0.37 mm/d).

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

The growth (positive, negative, and zero) of the 27 recaptured pit tagged 0+ Chinook salmon was successfully modeled using linear regression. The best model for any growth index included travel time as the independent variable (p ranged from 0.002 – 0.000001, R^2 ranged from 0.32 – 0.84, slope was positive for all tests); no significant relationships were detected using stream discharge or stream temperature even though the range in values for each was fairly wide. Percent change in FL was positively related to travel time, and travel time explained 84% of the variation in growth; likewise, absolute growth rate (FL) was positively related to travel time, which explained 69% of the variation in growth. Thus, fish that took longer to reach the lower trap gained more length or weight than fish that traveled the distance in a shorter amount of time. This in turn suggests fish that took a longer amount of time to migrate downstream had more time to forage for food, feed, and convert the food to growth. Beamer et al. (2004) found that the growth of juvenile ocean-type Chinook salmon (in Skagit Bay) was positively related to the amount of time that the juveniles spent in the delta.

The final size of recaptured pit tagged Chinook salmon fingerlings was positively related to the size at initial release (FL; $p < 0.0001$, $R^2 = 0.67$, power =1.0). Sixty-seven percent of the variation in the final FL was explained by the initial FL. Larger fish released at the upper trap site (time 1) were, on average, larger at recapture (time 2) 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 when they reached the lower trap (final size); the larger fish at the lower trap were more likely to have been the larger fish at the upper trap.

1+ Chinook Salmon

1+ juvenile Chinook salmon (stream-type) in Redwood Creek represent the third juvenile Chinook salmon life history, and appear to be in very low abundance as evidenced by trap catches in YR 2005 (n = 11) and YR 2004 (n = 2). Stream-type juvenile Chinook salmon are easily differentiated from ocean-type by size at time of downstream migration. The average juvenile FL in April 2005, for example, was 113 mm for 1+ Chinook salmon and 51 mm for 0+ Chinook salmon.

When present, 1+ Chinook salmon in Redwood Creek are more likely to be progeny of fall/winter-run Chinook salmon adults than from spring-run adults (Stream type) because few if any spring-run Chinook salmon are observed during spring and summer snorkel surveys in Redwood Creek (Dave Anderson, pers. comm. 2004). For example, in 21 years of adult summer steelhead snorkel dives, adult spring Chinook salmon were only observed in one year (1988) and in very low numbers (< 7 individuals) (Dave Anderson, pers. comm. 2005). Additionally, stream flows during late spring/summer months can become so low that adult upstream passage into upper Redwood Creek can become problematic. High average stream temperatures (eg > 20 °C) may also prevent any adult spring-run Chinook salmon migration into upper Redwood Creek, or inhibit their ability to over-summer in pools. Thus, a spring run of Chinook salmon adults was probably not responsible for the production of yearling Chinook salmon juveniles in Redwood Creek. Bendock (1995) also found both stream-type and ocean-type juvenile Chinook salmon in an Alaskan stream which only has one adult Chinook salmon race; and Conner et al. (2005) reported that fall Chinook salmon in the Snake River produced juveniles exhibiting an ocean-type or stream-type juvenile life history.

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

0+ Steelhead Trout

Relatively high catches of young-of-year steelhead trout by downstream migrant traps in small and large streams is not uncommon (USFWS 2001, William Pinnix pers. com. 2003, Rowe 2003, Johnson 2004, Don Chapman pers. comm. 2004, Sparkman 2005). Young-of-year steelhead trout downstream migration in Redwood Creek is considered to be stream redistribution (passive and active) because juvenile steelhead in California normally smolt and enter the ocean at one to two years old, with lesser numbers out-migrating at an age of 3^+ years (Busby et al. 1996).

The capture of 0+ steelhead trout in YR 2005 was 93% less than catches in YR 2004 and may reflect a change in the total number of adult spawners upstream of the trap site and/or a simple change in the percentage of the total 0+ juveniles (each year) that migrated downstream. The potential variable of trapping efficiency (not measured) among study years would not account for the large decrease we observed in YR 2005 because the trap was operated in the same manner as in YR 2004 (trap positioning, use of weir panels, etc).

The number of 0+ steelhead trout that can remain upstream of the trap site is considered to be some function of a fish's disposition to out-migrate (or not out-migrate) and habitat carrying capacity. Meehan and Bjornn (1991) comment that juvenile steelhead trout have a variety of migration patterns that can vary with local conditions, and that the trigger for out-migration can be genetic or environmental. They further state that some steelhead populations normally out-migrate soon after emergence from redds to occupy other rearing areas (we observe this as well in upper Redwood Creek). Habitat carrying capacity is generally thought to be related to environmental (hydrology, geomorphology, stream depth and discharge, stream temperatures, cover, sedimentation, etc) and biological variables (food availability, predation, salmonid behavior), and any interactions between the two (Murphy and Meehan 1991). The general idea is that when habitat carrying capacity is exceeded (over-seeding), the juvenile fish emigrate to find other areas to rear. A problem with the view of habitat carrying capacity's affect on migration is that it fails to explain why juvenile fish emigrate at low densities or low population levels.

0+ steelhead trout migration in YR 2005 was markedly different than migration in YR 2004. The peak in migration in YR 2005 occurred during May and the peak in YR 2004 occurred in June. In addition, weekly migration during 5/20 – 7/22, 2005 was considerably less than migration during this same time period in YR 2004.

The average FL in YR 2005 was about 1.5 mm greater than the average FL in YR 2004. The increase in size of migrants in YR 2005 was substantiated by a growth rate (0.34 mm/d) that was about 0.05 mm/d greater than the growth rate in YR 2004. However, these differences among years are un-likely to be biologically meaningful because of being so small. Average weekly FL increased over time each study year and indicate growth was taking place, which in turn suggests habitat conditions and the availability of prey items were sufficient for growth. Average weekly FL's during the first five weeks of trapping in YR 2005 were dominated by emergent fry, compared to the first 3 weeks in YR 2004. The rather sharp increase in weekly FL starting 5/21/2005 and 4/23/2004 was probably influenced by the increasing percentage of parr in the catch compared to fry.

The 0+ steelhead trout captured by the lower trap indicate these fish are going to rear for some time period in lower Redwood Creek, including the estuary. Dave Anderson (pers. comm. 2005), for example, routinely captures young-of-year steelhead trout (and coho salmon) in the estuary during summer and early fall sampling; thus, the condition of lower Redwood Creek and the estuary can impact 0+ steelhead trout.

1+ Steelhead Trout

One-year old steelhead trout were the most numerous juvenile steelhead migrating downstream in both study years. The ratio of 1+ steelhead trout to 0+ steelhead trout to

2+ steelhead trout was 4:1:1 in YR 2004 and 4:0.2:1 in YR 2005. On a percentage basis, 1+ steelhead trout comprised 67 and 76% of total juvenile steelhead downstream migration each study year. Population emigration in YR 2005 was 57% lower than emigration in YR 2004. The apparent decrease in numbers in YR 2005 was not due to the lack of trapping because only 3.4% of the population was estimated to emigrate from 4/2 – 4/18; and for the 12 days missed trapping, an estimated 3.9% (or 1,222 individuals) of the total population size was missed due to trap non-deployment. The estimated number of 1+ steelhead trout emigrating during the 12 days we missed trapping was included in the population estimate, thus the remaining 3.4% emigrating from 4/2 – 4/18 would have had a negligible effect on the total population estimate for 1+ steelhead trout in YR 2005.

In addition to a decrease in population abundance in YR 2005, there were temporal differences in migration. In YR 2005, slightly higher numbers of 1+ steelhead trout emigrated in April; and in YR 2004, more 1+ steelhead trout emigrated during May than other months. The two most important months in YR 2005 were April and May, compared to May and June for YR 2004. The pattern of emigration by week among the two study years was strikingly different. In YR 2005, migration was highest in the beginning of trapping, reached very low values during June to mid July, and then showed a small increase in numbers followed by a decrease to the end of the study period (late August). Weekly migration in YR 2004 showed a bell curve shaped pattern, such that migration was low in the beginning of trapping, peaked near the middle of the trapping period, and then decreased to the end of the study period with the exception of a few small increases on the descending limb of the curve. The peak in weekly population emigration was also different each study year, such that the peak in YR 2005 was two weeks earlier than the peak in YR 2004. Weekly population emigration in YR 2004 and YR 2005 closely resembled the catch distribution each year.

The large decline in 1+ steelhead trout emigrating from 5/7 – 7/15 in YR 2005 caused the population estimate to be much lower than the estimate for YR 2004; migration during this time period in YR 2005 equaled 6,680 individuals (or 21% of total) compared to 61,229 (or 79% of total) in YR 2004. The variation in trapping efficiencies among years during this time period cannot reasonably explain the large difference in numbers because there was only a 3% difference in efficiency. Thus, the large decrease observed in YR 2005 was not due to trap operation, and more likely represented an actual difference among years. This rationale also applies to the difference in total population emigration between YR 2004 and YR 2005.

The average size of 1+ steelhead trout migrants in YR 2005 (90.8 mm, 8.31 g) was about 6 mm and 1.3 g greater than the average for 1+ steelhead trout in YR 2004. The average weekly FL and Wt in YR 2005 was significantly greater than weekly FL and Wt in YR 2004. The larger size of 1+ steelhead trout could be attributable to a lower population size, assuming a negative influence of population size on average FL and Wt (density-dependence). However, for the past six consecutive years of trapping in the upper basin, I found that the average size of 1+ steelhead trout increased with increasing population size; and then speculated that if stream conditions were favorable for survival, they could also be favorable for growth (Sparkman 2005). Whether this will be true for 1+ steelhead migrating through lower Redwood Creek remains to be tested with more years of data collection.

The average FL and Wt over time (weeks) in both study years did not statistically change over the study period. This is not too surprising when viewing graphical representations of the data because in both years the size of 1+ steelhead trout started out relatively low, increased to reach a maximum, and then decreased to values nearly equal to the starting size. The increase in size near the middle of the trapping period warrants further investigation, such as an evaluation of diet and stomach contents. There may also be a relationship of increased food abundance (insects, Chinook salmon and steelhead trout fry, etc) for migrants during this time period. Warmer stream temperatures, within the normal range for growth, may also play a role.

Information in the literature indicates that steelhead smolting at age 1 is not uncommon, particularly in streams that are south of British Columbia (Quinn 2005, Busby et al. 1996). The percentage of 1+ steelhead trout showing parr characteristics in Redwood Creek was very low each study year (0.2%), and indicates that few 1+ steelhead trout migrated downstream in a stream-residence form (parr). In contrast, the majority of 1+ steelhead trout were emigrating in a smolt stage. The percentage of 1+ steelhead trout showing smolt characteristics in YR 2005 (86%) was greater than the percentage in YR 2004 (68%). This difference is 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) most of the crew members had worked on this study the previous year. In my report on trapping in upper Redwood Creek in YR 2005 (Sparkman 2005), I was able to statistically show that the percentage of 1+ steelhead trout showing smolt characteristics each year (n = 6) was negatively related to average stream temperature and positively related to average stream discharge during the trapping periods. Thus, more 1+ steelhead trout were in a smolt stage during years with colder temperatures and higher stream discharge. Whether this will be true for 1+ steelhead trout migrating through lower Redwood Creek remains to be seen. Quinn (2005) reported that both photo period and steam temperature play important roles in smoltification by providing an external stimulus for the endocrine system, which in turn drives the internal physiological changes necessary for smoltification.

1+ steelhead trout are actively migrating from the upper basin to the lower basin and estuary, as evidenced by trap catches in lower Redwood Creek of efficiency trial fish, elastomer marked fish, and pit tagged fish released from the upper trap. The marked 1+ steelhead trout emigrating from upper Redwood Creek and through lower Redwood Creek have also been captured in the estuary (Dave Anderson, pers. comm. 2005) since the beginning of our smolt trapping studies. The time required for 1+ steelhead trout to travel the 29 miles from the upper trap to the lower trap (n = 5) in YR 2005 ranged from 2 – 35 d, and averaged 12.4 d. These values were close to the 1+ steelhead trout travel time determined in YR 2004 (n = 9, ranged from 2 – 32 d, average = 14.9 d). Travel rate (mi/d) in YR 2005 ranged from 0.8 – 14.5 mi/d and averaged 5.8 mi/d; in YR 2004 travel

rate ranged from 0.9 – 14.9 mi/d, and averaged 4.3 mi/d. Thus, 1+ steelhead trout, on average, traveled at a higher rate in YR 2005 compared to YR 2004.
As previously mentioned, far more 1+ steelhead trout emigrated past the lower trap than other juvenile steelhead age-classes (0+, 2+). 1+ steelhead trout downstream migration is not unique to Redwood Creek, and other downstream migration studies have routinely documented 1+ steelhead trout emigration (USWFW 2001, Ward et al. 2002, Johnson 2004; among many others). However, the ratio of 1+ steelhead trout to 2+ steelhead trout (4:1 in both years) in Redwood Creek was much different than that determined in a nearby river (Mad River). In 2002, I reported that for two years of smolt trapping in the Mad River, the ratio of 1+ steelhead trout to 2+ steelhead trout equaled 1:6 (YR 2001) and 1:3 (YR 2002) (Sparkman 2002). The variability in trap locations among streams (Redwood Cr RM 4, Mad River RM 12.5) would probably not account for these differences.

Based upon studies in other streams, the number of returning adult steelhead trout that migrated to the ocean as one-year-old smolts is relatively low, and usually less than 29% (Pautzke and Meigs 1941, Maher and Larkin 1955, Busby et al. 1996, McCubbing 2002). Based upon a limited number of scale samples from adult steelhead trout (n = 10) collected in Redwood Creek, 30% of the adults entered the ocean as one-year-old juveniles. The most successful juvenile steelhead migrants to reach adulthood were 2+ steelhead trout. Therefore, the reason(s) for the large number of 1+ steelhead trout emigrating from the basin of Redwood Creek warrants further investigation. Pit tagging 1+ steelhead smolts should provide useful insights when conducted over multiple, consecutive years because if most of the 1+ steelhead trout are not actually entering the ocean, we should then be able to recapture a given percentage of those fish the following year with the rotary screw trap in lower Redwood Creek and seine nets in the estuary; if we fail to recapture any of the marked 1+ steelhead trout the following year, then a logical conclusion would be that the fish either stayed in the stream and suffered severe mortality during winter, actually entered the ocean, or some combination of the two factors.

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). Pautzke and Meigs (1941), for example, reported that 84% of returning adult steelhead in the Green River had spent two or more years as juveniles in freshwater. Maher and Larkin (1955) found that 98% of the adult steelhead they examined had spent two or more years in freshwater prior to entering the ocean, 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 in Redwood Creek is that it was far less abundant than 1+ steelhead trout smolts in both study years.

The population of 2+ steelhead trout smolts in YR 2005 was about 55% lower than the estimate in YR 2004. Similar to 0+ Chinook salmon and 1+ steelhead trout, the large decrease in numbers observed in YR 2005 was not due to the lack of trapping because 11% of the population was estimated to emigrate from 4/2 – 4/18. Eleven percent of the population expected to be missed would equal about 963 fish. The estimated number of 2+ steelhead trout emigrating during the 12 days we missed trapping was included in the population estimate, thus the remaining 11% emigrating prior to trap placement would have a negligible influence on population size. In addition, the 95% confidence interval for the YR 2005 estimate would encompass the 11% if added to the population estimate. Confidence intervals (and percent error) for 2+ steelhead trout population estimates were larger than the 95% confidence intervals for 1+ steelhead trout because: 1) 2+ steelhead trout are typically harder to catch than younger age-classes of steelhead trout, and 2) sample size for marking and subsequent recapture was low. During the trapping period we routinely adjust trap configuration and install weir panels to increase the capture efficiency of 2+ steelhead trout. Additionally, we perform numerous mark/recapture trials, and when combined with altering trap configuration and paneling, are able to produce a fairly reliable population estimate.

2+ steelhead trout migrated through lower Redwood Creek in higher numbers in May during both study years. However, the two most important months for emigration were April and May for YR 2005, and May and June for YR 2004. Migration in both study years dropped to very low values after mid June, with the exception of a few small peaks.

The weekly migration of 2+ steelhead trout at the population level in YR 2005 was positively influenced by stream discharge and stream gage height, and negatively related to trapping week number. Thus, more 2+ steelhead trout migrated during times when the stream flow was moderately high and stream temperatures were relatively cool. However, like other juvenile salmonids in Redwood Creek, they seem to substantially decrease migration during periods of high and turbid stream flow. A likely explanation is that the juvenile salmonids simply find refuge during high stream flow events. 2+ steelhead trout emigrating from the upper basin in YR 2005 also showed this migration pattern with respect to stream flow, gage height, and trapping week number (Sparkman 2005). The pattern of emigration by week among the study years was obviously different. In YR 2005, migration was highest during the first half of the study period, and from June 11th onward, was relatively low. In YR 2004, the pattern of migration approximated a bell curve shaped pattern, with the exception that emigration during the first three weeks was higher than the fourth week. Similar to YR 2005, migration from mid June onward in YR 2004 was much less than emigration during the first half of the study period. Weekly peaks in emigration occurred during the same time period each study year (4/30 – 5/6). Weekly population emigration in YR 2004 and YR 2005 also closely resembled the catch distribution each year.

Weekly migration through lower Redwood Creek in YR 2005 lacked a large number of migrants from 5/7 – 5/27 compared to migration in YR 2004. For example, the 2+ steelhead trout smolt population that emigrated during this time period equaled 7,365 (or 38% of total) in YR 2004 compared to 985 (or 11% of total) in YR 2005. The variation in trapping efficiencies among years during this time period cannot reasonably explain the large difference in numbers because there was only a 1% difference in trapping efficiency. Thus, the large decrease observed in YR 2005 was not due to trap operation, and more likely represented an actual difference in population emigration among years. The pattern of 2+ steelhead trout migration by week in YR 2005 was markedly similar to the pattern for 1+ steelhead trout in YR 2005, and may indicate that these fish travel together in schools. Data collected at the upper trap also shows that the two age classes appear to have very similar weekly migration patterns (Sparkman 2005).

The average fork length of 2+ steelhead smolts in YR 2005 (143.2 mm) was about 1 mm less than the average in YR 2004, and average weight in YR 2005 (31.25 g) was about 0.6 g less than the average in YR 2004. The average weekly FL and Wt in YR 2005 was not significantly different than the averages in YR 2004. The pattern of average weekly FL and Wt in YR 2005 was similar to YR 2004 in that values were relatively high in the beginning of trapping, decreased in value to the middle of trapping, and then increased in value to the end of the study period. However, average weekly FL and Wt significantly changed over time in YR 2004 but not in YR 2005. These results are not surprising when examining graphical representations of the data because the starting values in YR 2004 were greater than the ending values; and in YR 2005, the starting values were about the same as the ending values. 2+ steelhead trout smolts emigrating from upper Redwood Creek in YR 2005 showed the same pattern in FL and Wt over time as 2+ steelhead trout emigrating through lower Redwood Creek in YR 2005 (Sparkman 2005).

The percentage of 2+ steelhead trout emigrants showing smolt characteristics in YR 2005 (98%) was greater than YR 2004 (94% were smolts). The number of parr designations was zero each year, and indicated that 2+ steelhead trout did not emigrate through lower Redwood Creek in a stream-resident form (parr). My analysis of trapping data in upper Redwood Creek showed that the 2+ steelhead trout smolt index was negatively related to 2+ steelhead trout population size, and negatively related to average stream temperature during the study period (Sparkman 2005). Whether this will be true for 2+ steelhead trout populations emigrating through lower Redwood Creek remains to be tested.

2+ steelhead trout are actively emigrating from upper Redwood Creek because the lower trap in Redwood Creek (RM 4) has consistently captured efficiency trial fish and elastomer marked fish released from the upper trap site in both years of operation. Additionally, 2+ steelhead trout from upper Redwood Creek have been observed in the estuary of Redwood Creek every year since the beginning of our smolt trapping studies (Dave Anderson, pers. comm. 2005). The time required for one 2+ steelhead trout released from upper Redwood Creek to travel to the trap in lower Redwood Creek equaled 7 d in YR 2005. In YR 2004, the time required to travel from the upper trap to the lower trap ranged from 2 – 35 d, and averaged 13 d. Future trapping efforts will try to increase the sample size of recaptured 2+ steelhead trout for travel time experiments by increasing the sample size of releases from the upper trapping site.

Although there seems to be few studies that specifically look at steelhead smolt to adult survival, steelhead life history studies in a British Columbia stream (Keogh River) show there is a positive linear relationship between out-migrating 2+ smolts and returning adult steelhead (Ward and Slaney 1988, Ward 2000, Ward et al. 2002). Ward (2000) cites other authors who report similar positive linear relationships between smolts and adults along the British Columbia coast as well (eg Smith and Ward 2000). Survival from smolt to adult can be variable, and may range from an average of 15% (during 1976-1989) to an average of 3.5% (during 1990-1995) (Ward 2000). Ward and Slaney (1988), reporting on data from the Keogh River for 1978 – 1982 cohorts, determined survival from smolt to adult ranged from 7% to 26%, and averaged 16%. Meehan and Bjornn (1991) reported steelhead smolt to returning adult survival can be a relative high ranging from 10 – 20% in streams that are coastal to a low survival of 2% in streams where steelhead must overcome dams and travel long distances to reach spawning grounds. It is difficult to make specific inferences about 2+ steelhead smolt to adult survival for Redwood Creek steelhead based upon successful studies in the literature because of differences in latitude/longitude, geography, ocean conditions (physical and biological), estuaries, and trap locations in the watershed. However, the belief that the number of 2+ smolts relate to future adults (and watershed conditions) is hard to dismiss or invalidate.

With respect to younger juvenile stages (0+ and 1+), the 2+ steelhead smolt is the best candidate for assessing steelhead status, trends, and abundance when information on adult steelhead is unavailable or un-attainable. 2+ steelhead trout have overcome the numerous components of stream survival that younger steelhead (0+ and 1+) have not yet completely faced (over-summer, over-winter, etc), and 2+ steelhead smolts are also the most direct recruit to adult steelhead populations. Along these same lines, Ward et al. (2003) reported that the 2+ steelhead smolt was a more reliable response variable with respect to stream restoration than late summer juvenile densities because of being less variable.

Cutthroat Trout

A low number of cutthroat trout were captured in both study years relative to other juvenile salmonid species. Catches in YR 2004, for example, equaled 37 and catches in YR 2005 equaled 9. Cutthroat trout were caught in six of 19 total weeks of trap operation in YR 2005, with no discernable peak in weekly catches. In contrast, cutthroat trout catches in YR 2004 peaked during 5/14 – 5/20.

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 Redwood Creek. However, if there were large numbers present, we would probably catch much more than we do, as they re-distribute or migrate downstream. For example, juvenile salmonid trapping efforts in Prairie Creek consistently capture hundreds of cutthroat trout during spring/early summer as they migrate downstream (Roelofs and Klatte 1996, Roelofs and Sparkman 1999, Walt Duffy, pers. comm. 2003).

We did not consider any of the young-of-year steelhead trout to be progeny of cutthroat trout because few aged 1 and older cutthroat trout were captured in any given year. Far more older juvenile steelhead trout (1+ and 2+) migrated through lower Redwood Creek than cutthroat trout as evidenced by trap catches. In the two study years, for example, the ratio of 1+ and 2+ steelhead trout combined catches to cutthroat trout catches each year equaled 197:1 and 272:1, and using all data equaled 211:1. Ratios would be even higher if juvenile steelhead trout population data were used instead of catch data, and 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 cutthroat trout. Hybrid juveniles, the product of mating between steelhead trout and cutthroat trout, are commonly noted to be missing one or two of these characters. We have not observed any hybrids in the two years of study, and based upon visual identification, the number of potential hybrids (age 1 and greater) is extremely rare in Redwood Creek.

0+ Pink Salmon

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

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

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

Coho Salmon

0+ Coho Salmon

Few 0+ coho salmon were captured by the lower trap in either study year (YR 2004, n = 202; YR 2005, n = 53). 0+ coho salmon catches at the lower trap occurred in every month of trap operation, and for both study years, more were captured in July than other months. The two most important months for emigration was May and July for YR 2004 and June and July for YR 2005. The low catches of 0+ coho salmon in lower Redwood Creek is contrasted by often high catches in Prairie Creek. For example, trap catches of 0+ coho salmon in Prairie Creek from 1996 – 1998 ranged from a low of 372 to a high of 25,492, and averaged 9,659 per trapping season (Roelofs and Sparkman 1999). 0+ coho salmon catches at the lower trap indicate that these fish were moving downstream to rear. If the young-of-year coho do not move into Prairie Creek, then they must be moving downstream to the estuary. Thus, lower Redwood Creek and the estuary may serve as an important place for young-of-year coho salmon to rear.

1+ Coho Salmon

Low numbers of one plus-year-old coho salmon were caught at the lower trap in both study years (YR 2004, n = 69; YR 2005, n = 39) prior to mid June; no catches occurred after June 17th. Similar to 0+ coho salmon, the low catches of 1+ coho salmon in lower Redwood Creek is contrasted by much higher catches in Prairie Creek. For example, trap catches of 1+ coho salmon in Prairie Creek from 1996 – 1999 ranged from 1,475 – 2,302, and averaged 1,965 per trapping season (Roelofs and Sparkman 1999).

I did not calculate a 1+ coho salmon population estimate using 1+ coho salmon mark/recapture data in YR 2004 because I originally expected a very poor estimate based upon a low number of marked releases and subsequent recaptures. However, I re-calculated the estimate for YR 2004 in YR 2005 to compare with the mark/recapture based estimate determined in YR 2005, and discovered that the population estimate wasn’t as bad as originally thought. However, the estimated error for population estimates in both study years was high (63% for YR 2004, 69% for YR 2005), which is most likely due to small sample sizes for mark/recapture experiments. The lack of trapping the initial 19 days in YR 2005 was estimated to affect the 1+ coho salmon population estimate (26% of total) more than other species at age, however, it is unlikely that enough fish were missed to allow the point estimate to fall outside of the rather wide

95% CI. The population estimates I determined for 1+ coho salmon should be viewed cautiously, and the proper context could be that we are 95% sure that the population during either study year was less than 900 individuals (upper 95%CI for YR 2004 estimate). Population emigration of less than 900 individuals can be considered very low (alarmingly so), particularly for a stream the size of Redwood Creek.

1+ coho salmon emigrated in higher numbers in May during both study periods compared to other months. In YR 2004, for example, an estimated 70% of the total migrated in May, and in YR 2005, an estimated 69% of the total migrated in May; population emigration was basically over by the end of May. The two most important months for migration occurred in April and May for both study years, and the peak in weekly emigration in YR 2005 was one week later than the peak in YR 2004. Weekly population emigration in YR 2004 and YR 2005 closely resembled the catch distribution each year.

The reason(s) for the lack of sufficient numbers of 1+ coho salmon emigrating from Redwood Creek warrants further study.

CONCLUSIONS

The migration of juvenile salmonids from the majority of the Redwood Creek basin in YR 2005 was much lower than emigration in YR 2004 for all species at age. 0+ Chinook salmon experienced the greatest reduction (76%) in population size. The reduction could be attributable to high winter flows which either scoured or jostled redd gravels in early December, a simple decrease in the number of adult spawners upstream of the trap site, or a combination of the two factors. Higher numbers of 0+ Chinook salmon migrated through lower Redwood Creek in June in YR 2004, compared to July in YR 2005. The population of 0+ Chinook salmon emigrants in YRS 2004 and 2005 consisted of both fry and fingerlings, with fingerlings comprising the majority of the migrants. The average size of 0+ Chinook salmon migrants in YR 2005 was considerably larger than the average size in YR 2004, and could be a function of decreased population size or higher average size of fingerlings observed in YR 2005. The average size by week in both study years increased over the duration of the study period, and indicates that growth occurred. Both 0+ Chinook salmon fry and fingerlings from upper Redwood Creek are migrating downstream to lower Redwood Creek and the estuary. Travel time and growth experiments of pit tagged 0+ Chinook salmon released in upper Redwood Creek and recaptured in lower Redwood Creek were successful. Travel time ranged from 1.5 – 19.5 d, and averaged 7.5 d. Travel rate ranged from 1.5 – 19.3 mi/d, and averaged 8.2 mi/d. Travel rate was positively related, albeit weakly, to fish size at Time 1, whereas no statistical relationships of independent variables could be found with travel time (except the positive relationship with growth). 0+ Chinook salmon fingerlings, on average, traveled from upper Redwood Creek to lower Redwood Creek in less days than 1+ or 2+ steelhead trout in YR 2004 and YR 2005. Fifty-two percent of the downstream migrating pit tagged 0+ Chinook salmon showed growth (FL, Wt), 18% showed a decrease in Wt, 48% showed no change in FL, and 30% showed no change in Wt. Growth was positively related to travel time and negatively related to travel rate. Thus, fish that took longer to reach the lower trap gained more FL and Wt than fish that traveled the distance in less amount of time. The final size of recaptured pit tagged 0+ Chinook salmon was positively related to the initial size at tagging. The importance of this relationship is that fish size at the upper trap (initial size) had a large impact on fish size at the lower trap (final size); larger fish recaptured at the lower trap were more likely to have been the larger fish released at the upper trap.

0+ steelhead trout were captured in each week of the trapping period in both study years; however, very few 0+ steelhead trout were captured in YR 2005 compared with YR 2004. The difference in catch between years was an order of magnitude. Most of the 0+ steelhead trout were captured in June and July in YR 2004, compared to May and July in YR 2005. Migration during 5/20 – 7/22 was considerably less in YR 2005 compared to YR 2004. Average weekly FL's during the first three weeks of trapping in YR 2004 were dominated by emergent fry, compared to the first five weeks in YR 2005. Average weekly FL increased over the study period each year, and indicated that growth occurred. Sharp increases in FL over time in both years were probably influenced by the increasing percentage of parr in the catch compared to fry. Catches of 0+ steelhead trout in lower Redwood Creek indicate that these fish are going to rear for some time period in lower Redwood Creek and the estuary; thus, the condition of these habitats can impact 0+ steelhead trout.

1+ steelhead trout were the most numerous juvenile steelhead trout migrating downstream in both study years. Population emigration in YR 2005 was 57% lower than emigration in YR 2004. The large decline observed in YR 2005 was attributable to very low emigration (N = 6,680) during 5/7 – 7/15 which accounted for only 21% of total emigration. Emigration during this time period in YR 2004 equaled 61,229 individuals or 79% of the total for that year. The average size of 1+ steelhead migrants in YR 2005 was significantly greater than in YR 2004, and the pattern in average FL and Wt over time was fairly similar between study years. The percentage of 1+ steelhead trout showing smolt characteristics was higher in YR 2005 (86%) than YR 2004 (68%), and could be related to differences in stream discharge and water temperature among years. 1+ steelhead trout are actively migrating from upper Redwood Creek to lower Redwood Creek and the estuary based upon various recaptures of marked fish released from upper Redwood Creek. The time required for 1+ steelhead trout to travel the 29 miles between traps in YR 2005 averaged 12.4 d, which was close to the average value (14.9 d) determined in YR 2004. Travel rate averaged 5.8 mi/d in YR 2005, compared to 4.3 mi/d in YR 2004; thus, 1+ steelhead trout, on average, traveled the distance in a shorter amount of time in YR 2005 compared to YR 2004. The large number of 1+ steelhead trout emigrants compared to 2+ steelhead trout emigrants warrants further study, particularly if the majority of returning adult steelhead spend two years in freshwater prior to ocean entry.

2+ steelhead trout are probably the most important group of juvenile steelhead trout that contribute to adult steelhead trout populations in Redwood Creek. However, as previously mentioned, the paradox is that 2+ steelhead trout are much less numerous than 1+ steelhead trout. The ratio, for example, of 2+ steelhead trout to 1+ steelhead trout equaled 1:4 in both study years. The population of 2+ steelhead trout smolts in YR 2005 was 55% lower than emigration in YR 2004. The large decrease in numbers observed in YR 2005 could be attributed to very low emigration during 5/7 – 5/27, which in YR 2004 was a period of considerable migration (7,365 smolts, or 38% of the population). The most important month for emigration in both study years occurred in May, and migration beyond mid June was low in each study year. The pattern of 2+ steelhead trout weekly migration was strikingly similar to 1+ steelhead trout migration, and may indicate that both age classes traveled together as a group. The average size of 2+ steelhead trout in YR 2005 was slightly lower than the average size in YR 2004. Patterns of average FL and Wt over time (week) were similar among study years. Experiments of travel time and growth of 2+ steelhead trout marked and released in upper Redwood Creek and recaptured in lower Redwood Creek were unsuccessful, mainly due to low sample size and low recapture probability for marked releases. Future trapping efforts will try to increase the sample size of recaptured 2+ steelhead trout for travel time and growth experiments by increasing the sample size of marked releases from the upper trapping site.

Few cutthroat trout were captured in either study year relative to other juvenile salmonids, and therefore are considered to be in low abundance in Redwood Creek. However, additional sampling methods are warranted to further investigate cutthroat trout population size, status, and distribution in Redwood Creek.

Juvenile pink salmon were captured in lower Redwood Creek in YR 2005 in very low numbers (n = 2). However, prior to our work in Redwood Creek, no known or recorded observation(s) existed. Thus, downstream migrant trapping proved useful for showing that pink salmon, albeit in low numbers, are present in Redwood Creek.

Both 0+ and 1+ coho salmon migrants were in very low abundance in both study years. 0+ coho salmon were mostly captured towards the end of the study period, and contrasts the capture of 1+ coho salmon which occurred during the first two months of the study period. The migration of 1+ coho salmon ceased after June 10th in YR 2004 and May 27th in YR 2005. 1+ coho salmon smolts, at the population level, equaled 535 in YR 2004 compared to 183 in YR 2005. Although the point estimates had considerable error, the fact that few 1+ coho salmon smolts emigrated from the majority of the Redwood Creek basin upstream of Prairie Creek was apparent. Prairie Creek appears to be a very important stronghold for coho salmon populations in the Redwood Creek basin.

RECOMMENDATIONS

This study is one of the few studies that is designed to document smolt abundance and population trends of the California Coastal Chinook salmon ESU, Southern Oregon/Northern California Coasts Coho salmon ESU, and Northern California

Steelhead Trout ESU over a relatively, long time period. With respect to the Chinook salmon ESU, this study might be the only one that provides population data for a relatively large stream.

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

1. Collect base line data for future comparisons.

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

3. Detect any fish response (population, smolt size, etc) to stream and watershed restoration.

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

5. Offer data for comparison with other downstream migration smolt studies.

This study, when combined with juvenile salmonid smolt monitoring in the upper basin and the estuary will also help determine potential bottlenecks to anadromous salmonid production in Redwood Creek.

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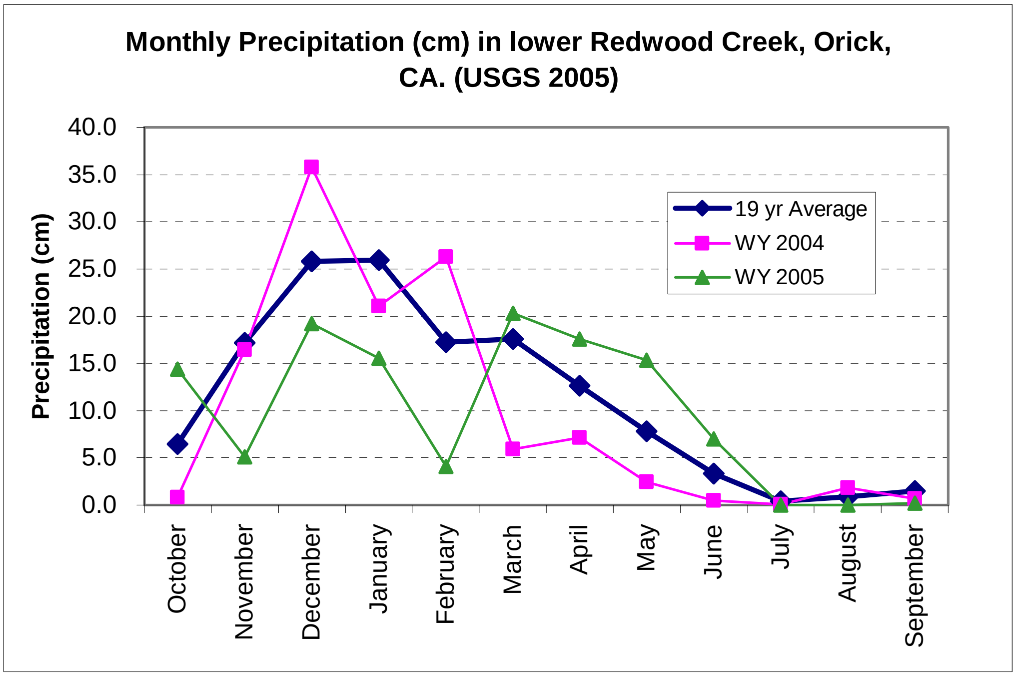
APPENDICES

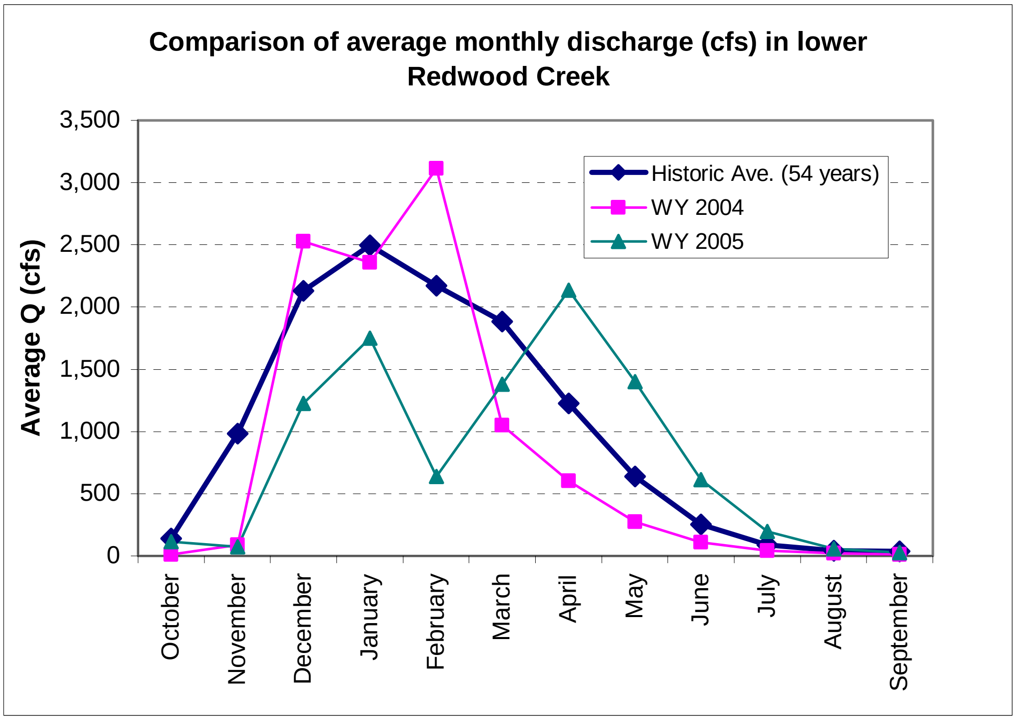
Appendix 1. Comparison of 19 year average monthly precipitation with monthly precipitation in WY 2004 and WY 2005, lower Redwood Creek, Orick, CA. (USGS 2005).

	Monthly Precipitation (cm)		
Month	Historic	WY 2004	WY 2005
October	6.5	0.8	14.4
November	17.2	16.5	5.1
December	25.8	35.8	19.2
January	25.9	21.0	15.5
February	17.3	26.3	4.1
March	17.6	5.9	20.3
April	12.6	7.1	17.6
May	7.8	2.4	15.3
June	3.3	0.5	7.0
July	0.4	0.1	0.0
August	0.9	1.8	0.0
September	1.5	0.7	0.2
Total:	136.8	119.0	118.8
Average:	11.4	9.9	9.9



Appendix 2. Comparison of 54 year average monthly discharge (cfs) with average monthly discharge in WY 2004 and WY 2005, Orick gaging station (#11482500), lower Redwood Creek (USGS 2005).

	Monthly Stream Discharge (cfs)		
Month	Historic	WY 2004	WY 2005
October	141	8	111
November	982	90	74
December	2,131	2,526	1,223
January	2,496	2,356	1,749
February	2,170	3,113	638
March	1,885	1,050	1,379
April	1,223	602	2,138
May	636	271	1,400
June	254	109	613
July	86	41	195
August	40	19	56
September	36	9	25
Average:	1,007	850	800



Appendix 3. Picture of rotary screw trap in lower Redwood Creek prior to storm event (top) and picture of rotary screw trap during storm event (bottom), Orick, CA., 2005.

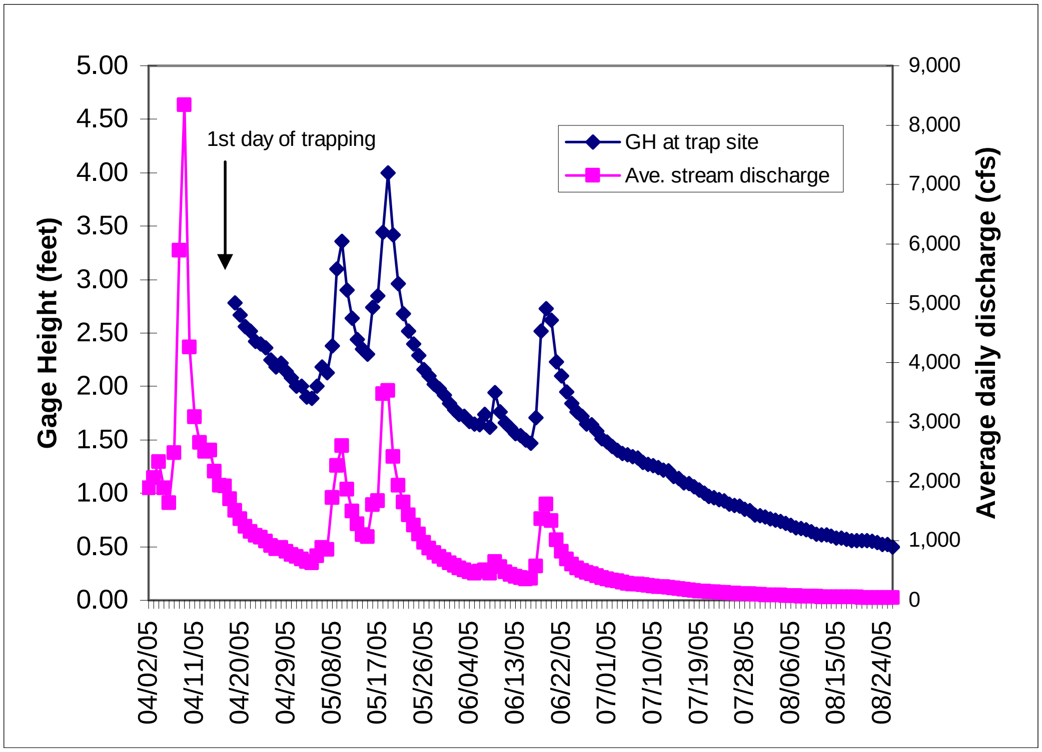
Date: May 13th, 2005, Lower Redwood Creek Rotary Screw Trap.

Date: May 19th, 2005, Lower Redwood Creek Rotary Screw Trap.

Appendix 4. Picture of rotary screw trap in lower Redwood Creek (RM 4) during low flow period in August, 2005.

Date: August 6, 2005, Lower Redwood Creek Rotary Screw Trap.

Appendix 5. Graphical representation of daily stream gage height (feet) at trap site and average daily streamflow (cfs) at Orick gaging station (USGS 2005), lower Redwood Creek, Humboldt County, CA.



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

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

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

** Recaptured at lower trap (RM4).

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

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

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

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

Appendix 8. Descriptive statistics of size at time 1 (T1) and time 2 (T2), percent change in size (FL, Wt), absolute growth rate (FL, Wt), relative growth rate (FL, Wt) and specific growth rate scaled (FL, Wt) for pit tagged 0+ Chinook salmon recaptured (n = 27) at the lower trap in Redwood Creek, Humboldt County, CA., 2005.

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

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

** SD = standard deviation of mean.

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

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

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

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