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The Resources Agency
DEPARTMENT OF FISH AND GAME**

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**REDWOOD CREEK JUVENILE SALMONID
DOWNSTREAM MIGRATION STUDY, Study Year 2004
PROJECT 2i3**

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Anadromous Fisheries Resource Assessment and Monitoring Program

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ABSTRACT

Juvenile anadromous salmonid trapping was conducted at two locations in Redwood Creek in the spring/summer of 2004 to estimate juvenile out-migrant population sizes for wild 0+ Chinook salmon, 1+ steelhead trout, 2+ steelhead trout, and 1+ coho salmon using stratified mark/recapture methods. The study also served to describe juvenile salmonid out-migration at the two trap locations in upper and lower Redwood Creek. The upper trap (RM 33) operated 133 nights out of a possible 134, and captured 206,261 0+ Chinook salmon, 128,885 0+ steelhead trout, 16,404 1+ steelhead trout, 1,298 2+ steelhead trout, 4 cutthroat trout, and 8 0+ pink salmon. The lower trap (RM 4) operated 109 nights out of a possible 113, and captured 61,778 0+ Chinook salmon, 2 1+ Chinook salmon, 18,642 0+ steelhead trout, 6,371 1+ steelhead trout, 907 2+ steelhead trout, 37 cutthroat trout, 202 0+ coho salmon, and 69 1+ coho salmon. Trap efficiencies at the upper trap were markedly higher than at the lower trap, most likely due to an increase in channel gradient and decrease in channel width compared to the lower trap site. Population estimates varied by species at age and trap location. I estimate that 629,847 0+ Chinook salmon, 41,434 1+ steelhead trout, and 5,778 2+ steelhead trout emigrated from upper Redwood Creek, and 554,890 0+ Chinook salmon, 77,221 1+ steelhead trout, and 24,095 2+ steelhead trout emigrated from the Redwood Creek basin upstream of the lower trap site. The size of 0+ Chinook salmon out-migrants at the upper trap were smaller than out-migrants at the lower trap, and 1+ and 2+ steelhead at the upper trap were slightly larger than those at the lower trap. We determined travel time for a small number of 1+ steelhead trout and 2+ steelhead trout released at the upper trap site to travel 29 miles downstream to the lower trap site. Travel time for 1+ steelhead ranged from 2 – 32 days and averaged 15 days; travel time for 2+ steelhead ranged from 2 – 35 days, and averaged 13 days. Other comparisons between traps are made in this report.

^{1/} This paper should be referenced as: Sparkman, MD. 2004. Redwood Creek juvenile salmonid downstream migration study, study year 2004. CDFG AFRAMP Annual Report, 2i3: 61 p.

INTRODUCTION

This paper presents the results of the California Department of Fish and Game's juvenile anadromous salmonid downstream migration study in Redwood Creek, Humboldt County, California, conducted during the spring/summer of 2004. The primary purpose of the study was to determine population estimates of downstream migrating smolts prior to their entry into the estuary and Pacific Ocean. The study utilized two rotary screw traps located at different locations in the watershed: upper Redwood Creek (Redwood Valley, RM 33) and lower Redwood Creek (Orick, RM 4). The upper Redwood Creek trap was funded by the California Department of Fish and Game's Steelhead Report Card Program and the Redwood Creek Landowners Association (RCLA). The lower trap was solely funded by the department of fish and game's steelhead report card program. The upper trap completed its' fifth consecutive year of trapping in 2004, whereas the lower trap completed it's first year of trapping. The department and RCLA hope to continue the study for a longer period of time (>10 yrs) in order for the study to encompass as much environmental and biological variation as possible.

Although there is abundant data on Redwood Creek with respect to geology, geomorphology, hydrology, forestry, and wildlife biology, relatively little information exists concerning anadromous salmonid populations upstream of the estuary. Studies of salmon and steelhead in Redwood Creek include: adult summer steelhead snorkel (dive) survey counts, estuarine juvenile salmonid monitoring, stream habitat typing, juvenile coho salmon presence/absence surveys, late summer juvenile steelhead and coho abundance surveys in selected Redwood Creek tributaries, and upper Redwood Creek out-migrant trapping. 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. 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.

Determining and documenting juvenile out-migration can be used to help assess: 1) the number of parents that produced the cohort, 2) redd gravel conditions, 3) in-stream habitat quality, 4) watershed health, 5) restoration activities, and 6) future recruitment to adult populations (i.e. population dynamics). To assess such factors, downstream migration studies need to be conducted over multiple consecutive years, particularly for trend analysis purposes. Studies of population dynamics rely upon the assumption that juvenile production will to some degree parallel adult population sizes in response to stream and oceanic conditions over time.

Site Description

Redwood Creek lies within the Northern Coast Range of California, and flows 70 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

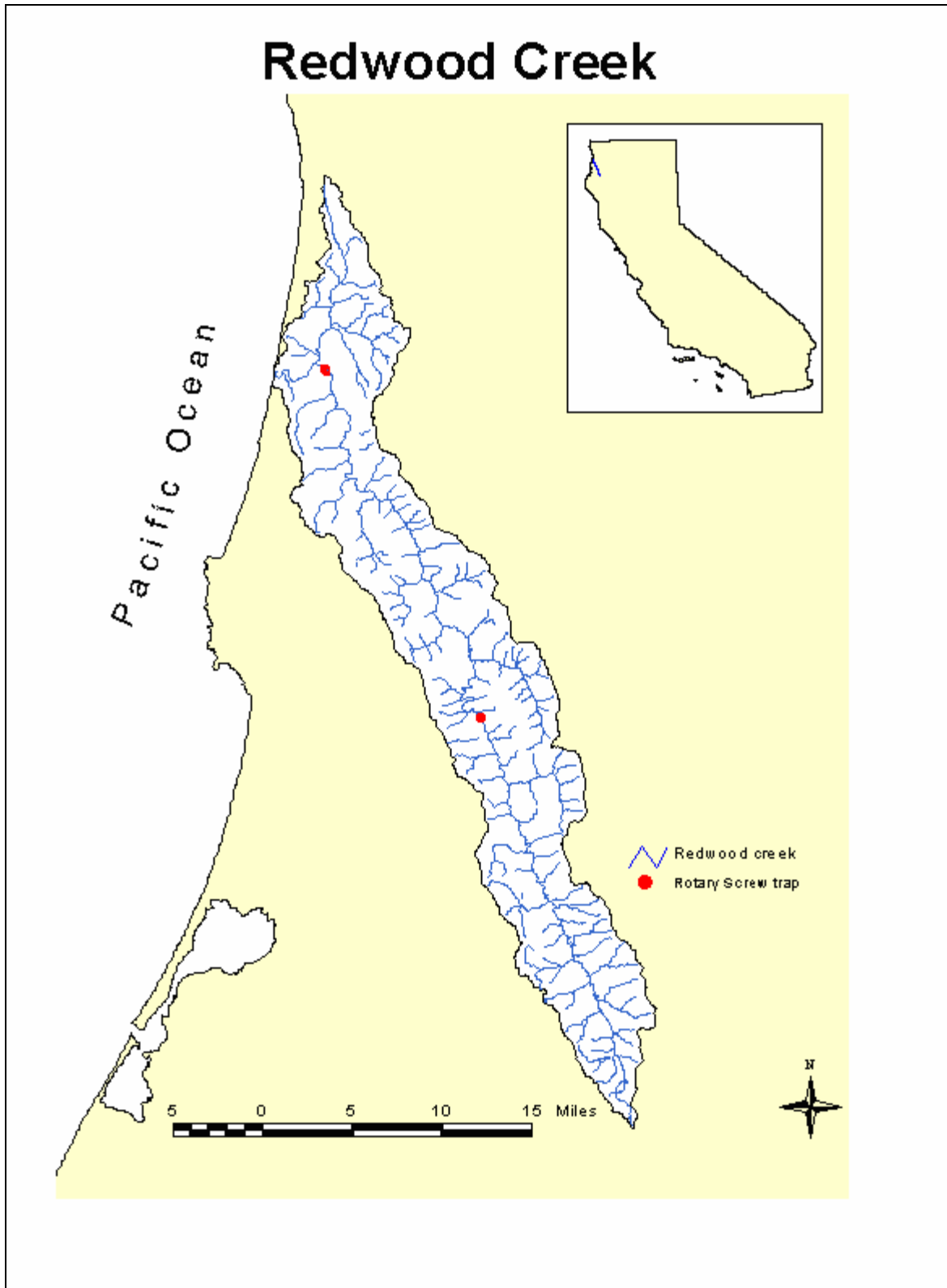


Figure 1. Redwood Creek watershed with rotary screw trap locations, Humboldt County, California.

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).

The geology of 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 upland areas that experience high and low temperatures. Summers are typically cool and moist on the coast, and hot and dry inland.

A weather station (Davis Vantage Pro Weather Station) is located at the Hinz family residence in Redwood Valley, about 5.25 miles downstream of the upper trap site and 23.75 miles upstream of the lower trap site. Rainfall records cover the period from 1986 to the present to total 19 years (Redwood National Park, in house data, 2004; Vicki Ozaki pers. comm. 2004). Most (97%) of the rainfall in Redwood Creek occurs from October through May, with peak monthly rainfall normally occurring in December and January. However, in some years peak monthly rainfall may occur in November or February as well. Annual precipitation ranges from 90 cm (35.4 in.) to 238 cm (93.7 in.), and averages 176 cm (69.3 in.). Rainfall in water year (WY) 2004 (October 2003 through September 2004) was about 178.8 cm (70.4 in.), and was slightly higher than the 19 year average. In WY 2004, monthly rainfall peaked in December (54.9 cm or 21.6 in.), with a smaller peak in February (44.2 cm or 17.4 in.). The total monthly rainfall during the majority of the 2004 trapping season (April – July) was 13.3 cm (5.3 in.), which was about 47% less than the historic average for this time period. Most of the rainfall during the 2004 trapping season fell in April (10.2 cm or 4.0 in.).

Stream Discharge

Upper Redwood Creek (O’Kane)

A USGS gauging station (#11481500) is located about 8.4 miles upstream of the upper trap site on Redwood Creek. Stream flow records cover the periods of 1953 – 1958, 1972 – 1993, and 1997 – 2004, and total 33 years (Thomas C Haltom pers. comm. 2004; USGS 2004). Following the pattern of rainfall, most of the high flows occur in the months of November through May, and typically peak in February. Low flows usually occur from July through October. Using all years’ data, mean monthly discharge is 233 cfs, and ranges from 8 – 564 cfs (Thomas C Haltom pers. comm. 2004; USGS 2004).

Preliminary data for water year 2004 show that the mean monthly discharge was 202 cfs, and ranged from 3 – 829 cfs. The average monthly flow during the trapping season was about 68 cfs, and ranged from 11 – 163 cfs (Thomas C Haltom pers. comm. 2004; USGS 2004). The average monthly flow during the trapping season in 2004 was about 49% less than the historic average for this time period.

Lower Redwood Creek (Orick)

A USGS gauging station (#11482500) is located about 0.7 miles downstream of the lower trap site on Redwood Creek. The gauging station is downstream of the confluence of Prairie Creek with Redwood Creek, thus the station is influenced by Prairie Creek streamflow. Stream flow records for the Orick gage cover the periods of 1911 – 1913, 1953 – 2004, and total 53 years (Thomas C Haltom pers. comm. 2004; USGS 2004). High flows usually occur from November through May, and typically peak in January. However, the months of December, February, and March can experience high flows as well. Using all years’ data, mean monthly discharge is 1,101 cfs, and ranges from 37 – 2,510 cfs (Thomas C Haltom pers. comm. 2004; USGS 2004).

Preliminary data for water year 2004 show that the mean monthly discharge was 850 cfs, and ranged from 8 – 3,113 cfs. The highest mean monthly discharge in WY 2004 occurred in February. The average monthly flow during the trapping season (April – July) was about 256 cfs, and ranged from 41 – 602 cfs (Thomas C Haltom pers. comm. 2004; USGS 2004). The average monthly flow during the trapping season in 2004 was less than the historic average flow for this time period by about 53%.

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 some 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.*), manzanita (*Arctostaphylos patula*), bracken fern (*Pteridium aquilinum*), blackcap raspberry (*Rubus spp.*), and elderberry (*Sambucus spp.*), among other species.

Redwood Creek Management 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 (Dave Anderson pers. comm. 2004). In conjunction with clear-cut logging, associated road building, geology types, 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). Additional high flows occurred in 1972, 1975, and 1995 as well, and have helped influence the current channel morphology of Redwood Creek.

Redwood Creek has recently been listed as sediment and temperature-impaired under section 303(d) of the Clean Water Act (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. 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 1999). 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 1999). 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 was to describe juvenile anadromous salmonid downstream migration at two locations in Redwood Creek, and to determine out-migrant population sizes for wild 0+ (young-of-year) Chinook salmon, 1+ (between 1 and 2 years old) steelhead trout, 2+ (2 years old and greater, in this study) steelhead trout, and 1+ coho salmon. The primary long term goal is to determine the status and trends of out-migrating juvenile salmonids in upper and lower Redwood Creek. A secondary goal is to document the presence or absence of juvenile coho salmon and 1+ Chinook salmon, particularly in upper Redwood Creek. Specific study objectives were as follows:

- 1) Determine the temporal pattern and species composition of downstream migrating juvenile salmonids at two locations in the watershed.
- 2) Enumerate species out-migration.
- 3) Determine population estimates for downstream migrating 1+ steelhead, 2+ steelhead, 0+ Chinook salmon, and 1+ coho salmon.
- 4) Record fork length (mm) and weight (g) of captured fish.
- 5) Investigate 1+ steelhead and 2+ steelhead travel time from the upper trap to lower trap.
- 6) Collect and handle fish in a manner that minimizes mortality.
- 7) Statistically analyze data for significance and trends.
- 8) Compare/contrast data between traps.

METHODS AND MATERIALS

Trap Operations

Upper trap

A modified E.G. Solutions (5 foot diameter cone) rotary screw trap was deployed in upper Redwood Creek (RM 33) on March 24, 2004 at the same location as in previous study years (i.e. downstream of a moderately high gradient riffle). Modifications to the trap involved using the larger pontoons normally equipped with the 8 foot cone so that a larger livebox could be used. The debris wheel of the E.G. solutions livebox was cut out, and aluminum was added to the livebox to increase the length nearly two-fold (L 218.4 cm x W 121.9 cm x H 55.9 cm). A framed perforated plate was then used to close the downstream end where the debris wheel was once located. Perforated plates with 2 mm holes were also placed in the sides (n = 2, 56 x 31 cm) and bottom (n = 1, 89 x 41 cm) of

the livebox to dissipate livebox water velocities. The modifications to the livebox decreased livebox water velocities, allowed for less fish crowding during peak catches, and enabled the trap to continue trapping under higher flows as compared to the stock model.

The upper rotary screw trap operated continually (24 hrs/day, 7 days a week) from March 24 through July 21 except for one day (April 22, 2004) when stream flows and debris loads were too high to trap safely. During this time, we pulled the trap to the side of the stream and raised the cone. The trap was re-set on the afternoon of April 22 in the thalweg of the stream. Both rock and panel type weirs were used from April 4 to July 21 to direct more flow into the cone area of the trap, and to help increase trap efficiencies. On July 22, 2004 the rotary screw trap was no longer functional due to low flows and low cone revolutions (less than 9 per 3 minutes), and a pipe trap similar to that used in YRS 2001-2003 was set on July 21, 2004. The system worked well, and enabled trapping to the end of the season. A more complete description of trap operations for the upper Redwood Cr trap can be found in Sparkman (2005, study 2a5, In progress).

Lower trap

A 'stock' E.G. Solutions (5 foot diameter cone) rotary screw trap was set in lower Redwood Creek (RM 4) on April 1, 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 trap was positioned in a run habitat type just downstream of a low gradient riffle. The trap location was about 1/3 mile upstream of the confluence of Prairie Creek with Redwood Creek.

The lower rotary screw trap operated continually (24 hrs/day, 7 days a week) from April 2 through July 27 except for four days (April 11 and April 21 – 23), three of which were due to high flows (April 21 – 23). During these periods we moved the trap to the side of the stream and raised the cone. The trap was re-set on the afternoon of April 12 and April 23. Panel weirs were used from June 7 to July 27 to direct flow and increase trap efficiencies. On July 27, 2004 streamflow was too low and the cone stopped spinning, thereby ending the study. This section of Redwood Creek is known to completely de-water during late July. A more complete description of trap operations for the lower Redwood Cr trap can be found in Sparkman (2005, study 2a7, In progress).

Biometric Data Collection

Both trap's live boxes were 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 were placed into 5 g buckets and carried to the processing station. At the station, fish were placed into a 23.5 gallon 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 that connected to a manifold with four ports. Garden hoses connected to the ports, with one line feeding the ice chest, and the other three feeding recovery buckets

for processed fish. Plumbing inside the ice chest consisted of two PVC pipes: one that served to dissipate the stream water into the livebox, 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 aerators, and decreased total fish processing time.

Each individual fish was observed and counted by species and age. Random samples of each species at age (e.g. 0+ Chinook salmon, 0+ steelhead trout, etc.) were netted from the ice chest for enumeration and biometric data collection.

Fork Lengths/Weights

Fish were anesthetized with MS-222 prior to data collection in 2 g 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+ steelhead trout (1+ SH), 2+ steelhead trout (2+ SH), 0+ coho salmon (0+ CO), 1+ coho salmon (1+ CO) and cutthroat trout (CT). Only fork lengths were taken for 0+ steelhead trout (0+ SH). A 350 mm measuring board (± 1 mm) and an Ohaus Scout II 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, Chinook salmon and coho salmon were used to determine age-length relationships at varying times throughout the trapping period. Scales were read to verify fork length cutoffs by age class. 0+ Chinook salmon and 1+ steelhead weights (g) were taken 2-3 times per week. 0+ coho salmon, 1+ coho salmon, 1+ Chinook salmon, cutthroat trout (ages 1 and greater), and 2+ steelhead weights were taken almost every day of trap operation and collection due to expected low sample sizes. Individuals were weighed in a tared plastic pan (containing water) on the electronic scale. The scale was calibrated every day prior to data collection.

Developmental Stages

We visually determined developmental stages (e.g. parr, pre-smolt, smolt) for every 1+ steelhead trout, 2+ steelhead trout, 1+ coho salmon and 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 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 each crew member and having all crew members

follow the same protocol. The most difficult stages to separate are for those fish which are between smolt and pre-smolt.

Population Estimates

The number of fish captured by the traps represented only a portion of the total fish moving in that time period. Total salmonid out-migration estimates (by age and species) were determined for each trap on a weekly basis for 0+ Chinook salmon, 1+ steelhead trout, and 2+ steelhead trout using stratified mark-recapture methodology described by Carlson et al. (1998). The approximately unbiased estimate equation for a 1-site study was used to determine total population size (U_h) in a given capture and trapping efficiency period (h) for each trap. Variance was computed, and the value was used to calculate 95% confidence intervals (CI) for each weekly population estimate. If there were not sufficient recaptures during most weeks for a species at age (2+ steelhead, lower trap), then I calculated a total population estimate by using the total recaptures, total marked releases, and total catch.

Trap efficiency trials were conducted three times a week for 0+ Chinook salmon and 1+ steelhead, and five times a week for 2+ steelhead and 1+ coho salmon (due to low sample sizes). Trap efficiency data was combined and run through the equation to determine the weekly population estimate. The overall ‘seasonal’ trap efficiency equals the total number of recaptures divided by the total number of marked releases. Partial fin clips were used to identify trap efficiency trial fish by squaring the round edge of a given fin (caudal, pectoral) with scissors. Clips were stratified by trap location, and by week when possible (e.g. 2+ steelhead trout). Marked fish were released 160 – 260 m upstream of the upper trap, and 152 – 183 m upstream of the lower trap.

The Carlson et al. (1998) model and my methods were (favorably) peer reviewed in 2003 (Phil Law, pers. comm. 2003) (see Sparkman 2004 study 2a5 for more information).

Additional Experiments

We investigated travel time from the upper trap to the lower trap (a distance of 29 miles) for 1+ steelhead trout (n = 577) and 2+ steelhead trout (n = 223) using plastic elastomer (Northwest Marine Technology, P.O. Box 427, Ben Nevis Loop Road, Shaw Island, Washington 98286 USA) over the course of the study. 1+ steelhead trout were treated separately from 2+ steelhead trout. Each week 13 – 80 fish were given an elastomer injection into the lower jaw with a color (green, blue, red, purple) unique for that week. By using multiple color combinations and adding a partial upper or lower caudal fin clip, we were able to further stratify the unique mark combination for any given week. The elastomer injection and potential fin clip were applied to the fish while under anesthesia. Marked fish were held in live cars in the stream for a 24 hour period to test for immediate and (short-term) delayed mortality, and then released into the stream.

Physical Data Collection

Continual stream temperatures were recorded with an Optic StowAway Temp Probe (Onset computer corporation, 470 MacArthur Blvd. Bourne, MA 02532) placed behind each rotary screw trap. Additional probes were set at the gage height meter and served for comparison. The probes were placed into a cylinder for protection, and holes were drilled for adequate ventilation. The probes were set to record stream temperature (°C) every hour. A total of 3,217 measurements were made at the upper trap, and 2,760 at the lower trap. Data was later downloaded into Microsoft Access© to determine daily mean, maximum, and minimum water temperatures.

Statistical Analyses

Numbers Cruncher Statistical System Software (NCSS) (Hintze 1998) was used for descriptive statistics, ANOVA, correlation, linear regression/ANOVA output, and Chi-square (contingency tables). Descriptive statistics were used to characterize the mean fork length (mm) and weight (g) of each species at age on a weekly and seasonal basis. ANOVA was used to test if the fork length and weight of each species at age was different between traps. ANOVA was also used to compare daily average temperatures and maximum temperatures between trap locations. Linear correlations were used to test for significant relations of biological data (e.g. FL, Wt) with temporal data (week of study). Chi-square was used to test for differences in the proportion of developmental stages (parr, pre-smolt, smolt) between traps, and for differences between pre-smolt and smolt classifications between traps. If the data was not appropriate for a Chi-square test, a Fisher exact test was used. When more than one Chi-square test (or Fisher exact test) was conducted on a data set, multiple error (or compounding error) correction factors were used by dividing alpha (0.05) by the number of tests involved (e.g. 3), to give a corrected alpha of 0.017 (in this case) for each test.

If data violated tests of assumptions (e.g. ANOVA and regression/correlation tests), data was transformed with Log (x+1), where x = the response or independent variable (Zar 1999). When transformations did not work for ANOVA, non-parametric equivalents were used (i.e. 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 all tests was set at 0.05, unless correction factors were used.

RESULTS

The upper Redwood Creek rotary screw trap operated from 3/24/04 – 7/21/04 and trapped 118 nights out of a possible 119. The pipe trap in upper Redwood Creek operated from 7/21/04 – 8/05/04, and trapped 15 nights out of a possible 15. Using both traps, trapping in upper Redwood Creek occurred 133 out of 134 nights possible (99%). The lower Redwood Creek rotary screw trap operated from 4/2/04 – 7/27/04, and trapped 109 nights out of a possible 113 (96%).

Species Captured

Juvenile salmonids

Salmonid species captured in the 2004 study year included: juvenile Chinook salmon (*Oncorhynchus tshawytscha*), juvenile coho salmon (*O. kisutch*), juvenile coastal steelhead trout (*O. mykiss irideus*), cutthroat trout (*O. clarki clarki*), and juvenile pink salmon (*O. gorbuscha*) (Table 1). Juvenile salmonid catches varied by species composition and numbers between traps. The upper trap caught considerably more fish than the lower trap (Table 1). Coho salmon have not been caught in upper Redwood Creek for the past five consecutive study years. Although in very small numbers, pink salmon were caught in upper Redwood Creek during YR 2004, as well as YRS 2000 and 2002.

Table 1. Juvenile salmonids captured by rotary screw traps in upper and lower Redwood Creek, Humboldt County, Ca. 2004.

Age/species	Number of juvenile salmonids captured	
	Upper Trap	Lower Trap
0+ Chinook Salmon	206,261	61,778
1+ Chinook Salmon	0	2
0+ Coho Salmon	0	202
1+ Coho Salmon	0	69
0+ Steelhead Trout	128,885*	18,642*
1+ Steelhead Trout	16,404	6,371
2+ Steelhead Trout	1,298	907
Cutthroat Trout	4	37
0+ Pink Salmon	8	NC**
Total:	352,860	88,008

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

** NC denotes not counted

Miscellaneous Species

Sculpin (*Cottus* spp.), sucker (*Catostomidae* family), three-spined stickleback (*Gasterosteus aculeatus*), juvenile (ammocoete) lamprey and adult Pacific Lamprey

(*Entosphenus tridentatus*) were also caught (Table 2). Amphibian catches included Coastal (Pacific) Giant Salamander (*Dicamptodon tenebrosus*), Rough Skinned newt (*Taricha granulosa granulosa*), Yellow Legged frog (*Rana muscosa*), Tailed Frog tadpole (*Ascaphus truei*) and American bullfrog (*Rana catesbeiana*) (Table 2). Numerous aquatic and semi-aquatic invertebrates were also caught.

Table 2. Miscellaneous species captured by rotary screw traps in upper and lower Redwood Creek, Humboldt County, CA. 2004.

Common Name	Miscellaneous species captured in 2004	
	Upper Trap	Lower Trap
Prickly Sculpin	7	68
Coast Range Sculpin	16	502
Sucker	19	156
3-Spined Stickleback	102	7,225
Brown Bullhead	0	0
Adult Pacific Lamprey	31	13
Juvenile Lamprey	2,214	154
Possible River Lamprey	0	0
Pac. Giant Salamander	185	4
Painted Salamander	3	0
Rough Skinned Newt	28	2
Red-Legged Frog	0	0
Yellow-Legged Frog	16	0
Tailed frog tadpole	4	0
American Bullfrog	2	0

Salmonid Captures

Catches of 0+ Chinook salmon, 0+ steelhead trout, 1+ steelhead trout, 2+ steelhead trout, 0+ coho salmon, and 1+ coho salmon were variable over time, with apparent multiple peak catch distributions (Sparkman 2005 2a5, 2a7, In progress).

Average daily catches at the upper trap for all species at age (excluding coho salmon) were much higher compared to the lower trap (Table 3). Any given day's catch at either trap did not equate to a large percentage of the total trap's catch (i.e. < 0.90%) (Table 3).

Table 3. Daily catch data summary and daily catch data expressed as a percentage of total catch for each species at age, Redwood Creek, 2004.

Species & Age Class	Daily Capture				Daily Capture as Percent of Total Capture			
	Range		Average		Range		Average	
	Trap Site				Trap site			
	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower
Chinook								
0+	0-10,700	0-2,196	1,539	547	0-5.2%	0-3.5%	0.75%	0.88%
Steelhead								
0+	0-6,428	0-639	969	154	0-5.0%	0-3.3%	0.75%	0.89%
1+	0-727	0-213	122	56	0-4.4%	0-3.3%	0.75%	0.89%
2+	0-31	0-39	10	8	0-2.4%	0-4.3%	0.75%	0.88%
Coho								
0+	0	0-15	n/a	2	n/a	0-7.4%	n/a	0.85%
1+	0	0-7	n/a	0.6	n/a	0-10.1%	n/a	0.85%

Days missed trapping

We missed one day of trapping at the upper trap (4/22) and four days (4/11, 4/21, 4/22, and 4/23) at the lower trap through the season due to high flow events (except on 4/11 when we observed the Easter holiday, lower trap). Days missed trapping did not influence the total catch (and population estimate) to any large degree because any given catch day did not equate to a large percentage of the total catch (see above), nor occur near days of peak catches. For example, if we interpolate the missed day's catches at the lower trap (for 1+ steelhead trout, in this case) using regression techniques and daily capture data (near the time frame of missed days), we estimate we missed (or undercounted) 125 fish, which equals about 1.9% of the total 1+ steelhead trout catch. Applying the missed catches to the population estimate equation (i.e. adding to the number caught by week), our population estimate increases by 2% (or 1,514 fish). In conjunction with peak catches not occurring near these time frames, we concluded the missed day's catches were negligible with respect to affecting the catch and population estimate.

0+ Chinook Salmon

The pattern of 0+ Chinook salmon catches by week show similarities and differences between traps (Figure 2). Catches at the upper and lower trap both started out relatively low, quickly increased, and then decreased. From 5/07 onward, the catches at the upper trap quickly increased to relatively high values as compared to the lower trap which gradually increased in catches over time. The catches at both traps, from 7/2 onward, descended to low values and remained low for the remainder of the study. The majority of 0+ Chinook salmon catches at the upper trap occurred in April (n = 91,163), May (n = 60,186) and June (n = 49,924), and those months collectively accounted for about 98% of the total 0+ Chinook salmon catch at the upper trap. The most important months for catching 0+ Chinook salmon at the lower trap was May (n = 20,072) and June (n = 28,832), which accounted for 79% of the total 0+ Chinook salmon catch.

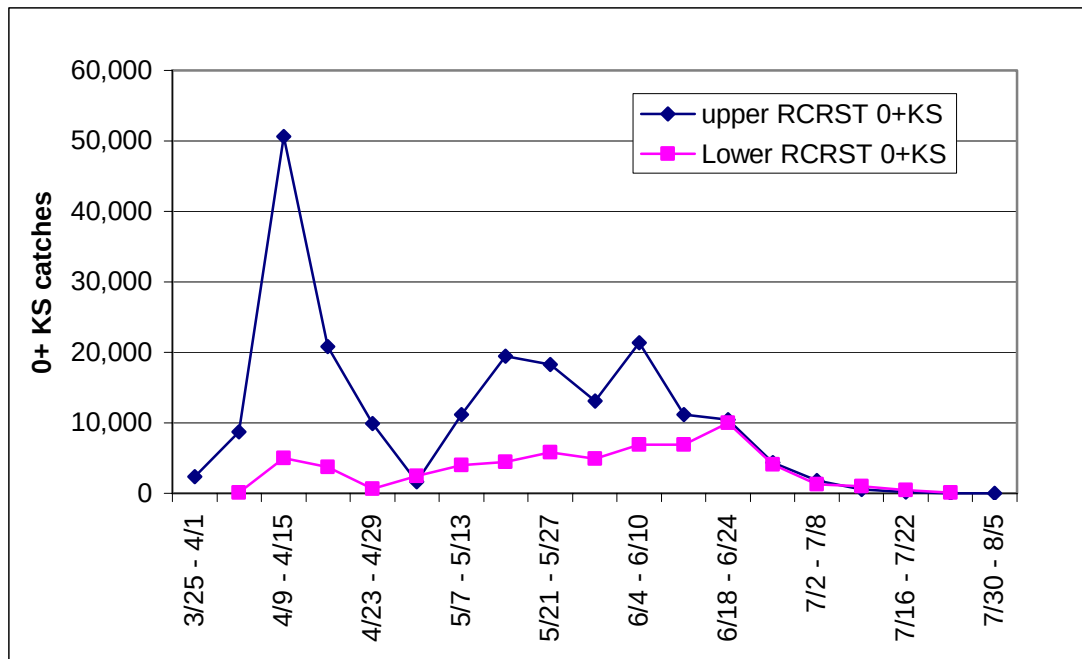


Figure 2. Comparison of 0+ Chinook salmon catches by week at two trap locations, Redwood Creek, 2004.

1+ Chinook Salmon

Very few 1+ Chinook salmon were captured in 2004, which may relate to the young of year cohort failure we found in 2003 (Sparkman 2004). The low catches in 2004 occurred on 5/12 and 5/14 at the lower trap.

0+ Steelhead Trout

The weekly catch distribution for young-of-year steelhead trout was markedly different between traps (Figure 3). Besides the upper trap catching far more 0+ steelhead trout, periods of high catches occurred at different times. At the upper trap, May (n = 79,162), June (n = 25,877), and July (n = 20,733) were important months, compared with June (n = 9,947) and July (n = 4,994) for the lower trap. The months of May – July accounted for 98% of the total 0+ steelhead trout catch at the upper trap, compared with June and July which accounted for 80% of the lower trap's 0+ steelhead trout catch.

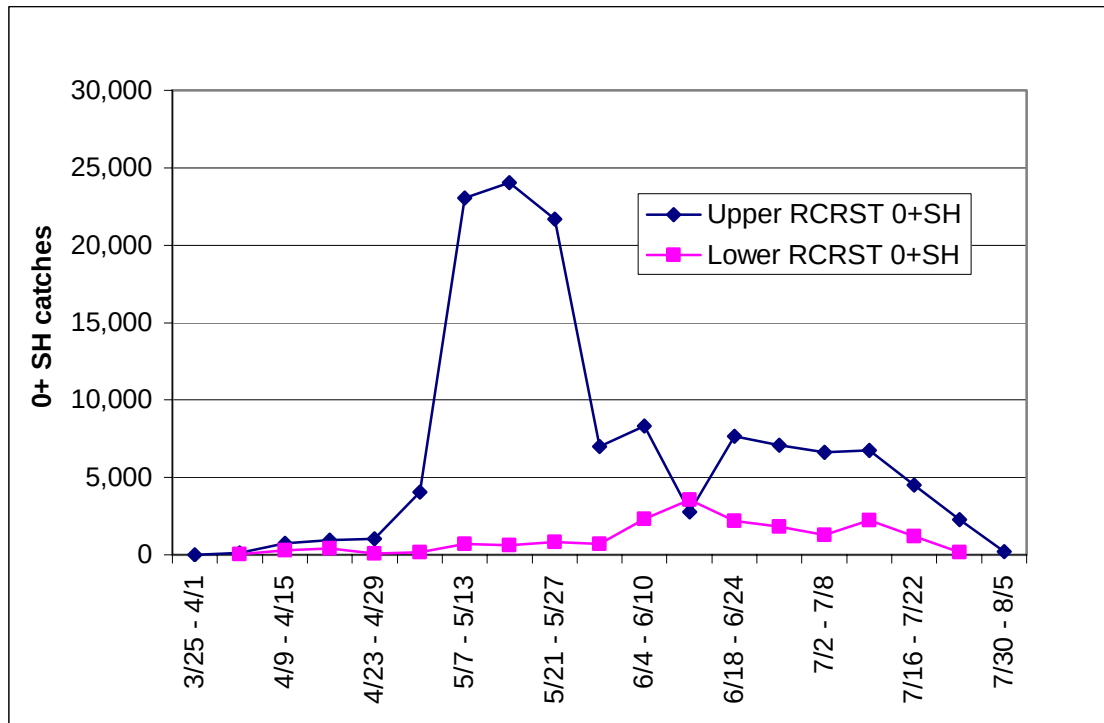


Figure 3. Comparison of 0+ steelhead trout catches by week at two trap locations, Redwood Creek, 2004.

1+ Steelhead Trout

The general pattern of 1+ steelhead trout catches for both traps was surprisingly similar (Figure 4). Although far more 1+ steelhead trout were caught at the upper trap, the peak in catches occurred during the same time period (5/14 – 5/20). The most important months for 1+ steelhead trout catches at the upper trap (April and May) accounted for 13,158 individuals, or 80% of the total 1+ steelhead trout catch, compared with May and June at the lower trap, which accounted for 4,778 individuals, or 75% of the total 1+ steelhead trout catch.

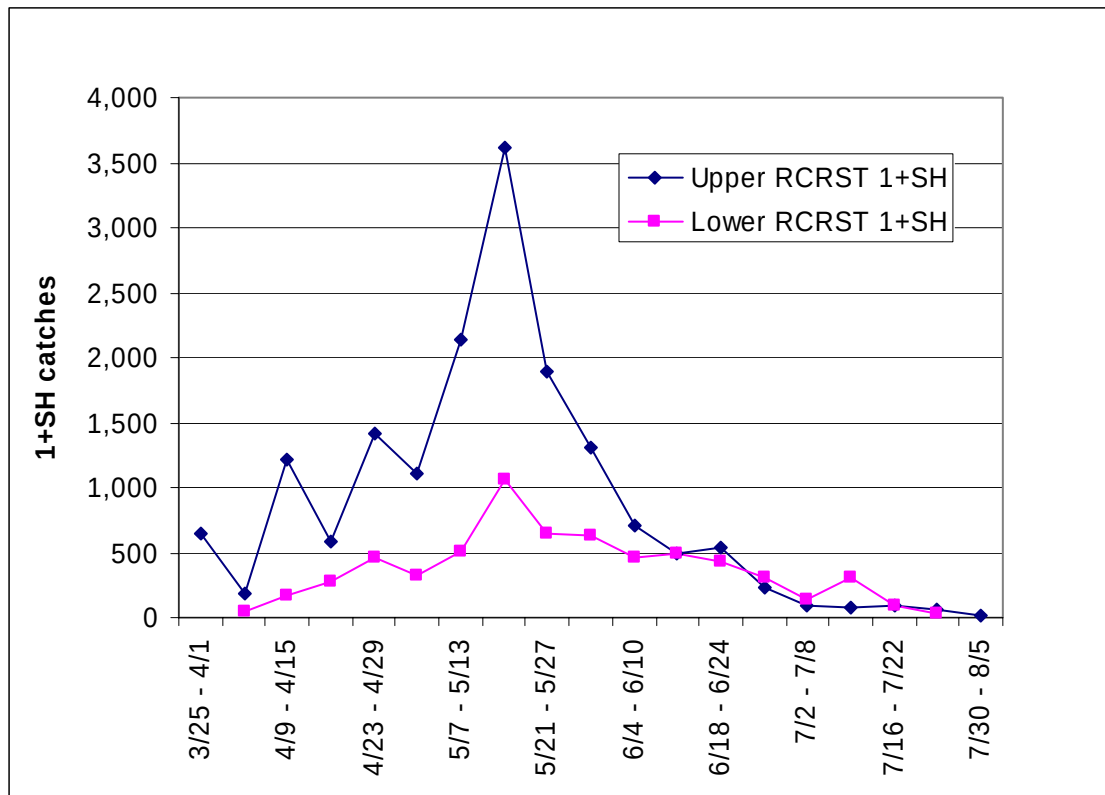


Figure 4. Comparison of 1+ steelhead trout catches by week at two trap locations, Redwood Creek, 2004.

2+ Steelhead Trout

The pattern of 2+ steelhead trout catches by week was also markedly similar for both traps (Figure 5). Catches started out moderately high, then descended, then reached a peak during 5/14 through 5/20, which was the same time period for peak 1+ steelhead trout catches (at both traps). 2+ steelhead trout catches at both traps then gradually decreased to the end of the study. The most important months for 2+ steelhead trout catches at the upper trap (April, May, and June) accounted for 1,080 individuals, or 83% of the total 2+ steelhead trout catch, compared with May and June at the lower trap, which accounted for 709 individuals, or 78% of the total 2+ steelhead trout catch.

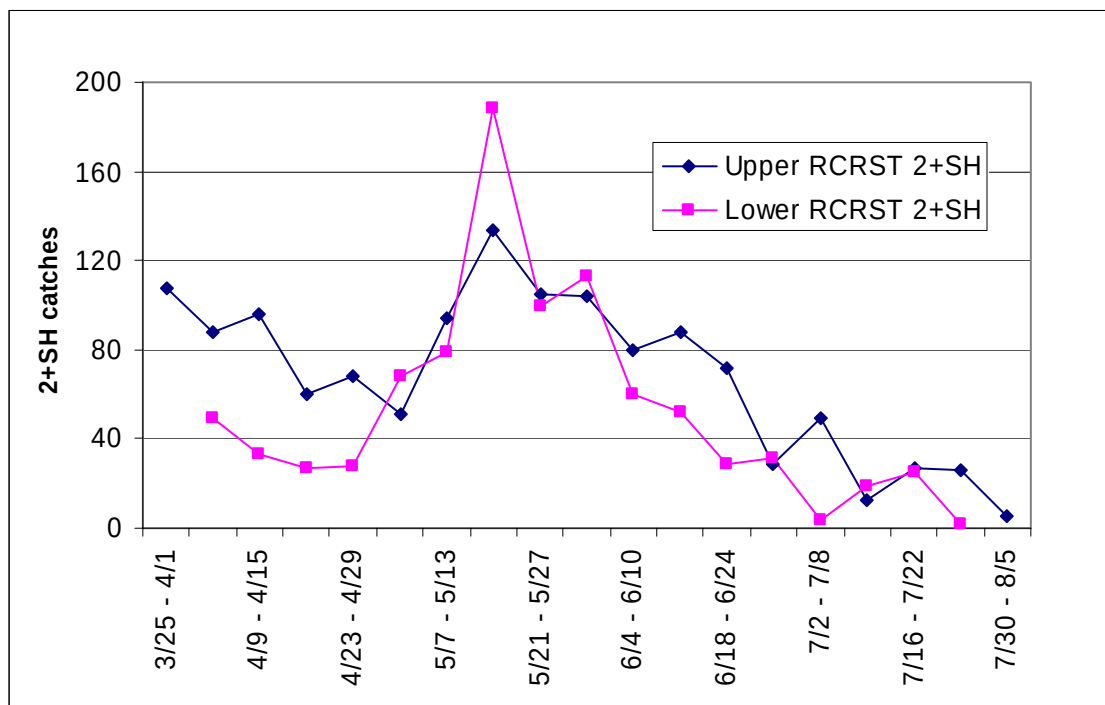


Figure 5. Comparison of 2+ steelhead trout catches by week at two trap locations, Redwood Creek, 2004.

0+ Coho Salmon

Young-of-year coho salmon were caught in each month of study at the lower trap (Figure 6). Catches generally increased over time, with the two largest peaks occurring in May and July. About 67% of the total 0+ coho salmon catch occurred during May and July. Catches severely dropped off the last week of trapping (7/23 – 7/29).

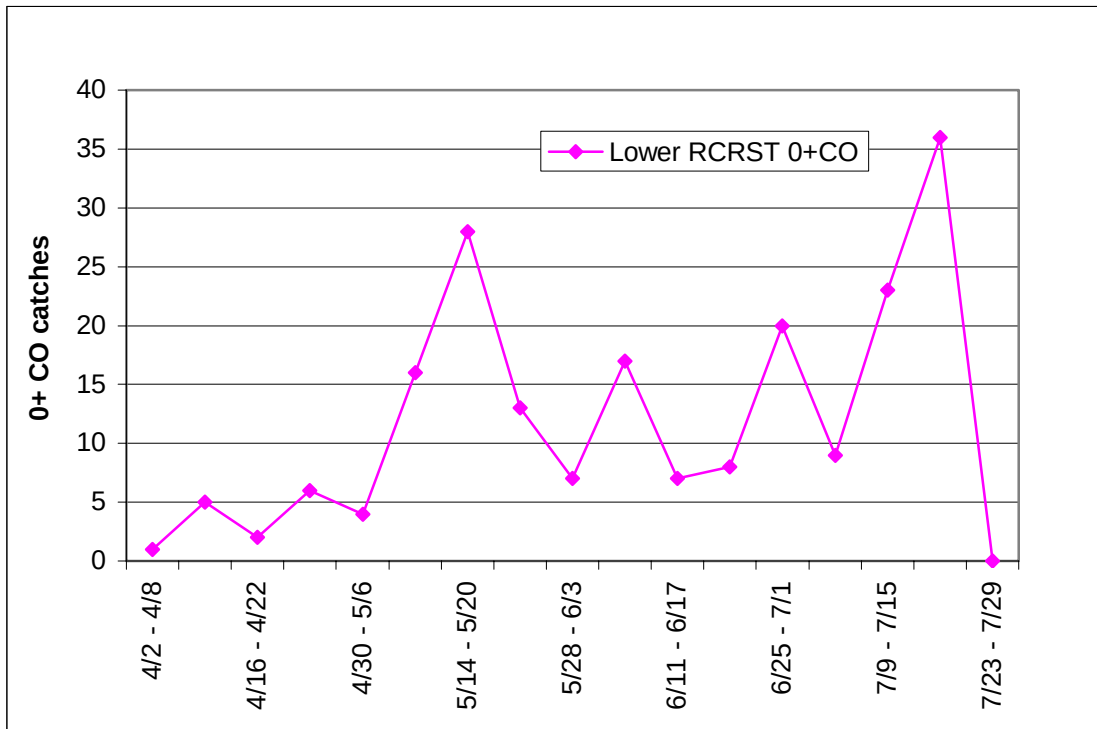


Figure 6. 0+ coho salmon catches by week at the lower Redwood Creek trap, 2004.

1+ Coho Salmon

1+ coho salmon catches occurred during April, May, and June (Figure 7). April and May accounted for 97% of the total catch.

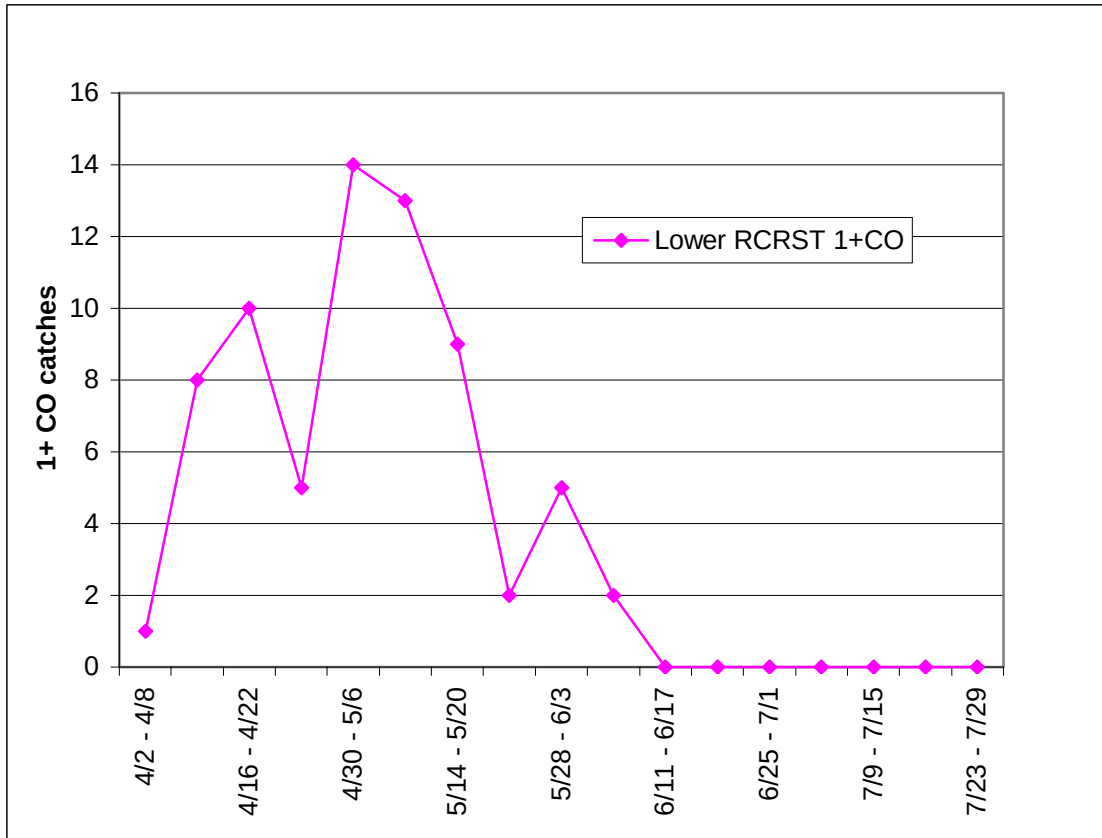


Figure 7. 1+ coho salmon catches by week at the lower Redwood Creek trap, 2004.

Cutthroat Trout

Few cutthroat trout were found to emigrate from upper Redwood Creek, as compared to those emigrating past the lower trap (Figure 8). Those that did emigrate from upper Redwood Creek, did so in April and May. At lower Redwood Creek, cutthroat trout were emigrating all months of trap operation (April – July).

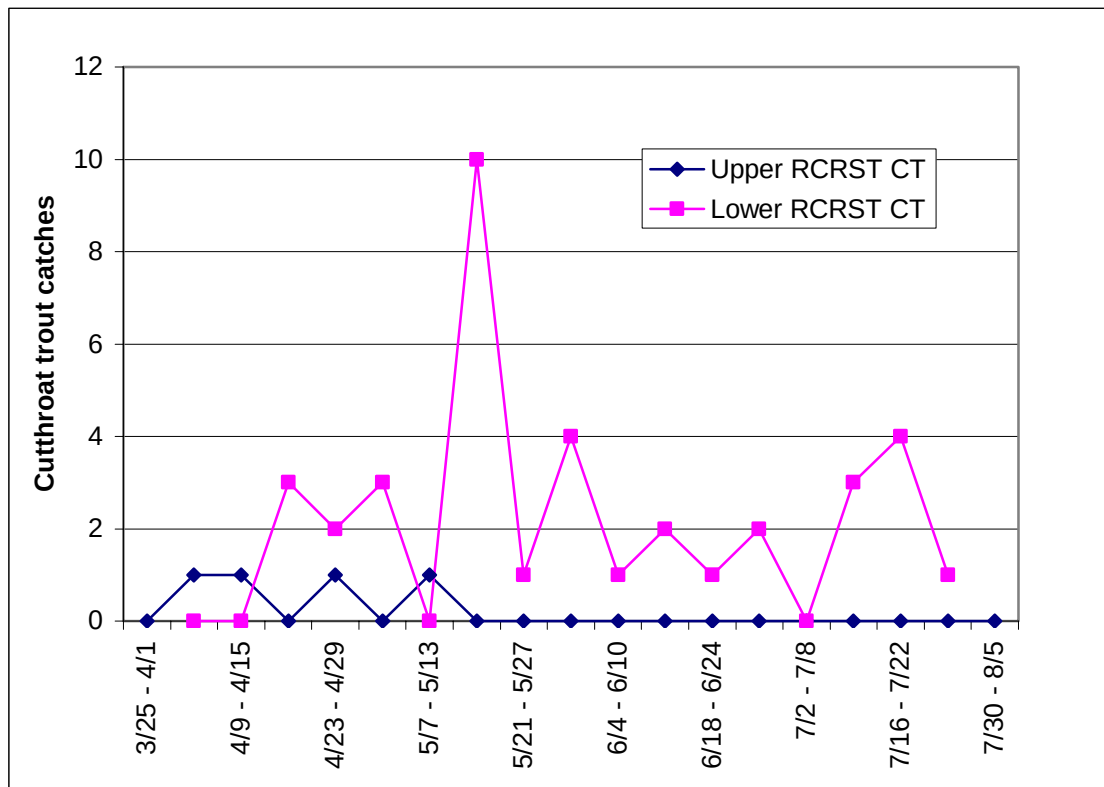


Figure 8. Comparison of cutthroat trout catches by week at two trap locations, Redwood Creek, 2004.

Fork Lengths and Weights

0+ Chinook Salmon

This year we measured (FL mm) 3,571 and weighed (g) 1,593 0+ Chinook salmon at the upper trap, and 3,192 (FL mm) and 1,429 (WT g) at the lower trap (Table 4). The median FL of 0+ Chinook salmon at the lower trap (61 mm) was significantly greater than the median FL (mm) of 0+ Chinook salmon at the upper trap (50 mm) (Kruskal Wallis One-Way ANOVA on Ranks, $p < 0.0001$). The median WT at the lower trap (2.4 g) was significantly greater than the median WT (g) at the upper trap (1.3 g) (Kruskal Wallis One-Way ANOVA on Ranks, $p < 0.000001$).

Table 4. 0+ Chinook salmon average fork length (mm) and weight (g) by trap location, 2004.

Trap	0+ Chinook Salmon							
	Fork Length (mm)				Weight (g)			
	n	Range	AVE.	SEM	n	Range	AVE.	SEM
Upper	3571	34 - 86	50.8	0.2	1593	0.4 – 5.8	1.61	0.03
Lower	3192	35 - 91	59.8	0.2	1429	0.3 – 8.0	2.55	0.04

The average weekly fork lengths of emigrating 0+ Chinook salmon followed similar trends over time for both traps (Figure 9). Average weekly fork lengths increased over the study period at the upper trap (Correlation, $r = 0.99$, $p < 0.000001$) and at the lower trap (Correlation, $r = 0.97$, $p < 0.000001$). Fork lengths were nearly the same for the first 3 – 4 weeks, however, from 4/23 onward, the average fork lengths by week at the upper trap were significantly less than those at the lower trap (ANOVA, $p = 0.046$, power = 0.52). At the end of the trapping season, the average weekly fork length at the upper trap (mean = 70.4 mm) was close to the last week's average for the lower trap (mean = 72.3 mm). The increase in average FL over time at both traps indicates the 0+ Chinook salmon are growing as they migrate downstream.

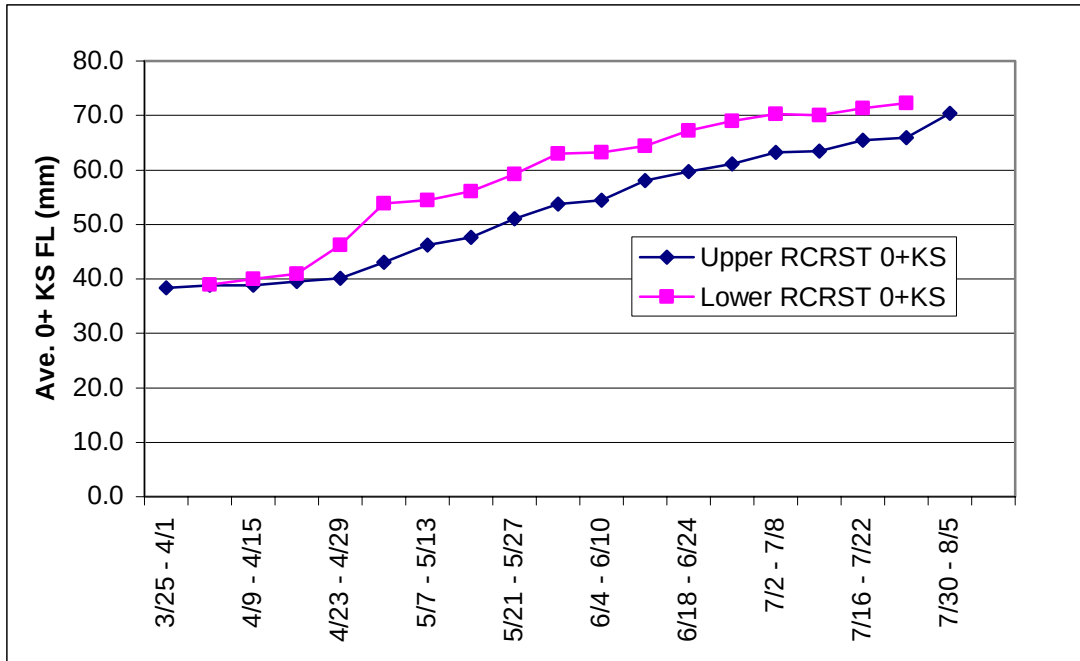


Figure 9. Comparison of 0+ Chinook salmon average fork length (mm) by week at both traps, 2004.

The average weekly weights of 0+ Chinook salmon also followed similar trends over time for both traps (Figure 10). Average weekly weights increased over the study period at the upper trap (Correlation, $r = 0.98$, $p < 0.000001$) and at the lower trap (Correlation, $r = 0.98$, $p < 0.000001$). For both traps, weights were nearly the same in the beginning of trapping. However, from 4/23 onward, the average weights by week at the upper trap were significantly less than those at the lower trap (ANOVA, $p = 0.039$, power = 0.55). Similar to FL data, the increase in average Wt over time at both traps indicates the 0+ Chinook salmon are growing as they migrate downstream.

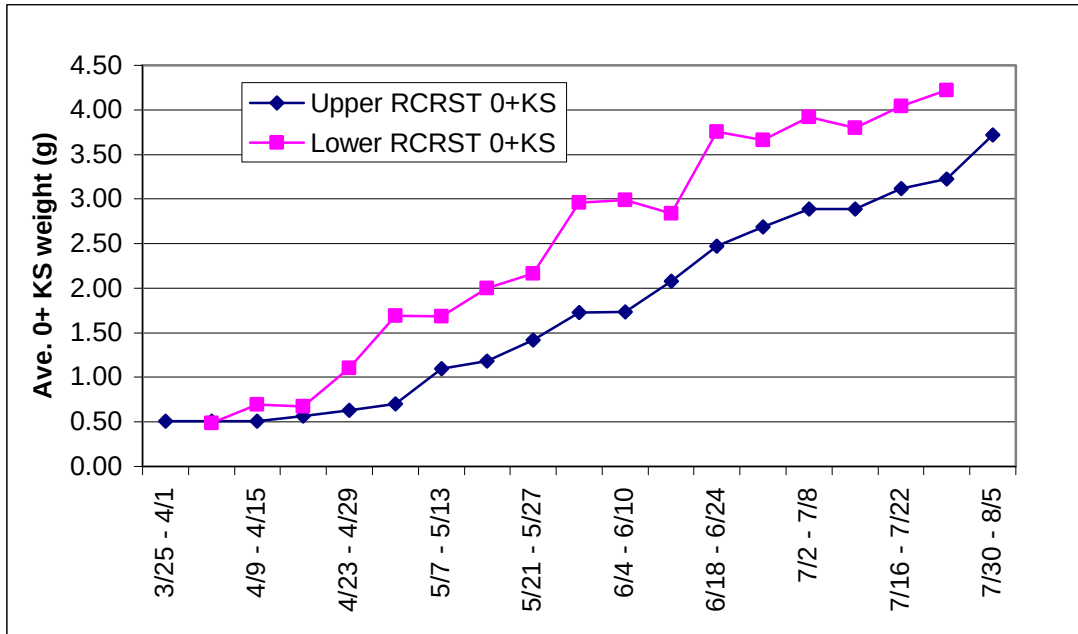


Figure 10. Comparison of 0+ Chinook salmon average weight (g) by week at both traps, 2004.

1+ Chinook Salmon

Only two 1+ Chinook salmon were captured in Redwood Creek during YR 2004 (5/12 and 5/14). The fork lengths were 96 and 106 mm, and the weights were 9.6 and 12.9 g, respectively.

0+ Steelhead Trout

This year we measured (FL mm) 3,615 0+ steelhead at the upper trap, and 2,939 0+ steelhead at the lower trap (Table 5). The median FL of 0+ steelhead trout at the lower trap (52 mm) was significantly greater than the median FL (mm) of 0+ steelhead trout at the upper trap (35 mm) (Kruskal Wallis One-Way ANOVA on Ranks, $p < 0.0001$).

Table 5. 0+ steelhead trout average fork length (mm) by trap location, 2004.

Trap	0+ Steelhead Trout							
	Fork Length (mm)				Weight (g)			
	n	Range	AVE.	SEM	n	Range	AVE.	SEM
Upper	3,615	24 - 69	37.5	0.2	-	-	-	-
Lower	2,939	26 - 74	49.6	0.2	-	-	-	-

The average weekly fork lengths of 0+ steelhead trout followed similar trends over time for both traps (Figure 11). Average weekly fork lengths increased over the study period at the upper trap (Correlation, $r = 0.96$, $p < 0.000001$) and at the lower trap (Correlation, $r = 0.98$, $p < 0.000001$). For both traps, fork lengths were nearly the same for the first three weeks. However, from 4/23 onward, the average fork lengths by week at the upper trap were significantly less than those at the lower trap (ANOVA, $p = 0.001$, power = 0.95). The increase in average FL over time at both traps indicates the 0+ steelhead trout are growing as they migrate downstream.

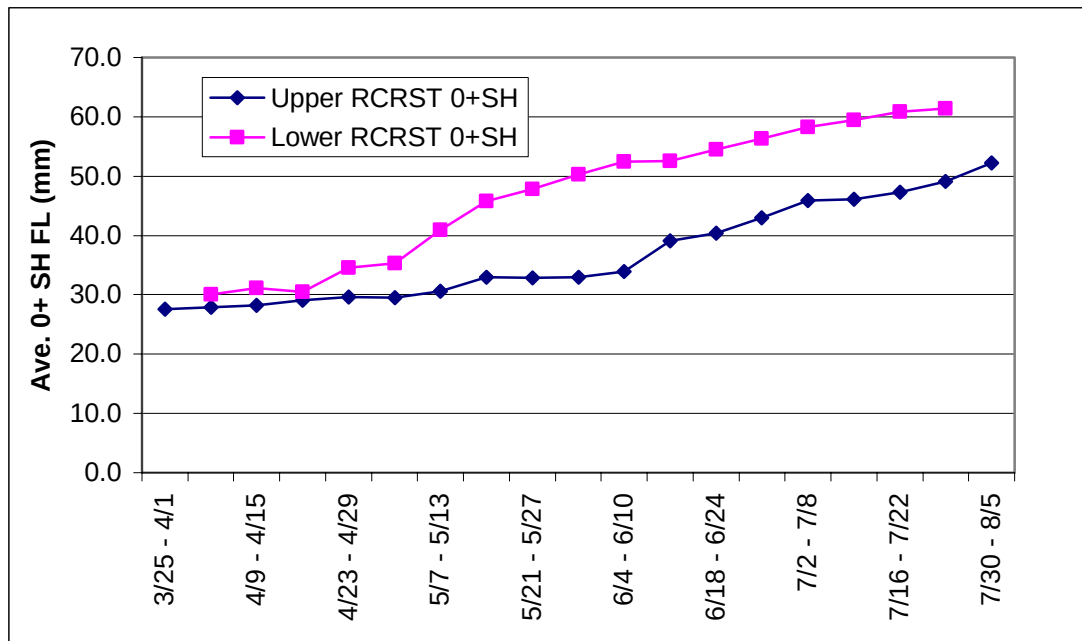


Figure 11 . Comparison of 0+ steelhead trout average fork length (mm) by week at both traps, Redwood Creek, 2004.

1+ Steelhead Trout

This year we measured (FL mm) 3,191 and weighed (g) 1,441 1+ steelhead trout at the upper trap, and 2,713 (FL mm) and 1,201 (WT g) at the lower trap (Table 6). The smallest 1+ steelhead at both traps were caught in the beginning of the trapping season. The median FL (mm) of 1+ steelhead trout at the lower trap (81 mm) was significantly less than the median FL (mm) of 1+ steelhead trout at the upper trap (84 mm) (Kruskal Wallis One-Way ANOVA on Ranks, $p < 0.00001$). The median WT (g) at the lower trap (5.8 g) was significantly less than the median WT (g) at the upper trap (6.4 g) (Kruskal Wallis One-Way ANOVA on Ranks, $p < 0.00001$).

Table 6. 1+ steelhead trout average fork length (mm) and weight (g) by trap location, 2004.

Trap	1+ Steelhead Trout							
	Fork Length (mm)				Weight (g)			
	n	Range	AVE.	SEM	n	Range	AVE.	SEM
Upper	3,191	52 - 119	85.7	0.3	1,441	1.4 – 21.1	7.57	0.10
Lower	2,713	50 - 119	84.4	0.3	1,201	1.3 – 21.4	7.04	0.11

The average weekly fork lengths of 1+ steelhead trout followed a similar trend at both traps up to 6/03/04 (Figure 12). From 6/04/04 onward, the average weekly fork lengths at the upper trap were greater than the lower trap, however, differences were not significant (ANOVA, $p > 0.05$). Fork lengths did not significantly change over time at the upper trap (Correlation, $r = 0.17$, $p = 0.48$), or at the lower trap (Correlation, $r = 0.25$, $p = 0.33$).

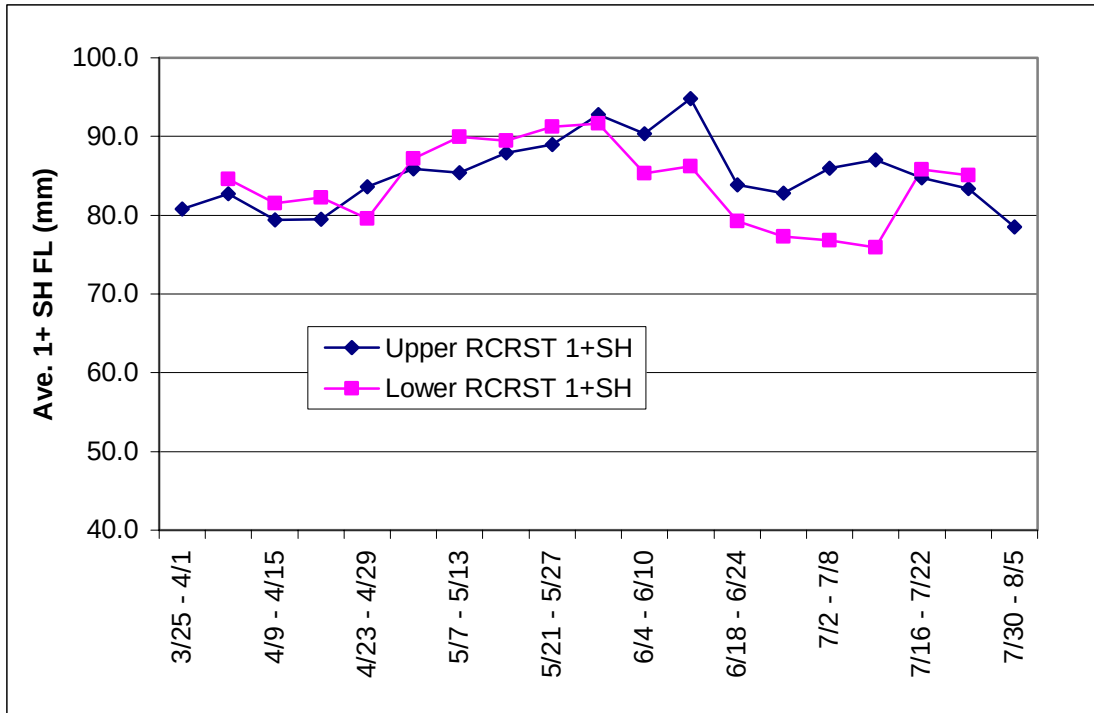


Figure 12. Comparison of 1+ steelhead trout average fork length (mm) by week at both traps, Redwood Creek, 2004.

The average weekly weights of 1+ steelhead trout followed a similar trend over time as the fork length data. Average weight by week was similar at both traps up to 6/10/04 (Figure 13); from 6/11 onward, the average weekly weights at the upper trap were significantly greater than at the lower trap (ANOVA, $p = 0.01$). Using all week's measurements, average weights did not significantly change over time at the upper trap (Correlation, $r = 0.36$, $p = 0.12$), or at the lower trap (Correlation, $r = 0.20$, $p = 0.41$).

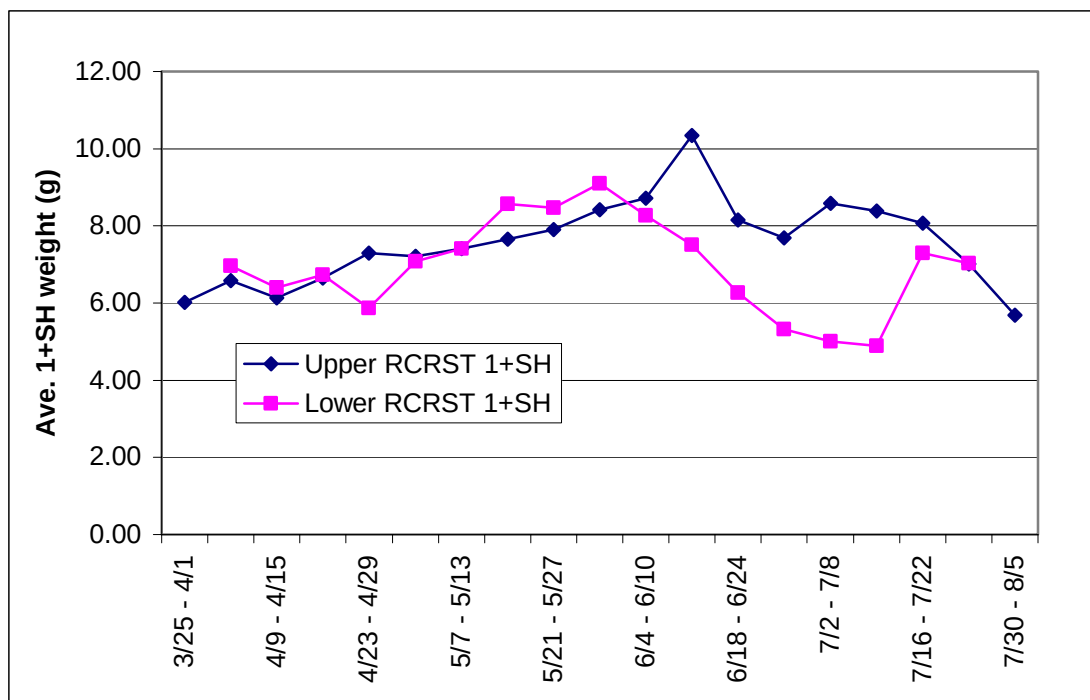


Figure 13. Comparison of 1+ steelhead trout average weight (g) by week at both traps, Redwood Creek, 2004.

2+ Steelhead Trout

This year we measured (FL mm) 1,277 and weighed (g) 1,244 2+ steelhead trout at the upper trap, and 886 (FL mm) and 864 (WT g) at the lower trap (Table 7). The median FL (mm) of 2+ steelhead trout at the lower trap (135 mm) was significantly less than the median FL (mm) of 2+ steelhead trout at the upper trap (138 mm) (Kruskal Wallis One-Way ANOVA on Ranks, $p < 0.00001$). The median WT (g) of 2+ steelhead trout at the lower trap (26.0 g) was significantly less than the median WT (g) at the upper trap (30.45 g) (Kruskal Wallis One-Way ANOVA on Ranks, $p < 0.00001$). The largest 2+ steelhead at the upper trap were probably three-year-old smolts, however, their numbers were relatively very low ($n = 4$, or 0.31% of the total 2+ steelhead catch at the upper trap).

Table 7. 2+ steelhead trout fork length (mm) and weight (g) by trap location, 2004.

Trap	2+ Steelhead Trout							
	n	Fork Length (mm)			n	Weight (g)		
		Range	AVE.	SEM		Range	AVE.	SEM
Upper	1277	120 - 240	144.1	0.6	1244	14.7 - 171.6	35.44	0.47
Lower	886	117 - 207	141.9	0.7	864	16.3 - 89.7	30.69	0.44

The average fork length by week for 2+ steelhead trout was markedly similar at both traps over the course of study (Figure 14). As expected from the graph below, no significant difference in weekly fork lengths between traps was detected (ANOVA, $p > 0.05$). Fork lengths did not significantly change over time at the upper trap (Correlation, $r = 0.41$, $p = 0.08$). However, fork lengths did significantly decrease over time at the lower trap (Correlation, $r = 0.79$, $p < 0.001$).

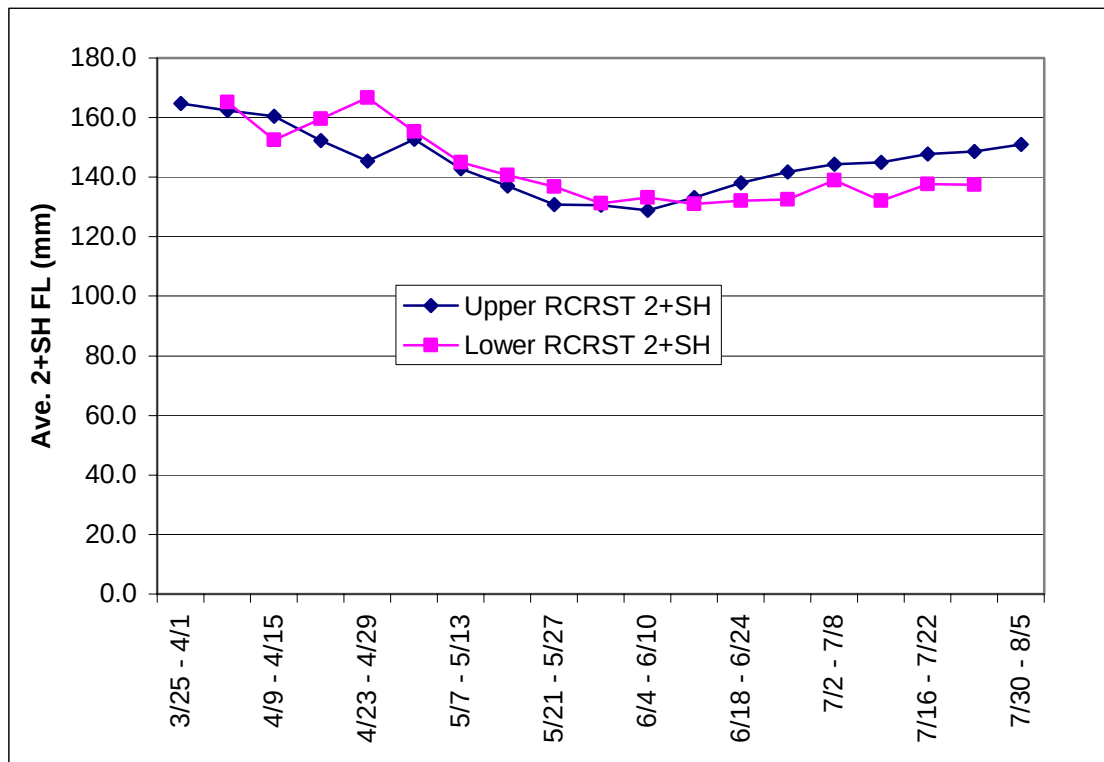


Figure 14. Comparison of 2+ steelhead trout average fork length (mm) by week at both traps, Redwood Creek, 2004.

The average weight (g) by week for 2+ steelhead trout at both traps started out high, then generally decreased until 6/11/04 (Figure 15). From 6/11/04 onward, weights at the upper trap increased over time as compared to the lower trap where weights remained relatively stable. There was no significant difference in weekly weights between traps from 4/2 through 6/10 (ANOVA, $p > 0.05$). However, from 6/11 onward, the average weights by week at the upper trap were significantly greater than at the lower trap (ANOVA, $p = 0.0001$). Average weights did not significantly change over time at the upper trap (Correlation, $r = 0.42$, $p = 0.07$). However, weights did significantly decrease over time at the lower trap (Correlation, $r = 0.80$, $p < 0.001$).

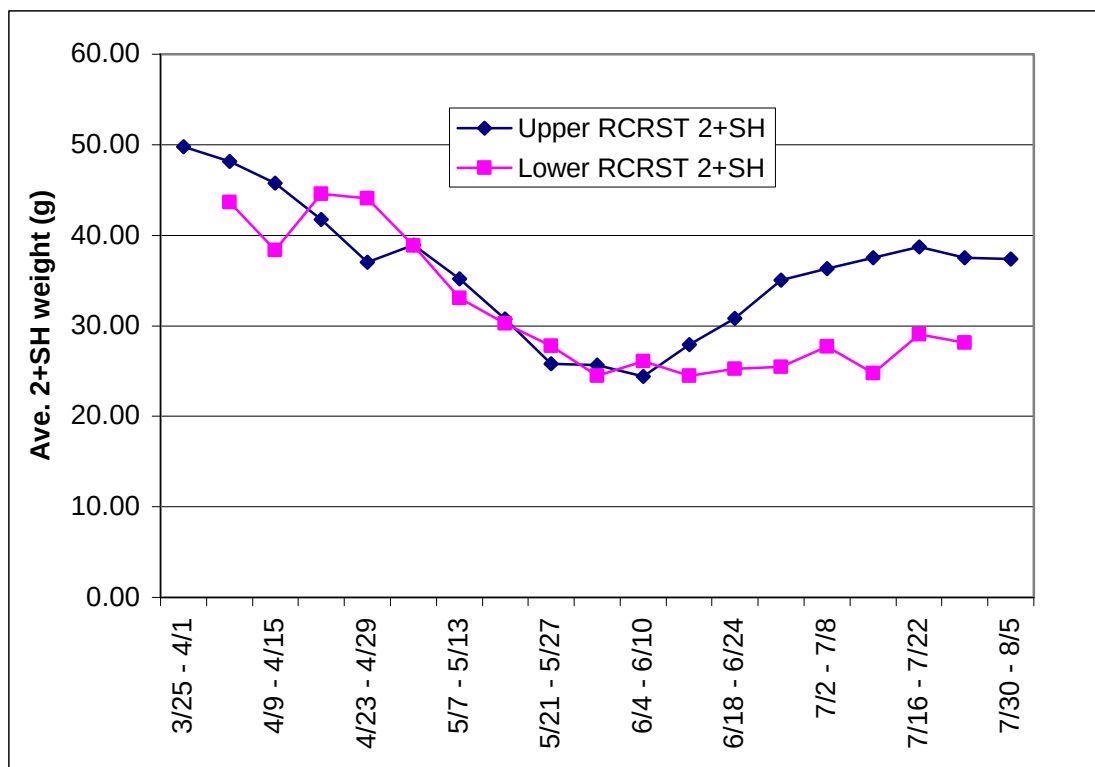


Figure 15. Comparison of 2+ steelhead trout average weight (g) by week at both traps, Redwood Creek, 2004.

0+ and 1+ Coho Salmon (Lower Trap)

We measured (FL mm) 202 and weighed (g) 198 young-of-year coho salmon at the lower trap (Table 8). Median fork length and weight was 66 mm and 3.5 g. We measured (FL mm) 69 and weighed (g) 67 1+ coho salmon at the lower trap (Table 8). Median fork length and weight was 105 mm and 12.9 g.

Table 8. 0+ and 1+ coho salmon fork length (mm) and weight (g) at the lower trap, 2004.

0+ and 1+ Coho Salmon								
Age/spp.	Fork Length (mm)				Weight (g)			
	n	Range	AVE.	SEM	n	Range	AVE.	SEM
0+ coho	202	35 - 87	66.2	0.7	198	0.4 - 8.1	3.76	0.11
1+ coho	69	88 - 123	105.3	1.0	67	7.2 - 19.1	13.09	0.37

The lack of sufficient 0+ and 1+ coho salmon captures (and measurements) in most weeks precluded weekly averaging of fork length and weight data.

Cutthroat Trout

This year we measured (FL mm) and weighed four cutthroat trout at the upper trap, and 36 at the lower trap (Table 9). Median fork length and weight was 187 mm and 71.95 g at the upper trap, and 161.5 mm and 43.15 g at the lower trap. The small sample size for the upper trap precluded any statistical comparisons.

Table 9. Cutthroat trout fork length (mm) and weight by trap location, 2004.

Trap	Cutthroat Trout							
	Fork Length (mm)				Weight (g)			
	n	Range	AVE.	SEM	n	Range	AVE.	SEM
Upper	4	159 - 225	189.5	17.5	4	42.3 - 113.3	74.88	18.70
Lower	36	125 - 249	171.0	5.4	36	23.1 - 187.2	61.28	7.11

The lack of sufficient cutthroat trout captures (and measurements) in most weeks also precluded weekly averaging of fork length and weight data.

0+ Pink Salmon

We captured eight 0+ pink salmon fry at the upper trap. Fork lengths (mm) ranged from 36 - 40 mm, and averaged 38.8 mm (SEM = 0.4 mm).

Developmental Stages

1+ and 2+ Steelhead Trout

There was an obvious non-random distribution of parr, pre-smolt, and smolt classifications (developmental stages) for 1+ and 2+ steelhead trout passing by each trap site (Table 10). A 2x3 contingency test showed that there were significant differences between traps concerning developmental stages for 1+ steelhead (Chi-square, $p < 0.001$; power = 1.00) and 2+ steelhead (Chi-square, $p < 0.001$; power = 1.00). Additional testing showed that the proportion of 1+ steelhead smolts passing by the lower trap was greater than the proportion of 1+ steelhead smolts passing by the upper trap (Chi-square, $p < 0.001$; power = 1.00); and that the proportion of 2+ steelhead smolts passing by the lower trap was greater than the proportion passing by the upper trap (Chi-square, $p <$

0.001; power = 1.00). The combined percentage of pre-smolts and smolts for 1+ steelhead at the upper and lower trap was 99.8%. The combined percentage of pre-smolts and smolts for 2+ steelhead at the upper and lower trap was 100%.

Table 10. Developmental stages for 1+ and 2+ steelhead trout captured at two locations in Redwood Creek, 2004.

Trap	Developmental Stage (as percentage of total catch)					
	1+ Steelhead Trout			2+ Steelhead Trout		
	Parr	Pre-smolt	Smolt	Parr	Pre-smolt	Smolt
Upper	0.2	59.1	40.7	0.0	15.5	84.5
Lower	0.2	31.5	68.3	0.0	5.7	94.3

1+ Coho Salmon and Cutthroat Trout

There was also an obvious non-random distribution of parr, pre-smolt, and smolt classifications (developmental stages) for 1+ coho passing by the lower trap, and for cutthroat trout passing by each trap site (Table 11). The majority of the 1+ coho salmon were smolts, and the majority of cutthroat trout at each trap site were also smolts. A Fisher exact test showed no significant differences between traps concerning pre-smolt and smolt designations for cutthroat trout ($p > 0.05$). The test conclusion was probably influenced by a small sample size at the upper trap.

Table 11. Developmental stages for 1+ coho salmon and cutthroat trout captured at two locations in Redwood Creek, 2004.

Trap	Developmental Stage (as percentage of total catch)					
	1+ Coho Salmon			Cutthroat Trout		
	Parr	Pre-smolt	Smolt	Parr	Pre-smolt	Smolt
Upper	-	-	-	0.0	25.0	75.0
Lower	0.0	1.4	98.6	0.0	0.0	100.0

Trapping Efficiencies

Trapping efficiencies were determined for 0+ Chinook salmon, 1+ steelhead trout, and 2+ steelhead trout. Only one 1+ coho salmon that was marked and released upstream of the trap (lower) was re-captured, therefore, we did not successfully determine our trapping efficiency for 1+ coho salmon at the lower trap. A much greater proportion of the stream is sampled in the upstream trap than in the downstream trap, therefore we expected higher trap efficiencies at the upstream trap.

0+ Chinook salmon

We fin clipped and released 4,862 young-of-year Chinook salmon upstream of the upper trap site during 51 efficiency trials over the course of trapping. The number of 0+ Chinook salmon released in our weekly trials (includes 3 – 4 efficiency trials per week) ranged from 117 to 300, and averaged 286 per week. We fin clipped and released 4,368 young-of-year Chinook salmon upstream of the lower trap site during 49 efficiency trials over the course of trapping. The number of 0+ Chinook salmon released in our weekly trials (includes 3 – 4 efficiency trials per week) ranged from 34 to 300, and averaged 257 per week.

The trapping efficiency for 0+ Chinook salmon was markedly higher at the upper trap compared to the lower trap (Table 12).

Table 12. 0+ Chinook salmon trap efficiencies, 2004.

Trap	0+ Chinook salmon trap efficiency (percentage)		
	Weekly trapping efficiency		Seasonal
	Range	Average	
Upper	12.0 – 61.0	42.5	41.8
Lower	7.3 – 20.7	11.9	11.9

1+ Steelhead Trout

We fin clipped and released 2,091 one-year-old steelhead trout upstream of the upper trap site during 53 efficiency trials over the course of trapping. The number of 1+ steelhead trout released in our weekly trials (includes 3 - 4 efficiency trials per week) ranged from 43 – 150, and averaged 123 per week. We fin clipped and released 1,862 one-year-old steelhead trout upstream of the lower trap site during 48 efficiency trials over the course of trapping. The number of 1+ steelhead trout released in our weekly trials (includes 3 - 4 efficiency trials per week) ranged from 16 – 150, and averaged 110 per week.

The trapping efficiency for 1+ steelhead trout was markedly higher at the upper trap compared to the lower trap (Table 13).

Table 13. 1+ steelhead trout trap efficiencies, 2004.

Trap	1+ steelhead trout trap efficiency (percentage)		
	Weekly trapping efficiency		Seasonal
	Range	Average	
Upper	17.3 – 56.0	38.9	39.1
Lower	4.8 – 37.5	9.4	7.9

2+ Steelhead Trout

We fin clipped and released 741 two-year-old steelhead trout upstream of the upper trap site during 70 efficiency trials over the course of trapping. The number of 2+ steelhead trout released in our weekly trials (includes 4 - 5 efficiency trials per week) ranged from 10 – 77, and averaged 44 per week. We fin clipped and released 610 two-year-old steelhead trout upstream of the lower trap site during 79 efficiency trials over the course of trapping. The number of 2+ steelhead trout released in our weekly trials (includes 2 - 5 efficiency trials per week) ranged from 4 – 104, and averaged 36 per week.

As expected, the trapping efficiency for 2+ steelhead trout was also markedly higher at the upper trap compared to the lower trap (Table 14).

Table 14. 2+ steelhead trout trap efficiencies, 2004.

Trap	2+ steelhead trout trap efficiency (percentage)		
	Weekly trapping efficiency		Seasonal
	Range	Average	
Upper	13.0 – 44.4	22.6	22.0
Lower	0.0 – 25.0	5.7	3.6

Population Estimates

Chinook salmon

We estimate that 629,847 (95% CI 584,199 – 675,495) 0+ Chinook salmon emigrated past the upper trap, and 554,890 (95% CI 493,160 – 616,620) emigrated past the lower trap in Redwood Creek (Table 15). Using point estimates, we estimate the upper trap had 74,957 more Chinook salmon pass by than the lower trap.

Table 15. 0+ Chinook salmon population estimates (percent error in parentheses), 2004.

Trap	0+ Chinook salmon
Upper	629,847 ($\pm$ 7.2%)
Lower	554,890 ($\pm$ 11.1%)

At the population level, more young-of-year Chinook salmon out-migrated past the upper trap during April, than the lower trap (Figure 16). At the lower trap, more Chinook salmon out-migrated during June than at the upper trap. The greatest peak in weekly population out-migration at the upper trap equaled $165,782 \pm 17\%$, compared with $110,980 \pm 35\%$ at the lower trap. April and May accounted for 81% of the total 0+ Chinook salmon population estimate for the upper trap, compared to May and June, which accounted for 78% of the total 0+ Chinook salmon population estimate for the lower trap. Out-migration at both traps reached very low values by July 9, 2004.

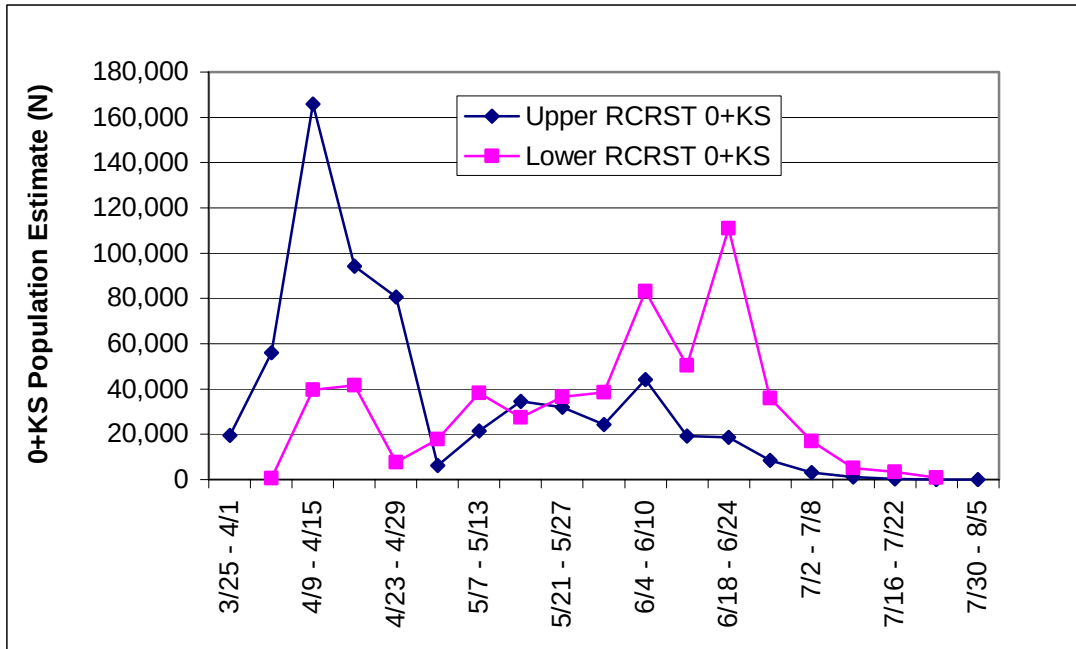


Figure 16. Comparison of 0+ Chinook salmon weekly population estimates at both traps, Redwood Creek, 2004.

1+ Steelhead Trout

We estimate that 41,434 (95% CI 38,591 – 44,278) 1+ steelhead trout emigrated past the upper trap, and 77,221 (95% CI 64,649 – 89,792) emigrated past the lower trap in Redwood Creek (Table 16). Using point estimates, we estimate the lower trap had 35,787 more 1+ steelhead trout pass by than the upper trap.

Table 16. 1+ steelhead trout population estimates (percent error in parentheses), 2004.

Trap	1+ steelhead trout
Upper	41,434 ($\pm$ 6.9%)
Lower	77,221 ($\pm$ 16.3%)

One year old steelhead trout population out-migration (by week) showed similar patterns between traps (Figure 17). The peak in out-migration for both traps occurred during the week of 5/14 – 5/20. April and May were important months for 1+ steelhead trout out-

migration at the upper trap (i.e. 74% of total population estimate), compared with May and June for the lower trap (i.e. 76% of total population estimate). Out-migration at the upper trap reached low values in late June, compared with late July for the lower trap.

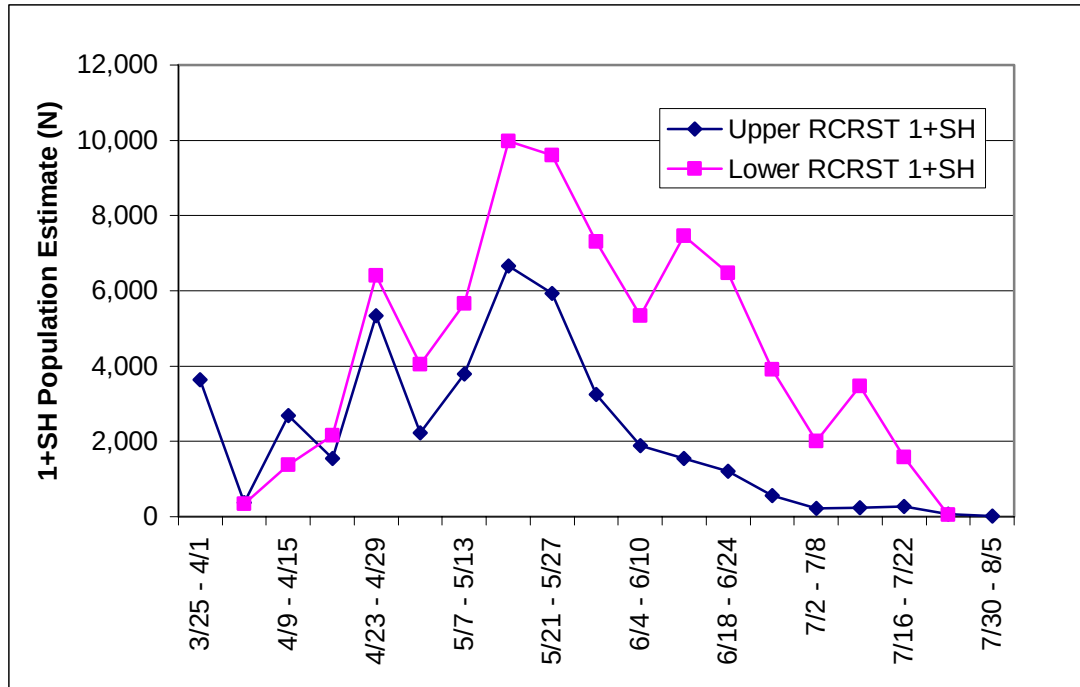


Figure 17. Comparison of 1+ steelhead trout weekly population estimates at both traps, Redwood Creek, 2004.

2+ Steelhead Trout

We estimate that 5,778 (95% CI 4,900 – 6,655) 2+ steelhead trout emigrated past the upper trap, and 24,095 (95% CI 14,519 – 33,670) emigrated past the lower trap in Redwood Creek (Table 17). Using point estimates, we estimate the lower trap had 18,317 more 2+ steelhead trout pass by than the upper trap.

Table 17. 2+ steelhead trout population estimates (percent error in parentheses), 2004.

Trap	2+ steelhead trout
Upper	5,778 ($\pm$ 15.2%)
Lower	24,095 ($\pm$ 39.7%)

2+ steelhead trout population estimates by week were made only for the upper trap because for the lower trap, too few recaptures of marked fish occurred during 30% of the weeks (strata) that we trapped. Therefore, we made a seasonal population estimate for 2+ steelhead trout at the lower trap (Table 17), and were not able to compare population out-migration by week between traps.

Additional Experiments

1+ and 2+ Steelhead Trout Travel Time

We marked 223 2+ steelhead trout and 577 1+ steelhead trout with elastomer injections (with or without partial fin clips) during 15 weekly trials over the course of the study at the upper trap. Numbers marked and released per week ranged from 2 - 28 for 2+ steelhead trout, and 4 - 51 for 1+ steelhead trout. The lower trap caught 3.14% of the marked 2+ steelhead trout, and 1.56% of the marked 1+ steelhead trout. The Travel time for 2+ steelhead trout to move 29 miles downstream ranged from 2 – 35 days (Table 18). Two separate groups of marked 2+ steelhead trout (released on 4/15 and 5/20) had two recaptures, with variable travel time within groups (18 and 35 d; 6 and 21 d). The average travel time for 2+ steelhead trout to move 29 miles downstream was 13 days (S.D. 12.0). On September 2, 2004 Dave Anderson caught a travel time marked 2+ steelhead in the Redwood Creek estuary that was released at the upper trap on June 9, 2004 (Dave Anderson, pers. comm. 2004). However, beyond June 29, 2004, this fish could not have entered the ocean because the mouth of Redwood Creek was closed by a sand bar (Dave Anderson, pers. comm. 2004).

Travel time for 1+ steelhead trout to move 29 miles downstream ranged from 2 - 32 days (Table 18). Similar to 2+ steelhead trout, two separate groups of marked 1+ steelhead trout (released on 5/13 and 5/20) had two recaptures with variable travel time within groups (2 and 26 d; 13 and 19 d). The average time for 1+ steelhead trout to move 29 miles downstream was 15 days (S.D. 10.7).

Table 18. Data for successful travel time experiments, Redwood Creek, 2004.

Age/species	Travel Time Experiments		
	Date released	Date recaptured	Travel time (d)
2+SH	4/15/04	5/03/04	18
2+SH	4/15/04	5/20/04	35
2+SH	5/06/04	5/08/04	2
2+SH	5/13/04	5/21/04	8
2+SH	5/20/04	5/26/04	6
2+SH	5/20/04	6/10/04	21
2+SH	5/27/04	5/30/04	3
1+SH	4/15/04	4/18/04	3
1+SH	5/06/04	5/12/04	6
1+SH	5/13/04	5/15/04	2
1+SH	5/13/04	6/08/04	26
1+SH	5/20/04	6/02/04	13
1+SH	5/20/04	6/08/04	19
1+SH	5/27/04	6/19/04	23
1+SH	6/13/04	7/15/04	32
1+SH	6/17/04	6/27/04	10

Trapping Mortality

The mortality of fish that were captured in the traps and handled was closely monitored over the course of the trapping period. Mortality by species at age ranged from 0.00 – 0.59%, and using all species was 0.34% at the upper trap and 0.19% at the lower trap (Table 19).

Table 19. Trapping mortality of captured fish at both traps, Redwood Creek, 2004 (number in parentheses are actual mortalities).

Age/species	Trap Mortality	
	Upper Trap	Lower Trap
0+ Chinook	0.21% (432)	0.20% (121)
1+ Chinook	-	0.00% (0)
0+ Steelhead	0.59% (754)	0.24% (44)
1+ Steelhead	0.03% (5)	0.03% (2)
2+ Steelhead	0.08% (1)	0.00% (0)
0+ Coho	-	0.00% (0)
1+ Coho	-	0.00% (0)
Cutthroat	0.00% (0)	0.00% (0)
0+ Pink	0.00% (0)	-
Overall	0.34% (1192)	0.19% (167)

Flow Events

This trapping season was noted by having few high flow events, particularly when compared with stream flows in 2003. High flows at the lower trap in 2004 occurred April 20 – 24, and peaked at 2,400 cfs on April 21. Prior to this event, flows were stable at about 450 cfs. We re-set the trap on April 23, at a flow of about 1,100 cfs. At the upper trap, a high flow event also occurred 4/20 – 4/24 when flows went from about 150 cfs to 600 cfs, and then descended. We fished most of the high flow event, and only missed one day of trapping (4/22).

Stream Temperatures

The average daily (24 hr period) stream temperature at each trap site increased over the course of the study (Correlation, $r = 0.96$ and 0.95 , $p = 0.000001$). Average temperatures at the upper trap ranged from 46.9 to 74.6 F (8.3 – 23.7 °C), and averaged 60.51 F (15.8 °C); at the lower trap average daily temperatures ranged from 50.3 to 67.0 F (10.2 – 19.4 °C), and averaged 59.90 F (15.5 °C). As expected from the graph below, stream temperatures at each trap site were similar from 4/4 – 6/15 (Figure 18). However, from 6/16 – 7/29, stream temperatures at the upper trap site were significantly greater than at the lower trap site (ANOVA, $p < 0.000001$; power = 1.00). The mean temperature at the upper trap site for this time period was 69.4 F (20.8 °C), compared with 64.6 F (18.1 °C) at the lower trap site.

There were a total 37 days at the upper trap when the average stream temperature exceeded 68 F (20.0 °C) during the course of the study. Average stream temperatures did not exceed 68 F (20.0 °C) at the lower trap.

Maximum daily stream temperatures at the upper trap ranged from 47.7 to 83.8 F (8.7 – 28.8 °C), compared to 50.9 to 72.7 F (10.5 – 22.6 °C) for the lower trap (Figure 19). Maximum stream temperatures at both trap sites closely paralleled each other until June 15, 2004. From June 16 onward, maximum temperatures at the upper trap site were clearly higher than at the lower trap site (ANOVA, $p = 0.000001$, power = 1.00).

There were a total of 52 days at the upper trap when the maximum stream temperature exceeded 70 F (21.1 °C), and nine days when the maximum stream temperature exceeded 80 F (26.7 °C); at the lower trap site there were 28 days in which maximum stream temperature exceeded 70 F. Maximum temperatures at the lower trap site did not exceed 72.7 F (22.6 °C).

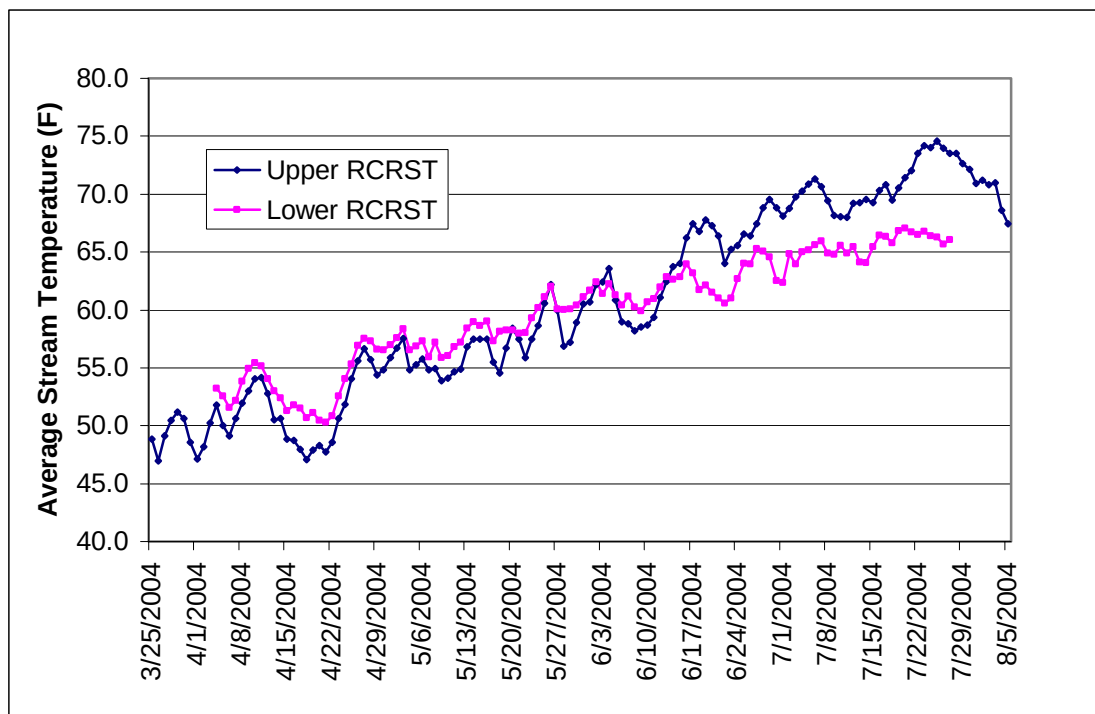


Figure 18. Comparison of average daily temperatures (F) at both trap sites, Redwood Creek, 2004.

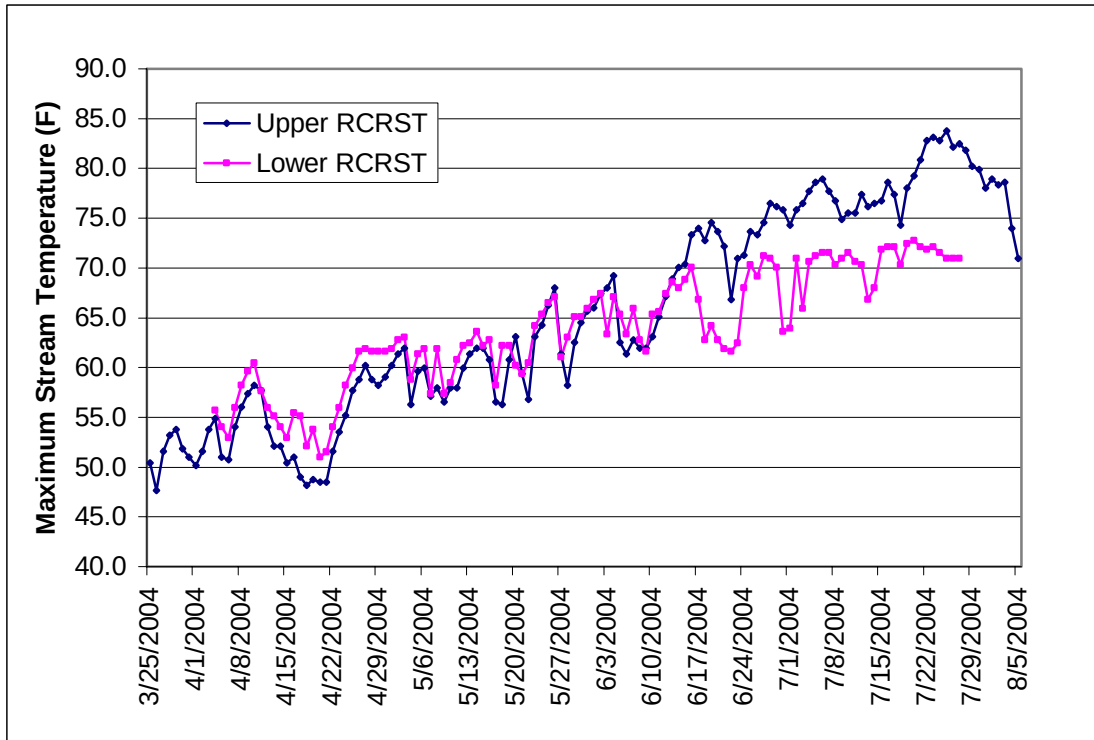


Figure 19. Comparison of maximum daily stream temperatures (F) at both trap sites, Redwood Creek, 2004.

DISCUSSION

We successfully completed many of the stated objectives in this study using rotary screw traps at two locations in Redwood Creek. For the first time in Redwood Creek's salmonid monitoring history, we were able to determine population estimates for 0+ Chinook salmon, 1+ steelhead trout, and 2+ steelhead trout at the lower trap site with acceptable error terms. Not counting production from Prairie Creek, these lower trap population estimates represent the smolt production of the Redwood Creek watershed for study YR 2004. Although we have only conducted one year of trapping in lower Redwood Creek, we have shown that, under a modest water year, it is possible. Additionally, we were able to further prove (using travel time experiments and unique efficiency trial marks for each trap) that the 1+ steelhead trout emigrating from upper Redwood Creek are reaching lower Redwood Creek; and that travel time for 1+ and 2+ steelhead trout from upper to lower Redwood Creek is variable. We are hopeful that we can continue to operate the two traps in Redwood Creek over many years, and when combined with data collected in Prairie Creek and the estuary of Redwood Creek, we should be able to more fully understand the status and trends of out-migrating juvenile salmonids in Redwood Creek. Additionally, we will be able to identify restoration needs in the basin, help focus restoration efforts, and monitor any changes to fish populations.

0+ Chinook Salmon

Young-of-year Chinook salmon (Ocean type life history) dominated the catches at both trap sites, and were the most numerous out-migrant at the population level in study year 2004. The upper trap caught considerably more juvenile Chinook salmon ($n = 206,261$) than the lower trap ($n = 61,778$), which is likely attributable to a much higher trapping efficiency and in-stream mortality of young-of-year Chinook salmon as they migrate downstream to the lower trap. The greatest weekly catch at the upper trap occurred 4/9 – 4/15 ($n = 50,671$), compared with the lower trap's greatest weekly 0+ Chinook salmon catch during 6/18 – 6/24 ($n = 9,955$). The most important months for capturing 0+ Chinook salmon at the upper trap were April, May, and June, as compared with May and June at the lower trap. Unfortunately, we were not able to determine travel time for 0+ Chinook salmon between traps because the fish were generally too small to mark at the upper trap site for most of the season.

Using all measurements, the median fork lengths and weights of 0+ Chinook salmon at the upper trap site were statistically smaller than those at the lower trap site by 11 mm and 0.9 g. This was expected *a priori* because the juvenile Chinook salmon will eat and grow as they migrate downstream. Average weekly fork lengths and weights at each trap site statistically increased over the study period, indicating that growth was taking place. Average fork lengths and weights by week at each trap site were nearly the same for the first three weeks where measurements were comparable, probably because these fish were primarily newly emerged fry from redds. Thereafter, the average weekly fork length and weight of 0+ Chinook salmon at the upper trap were statistically less than at the lower trap. However, the average weekly fork length and weight at the end of the season for the upper trap were close to the average for the lower trap (difference of 1.9 mm and 0.5 g).

One benefit of operating the lower trap was to document that the 0+ Chinook salmon are larger than those at the upper trap site, prior to reaching the estuary. Therefore, as the young-of-year Chinook salmon leave upper Redwood Creek they are continuing to grow. This is important because ocean survival is often correlated to the size of the out-migrant. Preliminary data of 0+ Chinook salmon fork lengths collected in the estuary on three sample dates from June 21 – July 19, 2004 averaged 73.9 mm (Dave Anderson, pers. comm. 2004), as compared to the lower trap's average fork length of 69.1 mm for the same sample time period. By the time the Chinook salmon juveniles pass the lower trap, they are nearly as big as those that are in the estuary.

0+ Chinook Salmon Population Size

Trap efficiencies were much higher at the upper trap site because the channel is steeper and narrower than at the lower trap site. Both traps successfully determined out-migrant population estimates with low error terms ($\pm 7.2\%$ and $\pm 11.1\%$). We estimated 629,847 Chinook salmon migrated past the upper trap, which is the highest point estimate in the five consecutive years of study. Surprisingly, the lower trap site's point estimate was lower than the upper trap by 74,957 fish. I believe the lower trap's estimate was accurate

because trap efficiencies appeared to fit with the trap configuration, channel width, and channel gradient. Additionally, the error term to the point estimate was low. *A priori*, I thought the lower trap would have a much higher population estimate than the upper trap because there is much more available habitat for the adults to spawn. Reasons for the apparent decrease at the lower trap could be: 1) more adult Chinook salmon spawned upstream of the upper trap site, with few spawning between trap sites, 2) high mortality of juvenile Chinook salmon between traps, and 3) possibly some combination of factors 1 and 2. Unfortunately, we have no idea of the adult Chinook salmon spawner distribution in the watershed in YR 2004. Additionally, we did not design a study to estimate the mortality of the upper trap's juvenile Chinook salmon as they migrate downstream to the lower trap. However, we estimate that about 42.9% ($n = 270,204$) of the 0+ Chinook salmon population estimate at the upper trap ($n = 629,847$) had fork lengths less than 40 mm (Sparkman 2005, study 2a5, In progress). Juvenile Chinook salmon under 40 mm FL may have a high in-stream mortality due to various factors. We are hoping that by performing this two trap study over multiple consecutive years, we will determine if this type of discrepancy in 0+ Chinook salmon population estimates between traps is an anomaly. We do know that 0+ Chinook salmon from the upper trap were caught by the lower trap because we observed the upper trap's efficiency mark (partial upper caudal fin clip) on 0+ Chinook salmon in the lower trap's catch. Currently we are investigating whether we can partition the lower trap's estimate into those that came from the upper trap, and those that came from between the two trap locations. It is unlikely that the juvenile Chinook salmon at the upper trap did not reach the lower trap because of holding over for another year, to become a 1+ Chinook salmon in 2005. The overwhelming percentage of the ocean type life history for Chinook salmon in Redwood Creek suggests that these fish have to emigrate to the estuary and ocean within the first year of their life. However, given adequate funding for the lower trap in 2005, we should be able to determine the number of 1+ Chinook salmon (in YR 2005) that held over as 0+ Chinook salmon (from YR 2004) that are now emigrating from Redwood Creek to the estuary and ocean.

The weekly population estimates of 0+ Chinook salmon at both traps closely followed the catch distributions. At the upper trap, the week of 4/9 – 4/15 had the biggest peak in population out-migration of 165,782 ($\pm 17\%$). Normally the months of May and June are the most important for population out-migration at the upper trap, however, in 2004, April and May accounted for 81% of the total estimate. At the lower trap, population out-migration was delayed compared to the upper trap. The largest peak in weekly out-migration occurred 6/18 – 6/24, and equaled 110,980 ($\pm 35\%$) individuals. The months of May and June accounted for 78% of the total juvenile Chinook salmon population estimate at the lower trap.

1+ Chinook Salmon

Very few one-year-old Chinook salmon (stream type life history) were caught in Redwood Creek during YR 2004 ($n = 2$), which may relate to the young-of-year cohort failure in YR 2003 (Sparkman 2005, study 2a5, In progress). However, we have never

caught many 1+ Chinook salmon in upper Redwood Creek. The two 1+ Chinook salmon were caught at the lower trap, and none were captured at the upper trap. We have caught 1+ Chinook salmon at the upper trap in three of the four previous study years; we caught 21 in YR 2001, 18 in YR 2002, and 29 in YR 2003. Thus, 1+ Chinook salmon constitute only a very small percentage of juvenile Chinook salmon out-migration in Redwood Creek.

The 1+ stream life history pattern may be important for increased ocean survival of Chinook salmon juveniles, and general species diversity (Don Chapman pers. comm. 2003; Sparkman 2002a). Although in coastal streams the 1+ Chinook salmon juvenile life history occurs less often, the U.S. Fish and Wildlife Service reported 1+ Chinook salmon catches ($n = 100$) in Little River, Humboldt County, California in 1994 (Shaw and Jackson 1994). In addition, CDFG Steelhead Research and Monitoring Program's out-migrant studies in the Mad River in YR 2001 and YR 2002 also reported captures of 1+ Chinook salmon (Sparkman 2002b).

0+ Steelhead Trout

The upper trap caught considerably more 0+ steelhead trout than the lower trap, by a factor of about 7:1. The upper trap has consistently captured large numbers of migrating 0+ steelhead trout in each of the previous four years of study (mean = 96,228; range = 55,126 – 124,426). The mainstem of Redwood Creek appears to be vital for 0+ steelhead trout rearing, and should not be underestimated. In an analysis of the Redwood Creek Watershed, Redwood National and State Park personnel report that tributary streams to Redwood Creek provide relatively little habitat for anadromous salmon and steelhead, exclusive of Prairie Creek (Redwood National and State Parks 1997).

Young-of-year steelhead trout downstream migration in Redwood Creek is considered to be stream redistribution (passive and active) because juvenile steelhead normally smolt and enter the ocean at one to two years old, with lesser numbers out-migrating at ages of 3+ years. The reasons for active redistribution can relate to many factors, such as 1) genetic predisposition, and 2) environmental quality (eg hydrology, water temperature, cover, stream depth, sedimentation, food availability, etc) (Meehan and Bjornn 1991). Passive redistribution refers to movements made during high stream flows when the small fish are at the mercy of strong currents, and are swept downstream.

Although the lower trap caught far less 0+ steelhead than the upper trap, the 18,642⁺ individuals passing by the lower trap site indicate these fish are going to rear for some time period in lower Redwood Creek, including the estuary. For example, Dave Anderson routinely captures young-of-year steelhead trout (and coho salmon) in the estuary during summer and early fall sampling (Dave Anderson, pers. comm. 2004). Thus, the condition of lower Redwood Creek and the estuary will have an impact on these fish.

The most important months for 0+ steelhead trout downstream migration at the upper trap were May, June, and July, which accounted for 98% of the total catch. At the lower trap, June and July were the most important months for catching 0+ steelhead (i.e. 80% of total catch). The greatest weekly capture at the upper trap occurred 5/14 – 5/20 ($n = 24,026$), compared with the week of 6/11 – 6/17 at the lower trap ($n = 3,547$).

Similar to 0+ Chinook salmon fork length data, the median fork length of 0+ steelhead trout at the upper trap site was statistically smaller than the median fork length at the lower trap site (in this case by 17 mm). Average weekly fork lengths at each trap site statistically increased over the study period, and indicated that growth was taking place. Average fork lengths by week at each trap site were nearly the same for the first three weeks where measurements were comparable, probably because these fish were primarily newly emerged fry from redds. Thereafter, the average weekly fork length of 0+ steelhead trout at the upper trap was statistically less than at the lower trap. The average weekly fork length at the end of the season for the upper trap was much less than the last week's average fork length at the lower trap (difference of 9.2 mm).

1+ Steelhead Trout

The upper trap caught far more 1+ steelhead than the lower trap because of a much higher trapping efficiency. The upper trap's weekly efficiency for catching 1+ steelhead was about four times greater than at the lower trap. Reasons for the difference in trapping efficiencies among traps are the same as for the 0+ Chinook salmon (most likely due to a steeper gradient and narrower channel width at the upper trap site, which corresponded to trapping a greater percentage of the total flow). The catch distribution of 1+ steelhead trout at both traps was markedly similar, and both approximated a bell shaped curve. However, most of the 1+ steelhead trout at the upper trap were caught during April and May (i.e. 80%), compared with May and June (i.e. 75%) at the lower trap. The peak in weekly catches at both traps occurred 5/14 – 5/20.

The median fork length and weight of 1+ steelhead trout at the upper trap were statistically greater than at the lower trap, although differences were slight (3 mm and 0.6 g) and will probably not have any overall effect on survival. Average weekly fork length and weight data did not significantly change over time, and followed similar trends at both trap sites.

The observed developmental stages of 1+ steelhead at the upper trap site were statistically different than at the lower trap site. A higher percentage of 1+ steelhead were in a smolt condition at the lower trap site compared with the upper trap site. I expected this to be the case because the parr to pre-smolt to smolt transformation is a process that takes time, and the 1+ steelhead trout should be more 'smolt like' when near the estuary and ocean.

1+ steelhead travel time experiments showed that these fish may take anywhere from 2 – 32 days (average = 15 days) to travel 29 miles downstream. We also discovered that fish

released at the same time may have different travel rates. For example, in one group, a 1+ steelhead took 2 days to travel the distance, and another fish (released at the same time) took 26 days to reach the lower trap. 1+ steelhead trout travel time experiments also showed that the 1+ steelhead trout from the upper trap are moving downstream and passing the lower trap. This was not a surprise because in previous study years, Dave Anderson (pers. comm. 2004) would find marked one-year-old steelhead (from the upper trap) in the estuary while sampling there. In YR 2004, the lower trap also caught efficiency trial fish (1+ and 2+ steelhead trout) that were released at the upper trap, and supports the fact that some portion of the upper trap 1+ steelhead are traveling downstream to lower Redwood Creek and the estuary. The lower trap's efficiency at capturing travel time 1+ steelhead trout (1.56%) was markedly lower than the lower trap's efficiency for capturing lower trap efficiency marked 1+ steelhead (7.9%). This suggests that some of the 1+ steelhead travel time fish may have lingered somewhere between traps, and not traveled the complete distance to the lower trap. However, the number of recaptures (of 1+ steelhead) used in travel time experiments was fairly low ($n = 9$), and may not be indicative of the 'true' trap efficiency for the lower trap catching travel time marked 1+ steelhead trout. Additionally, some of the 1+ steelhead marked and released at the upper trap could have been preyed upon (i.e. by kingfishers, mergansers, etc) while traveling downstream.

1+ Steelhead Trout Population Size

Both traps successfully determined 1+ steelhead trout population sizes with low error terms (6.9% and 16.3%). We estimated that 41,434 1+ steelhead trout emigrated past the upper trap, and 77,221 emigrated past the lower trap. These estimates 'fit' because there is more available habitat upstream of the lower trap site than upstream of the upper trap site. Assuming that overall mortality of the upper trap's 1+ steelhead is relatively low as they migrate downstream, it appears that upper Redwood Creek produces a significant amount of 1+ steelhead in the basin. The high numbers of 1+ steelhead trout emigrating past the lower trap indicates that these fish are going to reside or rear in lower Redwood Creek and the estuary for at least some time period before entering the ocean. Thus, the condition of the Redwood Creek estuary is important for these fish, as well as for other juvenile species and age classes.

The weekly population estimates of 1+ steelhead trout at both traps followed the catch distributions. Similar to the catch data, the biggest peak in weekly out-migration (for both traps) occurred 5/14 – 5/20. The most important months for population out-migration at the upper trap was April and May (74% of population estimate), compared with May and June (76% of population estimate) for the lower trap. Thus, significant out-migration at the lower trap was about one month later than the upper trap.

The reason(s) for the large numbers of 1+ steelhead emigrating from upper Redwood Creek and from the basin of Redwood Creek warrants further investigation. Based upon studies in other streams, the number of adults that went to the ocean as one-year-old steelhead smolts is relatively low, and usually less than 20% (Pautzke and Meigs 1941, Shapovalov and Taft 1954, Maher and Larkin 1955, McCubbing 2002). In Redwood

Creek, there is a far greater population of 1+ steelhead emigrating than 2+ steelhead, by a factor of 7:1 at the upper trap, and about 3:1 at the lower trap. We need to find out what percentage of the adult steelhead in Redwood Creek entered the ocean as one-year-old and two-year-old juveniles, and we can determine this by collecting and reading adult steelhead scales. To date, we have a limited collection from Redwood Creek which shows that some adult steelhead did enter the ocean as one-year-old juveniles.

2+ Steelhead Trout

In several studies investigating steelhead trout 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; Smith and Ward 2000; Ward 2000; McCubbing 2002). If this applies to steelhead trout in Redwood Creek, then the 2+ steelhead smolt is the best surrogate for assessing steelhead status, trends, and abundance when information on adult steelhead is unavailable or un-attainable. 2+ steelhead have overcome the numerous components of stream survival that younger steelhead have not yet completely faced (over-summer, over-winter, etc). For example, any given estimate for 0+ and 1+ steelhead abundance will be particularly tenuous for use as a trend or status indicator if high mortality occurs over the winter. Additionally, there may be high mortality weeks to months prior to the late summer sampling period(s). However, the spring/summer emigrating 2+ steelhead smolt survived the over-summer and over-wintering periods (and all previous potential bottle necks in the stream, excluding the estuary), and is actively migrating to the estuary and ocean.

The upper trap caught more 2+ steelhead than the lower trap because of a noticeably higher trap efficiency for 2+ steelhead (seasonal efficiency, 22% vs. 3.6%). Reasons for the difference in trapping efficiencies among traps are the same as for the 0+ Chinook salmon and 1+ steelhead trout (likely due to a steeper gradient, and narrower channel width at the upper trap site). The catch distribution of 2+ steelhead trout at both traps was similar, except that more 2+ steelhead were caught in the beginning weeks of trapping at the upper site compared to the lower site. Most of the 2+ steelhead trout at the upper trap were caught during April, May, and June (i.e. 83%), compared with May and June (i.e. 78%) at the lower trap. The peak in weekly 2+ steelhead catches at both traps occurred 5/14 – 5/20.

The median fork length and weight of 2+ steelhead trout at the upper trap were statistically greater than those collected at the lower trap, although differences were slight (3 mm and 4.45 g) and will probably not have any overall affect on survival. However, the 2+ steelhead trout emigrating from upper Redwood Creek were larger than those emigrating from the basin. Average weekly fork length and weight data did not significantly change over time at the upper trap, which contrasted the lower trap where average fork length and weight significantly decreased over time.

The developmental stages of 2+ steelhead at the upper trap site were statistically different than at the lower trap site. A higher percentage of 2+ steelhead were in a smolt condition

at the lower trap site compared with the upper trap site by about 10%. Similar to 1+ steelhead data, I expected this to be the case because the parr to pre-smolt to smolt transformation takes time, and the 2+ steelhead trout should be more ‘smolt like’ when near the estuary and ocean.

2+ steelhead travel time experiments showed that these fish may take anywhere from 2 – 35 days (average = 13 days) to travel 29 miles downstream. Similar to 1+ steelhead, we discovered that fish released at the same time may have different travel rates. For example, in one group, a 2+ steelhead took 18 days to travel the distance, and another fish (released at the same time) took 35 days to reach the lower trap. The lower trap’s efficiency at capturing travel time 2+ steelhead trout (3.14%) was similar to the lower trap’s efficiency for capturing lower trap efficiency marked 2+ steelhead (3.6%). Although the sample size of travel time recaptures was low ($n = 7$), the nearly equal trap efficiencies strengthen our belief that the trap efficiency used in the 2+ steelhead population estimate for the lower trap was accurate; and suggests that little mortality to the 2+ steelhead trout migrating from upper Redwood Creek occurred.

2+ Steelhead Trout Population Size

Both traps successfully determined 2+ steelhead trout population sizes with reasonably acceptable error terms (15.2 % and 39.7 %). 2+ steelhead are wily and elusive, and therefore rather difficult to catch compared to younger age classes and different species. The lack of enough recaptures in many weeks (about 30%) for the lower trap’s 2+ steelhead population estimate precluded estimating population size by week. However, the overall trapping efficiency for 2+ steelhead trout at the lower trap appeared to fit the trap configuration, channel width, channel gradient, and stream discharge.

We estimated that 5,778 2+ steelhead trout emigrated past the upper trap, and 24,095 emigrated past the lower trap. I expected the lower trap to have a higher population estimate because there is more available habitat upstream of the lower trap site than upstream of the upper trap site. Assuming that overall mortality of the upper trap’s 2+ steelhead is relatively low as they migrate downstream, it appears that upper Redwood Creek contributes a good amount of the 2+ steelhead in the basin.

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).

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. Juvenile pink salmon are similar in appearance to juvenile Chinook salmon, however, an easily observable difference does exist (e.g. lack of parr marks). I used a taxonomic key (Pollard et al. 1997) to identify the pink salmon, and also took photographs. I sent the photographs to an Alaska Department of Fish and Game Fisheries Biologist (Brian Marston pers comm. 2004) and to Gary Fandrei (pers. comm.. 2004), who is the executive director of Cook Inlet Aquaculture Association. They both confirmed that the fish were juvenile pink salmon. Brian Marston passed the photos to other Alaska Fish and Game Biologists, and they also confirmed that the juvenile fish were pink salmon. Gary Fandrei oversaw operations of the Tutka Bay Lagoon Hatchery near Homer, Alaska, which raised about 125,000,000 pink salmon each year. He sent me photographs of juvenile pink salmon that he had taken, and they looked identical to the juvenile pink salmon photos I had taken.

The pink salmon in Redwood Creek are in very low numbers, and were only caught in even numbered years (e.g. YR2000, YR2002, and YR2004). It is hard to say if their parents were stays, or remnants of a historic run because so little information exists about adult salmon in Redwood Creek. According to the Habitat Conservation Planning Branch (HCPB) of CDFG, pink salmon are considered to be “probably extinct” in California (CDFG 1995). However, the HCPB does state that “more efforts need to be conducted to prove (or disprove) that reproducing populations exist anywhere in California” (CDFG 1995). Based upon our trapping data from upper Redwood Creek, it appears that pink salmon are present and reproducing, albeit in low numbers.

Coho Salmon

Few coho salmon were captured by the lower trap (0+ coho salmon, n = 202; 1+ coho salmon, n = 69), and none were caught by the upper trap in Redwood Creek during 2004. For the past five consecutive years we have not seen any coho salmon at the upper trap (see Sparkman 2005, study 2a5, In progress). 0+ coho salmon catches at the lower trap occurred in every month of trap operation, however, most were caught in May and July. 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.

Low numbers of one plus-year-old coho salmon were caught at the lower trap during April, May, and June, with most catches occurring in April and May. Although we did not successfully determine trapping efficiencies for 1+ coho salmon (mainly due to low sample size of marked releases), they should be somewhere between those for 1+ steelhead (seasonal, 7.9%) and 2+ steelhead (seasonal, 3.6%) for the lower trap. This assumption is based upon fish size and the fact that the average 1+ coho salmon fork length was in-between average fork lengths for 1+ and 2+ steelhead trout. If so, then we would expect a population point estimate to be anywhere from 755 to 1,400 individuals,

with a 95% CI ranging from 104 – 2,668. This point estimate should be viewed cautiously, and only as a ‘best guess’. Given the area of coho salmon anadromy in Redwood Creek (most recently, up to Lack’s Creek, Bill Jong, pers. comm. 2003), coho salmon appear to be in very low numbers (excluding Prairie Creek coho salmon).

Cutthroat Trout

Few cutthroat trout were captured at the upper trap ($n = 4$) in YR 2004, which is consistent with previous trapping data collected from YR 2000 – YR 2003. More cutthroat trout were captured at the lower trap compared to the upper trap, however, the total number was less than 50 individuals. At the lower trap, cutthroat trout were captured throughout the trapping period, with a peak in weekly catches occurring 5/14 – 5/20 ($n = 10$). An unknown number 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 more than we do, as they re-distribute or migrate downstream. For example, juvenile salmonid trapping efforts in Prairie Creek consistently capture numerous cutthroat trout during spring/early summer as they migrate downstream (Walt Duffy, pers. comm. 2003).

We did not consider any of the young-of-year steelhead to be progeny of cutthroat trout because few aged 1 and older cutthroat trout were captured at either trap site. 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 included in the 0+ steelhead catch to be low and negligible. Redwood Creek has far more older juvenile steelhead (1+ and 2+) than cutthroat trout as evidenced by trap catches. For example, the lower trap caught 6,371 1+ steelhead trout and 907 2+ steelhead trout compared to 37 identifiable cutthroat trout. The ratio of 1+ and 2+ steelhead trout catches to cutthroat trout catches equaled 197:1. At the upper trap, the ratio of 1+ and 2+ steelhead trout captures to cutthroat trout captures was much greater, and equaled 4,425:1.

CONCLUSIONS

We found that more 0+ Chinook salmon emigrated from upper Redwood Creek than from the Redwood Creek basin (excluding Prairie Creek tributary). Significant numbers of 0+ steelhead trout emigrated from upper Redwood Creek, but did not appear to move downstream past the lower trap in comparable numbers. These fish likely settled somewhere between the two trap locations. Coho salmon were not present at the upper trap site (for the fifth consecutive year), but were present at the lower trap site, albeit in low numbers. Cutthroat trout catches were relatively infrequent, with most being captured at the lower trap site. Fewer 1+ and 2+ steelhead trout emigrated from upper Redwood Creek than from the Redwood Creek basin, which was expected because available habitat is much greater for the entire basin compared to the available habitat

upstream of the upper trap site. However, the contribution of upper Redwood Creek's steelhead smolt population to the basin's steelhead smolt population appears to be considerable. More monitoring (and research) is needed to fully understand these relationships.

RECOMMENDATIONS

The single most important recommendation I can make is to continue this two trap study over multiple consecutive years. Information gathered from one year can be informative, but will obviously lack the power and significance of a multi-year study. Additionally, any relationships and comparisons described in this report can only represent the data collected in YR 2004. The study design utilizing two traps located at different locations in Redwood Creek had many benefits over using a single trap design, particularly when we compare smolt population estimates among traps. Currently, funding for this project in YR 2005 is questionable, and I am exploring (and open to suggestion for) possible funding sources. Below is a list of why we consider the Redwood Creek study to be important:

- The study is a cooperative between Redwood Creek Landowners Association, Humboldt State University, Redwood National Park, and the California Department of Fish and Game.
- The data we collect can be combined with Humboldt State University's efforts in Prairie Creek, and the Redwood National Park's long term monitoring in the Redwood Creek estuary to determine potential bottlenecks to anadromous salmonid production in Redwood Creek.
- By combining our data we can better focus restoration efforts and needs in the basin.
- Our peer reviewed trapping methods and protocol can serve as a model for determining juvenile smolt population estimates in many streams, such as the Van Duzen, South Fork Eel River, Middle Fork Eel River, Mad River, and South Fork Smith River, among other rivers.
- Our study describes natural variability in wild smolt populations and provides population estimates, presence/absence data, timing of out-migration, smolt sizes and weights, and travel time from the upper to lower trap, among other aspects to smolt out-migration and juvenile salmonid life histories.
- Our study is designed to be long term in order to fully address both environmental and biological variability of anadromous salmonids in Redwood Creek. For example, during the fourth consecutive year of trapping in upper Redwood Creek, the Chinook salmon experienced a cohort failure, which would not have been detected had we not trapped that year.

The following recommendations pertain to collecting additional biological data:

- Adult Steelhead Trout Scale Samples: We need to collect scale samples from adults to determine the juvenile life history that adults exhibited. Such information would provide information about the percentage of adult steelhead that entered the ocean as one or two year old smolts.
- 2+ Steelhead Trout Diet Analysis: Stomach pumping a random sample of 2+ steelhead trout during months where differences exist would be useful in assessing why the upper trap's 2+ steelhead trout were heavier than the lower trap's 2+ steelhead trout.
- Coho Salmon: Efforts should be continued to determine the current spatial structure of coho salmon within the watershed.
- Cutthroat Trout: Trapping, electro-fishing, and snorkel surveys should be conducted within Redwood Creek basin to determine the current spatial structure (i.e. presence).

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