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2002 ANNUAL REPORT
UPPER REDWOOD CREEK JUVENILE SALMONID DOWNSTREAM MIGRATION STUDY, 2000-2002 Seasons
PROJECT 2a5

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Steelhead Research and Monitoring Program
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ABSTRACT

Juvenile anadromous salmonid trapping was conducted in upper Redwood Creek from March 28 – August 4, 2002 to estimate population size of downstream migrating juvenile 0+ chinook salmon, 1+ steelhead trout, and 2+ steelhead trout using stratified mark/recapture methods. The trap operated 127 nights out of 129 nights possible, and captured 223,167 0+ chinook salmon, 18 1+ chinook salmon, 124,426 0+ steelhead trout, 12,217 1+ steelhead trout, 1,589 2+ steelhead trout and 9 cutthroat trout. No juvenile coho salmon were captured. 0+ chinook salmon, 1+ steelhead trout, and 2+ steelhead trout catches were positively related to the relative gage height of the stream at the trapping site. 0+ steelhead trout catches were negatively related to the gage height. Trap efficiencies for 0+ chinook salmon, 1+ steelhead trout, and 2+ steelhead trout by week averaged 50.6, 42.3, and 20.4%, respectively. 0+ chinook salmon trap efficiencies were negatively related to stream gage height, and 1+ steelhead trout trap efficiencies showed positive relations. 2+ steelhead trap efficiencies were positively related to gage height and night releases of marked fish. Total population estimates with 95% confidence intervals for 0+ chinook salmon, 1+ steelhead trout, and 2+ steelhead trout were 518,189 (494,834 - 541,543), 28,501 (26,701 - 30,300) and 7,370 (6,286 - 8,455), respectively. Peak population out-migration for 0+ chinook salmon, 1+ steelhead trout, and 2+ steelhead trout occurred during April-June, May-June, and April-May, respectively, and followed trends of actual catches. 0+ chinook salmon average fork length and weight, and 0+ steelhead trout average fork length significantly increased over the course of the study. No significant relationships of fork length and weight with time were found for 1+ steelhead. 2+ steelhead average fork lengths decreased over time, and average weight showed no significant relationship. Comparisons are made with downstream migration data collected in 2001 and 2000.

[1/] This paper should be referenced as: Sparkman MD. 2002. Upper Redwood Creek juvenile salmonid downstream migration study, 2002-2000. CDFG S-RAMP Annual Report 2a5: 62 pps.

INTRODUCTION

This study is the third consecutive year of juvenile salmonid downstream migration trapping in Upper Redwood Creek, Redwood Valley, Humboldt County, California. The first study year in 2000 was funded by the Redwood Creek Landowners Association (RCLA), and carried out by Michael Sparkman and Douglas Parkinson (Sparkman 2000). The second and third years of study have been a cooperative effort between the California Department of Fish and Game Steelhead Research and Monitoring Program (CDFG S-RAMP) and RCLA. S-RAMP and RCLA plan on continuing the study for at least a five year period, which may be extended to cover a longer period of time in order to more fully address biological and environmental variability.

Although there is abundant data on Redwood Creek with respect to hydrology, geology, geomorphology, forestry, and wildlife biology, relatively little information exists concerning anadromous salmonids upstream of the estuary. The more recent studies of salmon and steelhead in Redwood Creek include: summer steelhead snorkel (dive) survey counts, estuarine juvenile salmonid research, habitat typing, and upper Redwood Cr out-migrant trapping.

Documenting and determining juvenile out-migration can be used to assess: 1) the number of parents that produced the cohort, 2) redd gravel conditions, 3) in-stream habitat quality, 4) watershed health, and 5) 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. Such studies rely upon the assumption that juvenile production will to some degree parallel adult population sizes in response to stream and oceanic conditions over time.

The two-year-old (2+) steelhead smolt is considered to be the best surrogate for steelhead status and trends when adult population estimates are difficult, if not impossible at times, to determine. The 2+ steelhead may be the most biologically significant life history juvenile stage with respect to predicting adult steelhead returns because we can expect higher survival from 2+ smolt to adult, than 1+ or 0+ steelhead to adult. Additionally, 2+ steelhead status and trends should give a better indication of watershed and stream health because these fish have had to overcome the numerous components to stream survival.

Site Description

Redwood Creek flows through Trinity and Humboldt Counties 70 miles before reaching the Pacific Ocean (Figure 1). Headwaters originating at an elevation of about 4,000 ft flow north to northwest to the Pacific Ocean, near the town of Orick in Northern California. The basin of Redwood Creek is 179,151 acres, and about 49.7 miles long and 6.2 miles wide (Cashman et. al 1995). The study area entails approximately 65,000 acres of upper Redwood Creek watershed, with about 37 stream miles of accessible salmon and steelhead habitat (Brown 1988).

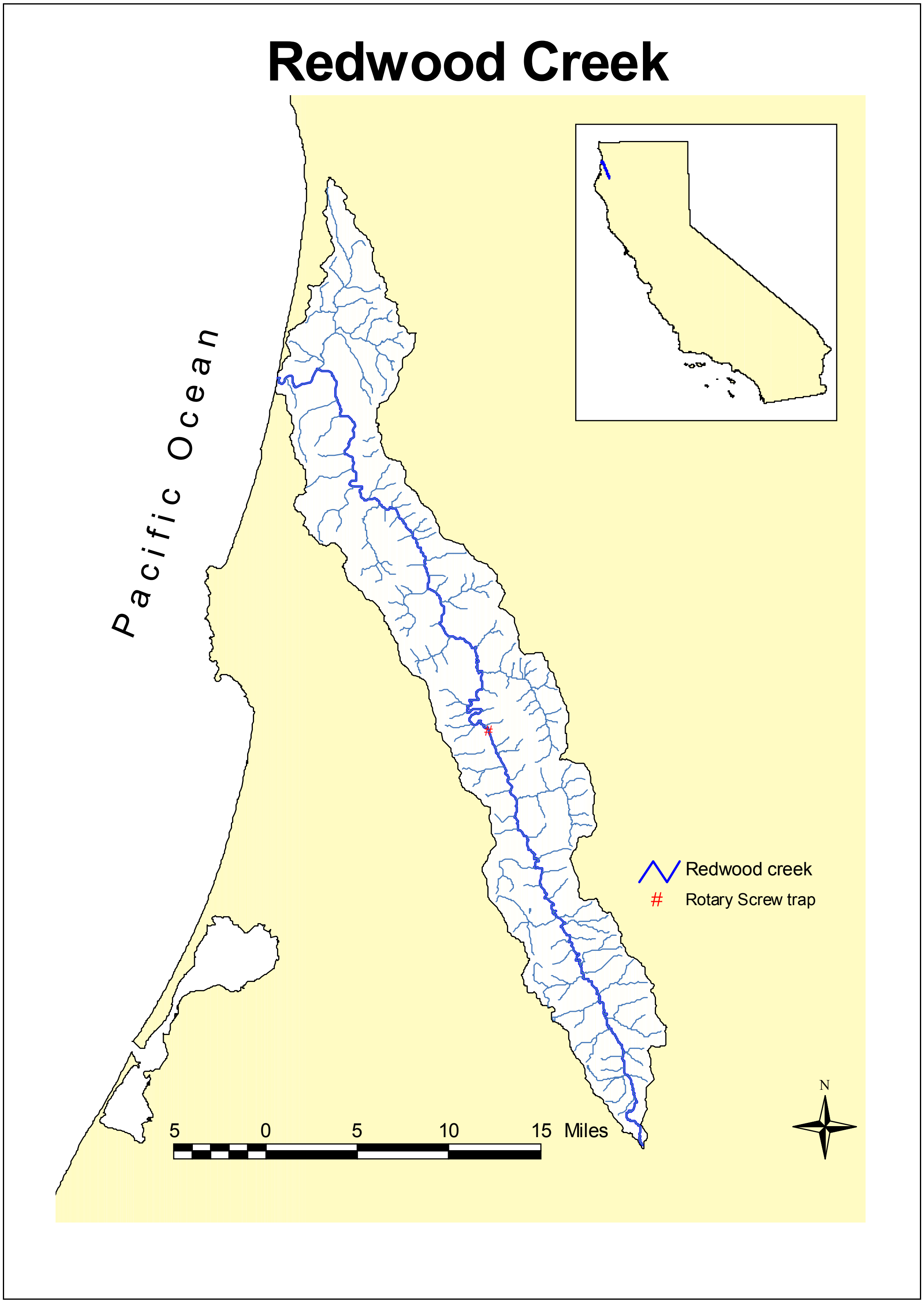

Figure 1. Redwood Creek watershed, Humboldt County, California (scale is slightly inaccurate due to reproduction process; Peters 2001).

Geology

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).

Average Rainfall

Most of the rainfall in Redwood Creek occurs from October through May. Based upon limited data, the mean annual rainfall is 61.7 inches, and ranges from 49.7 – 77.3 inches (CDWR 1981). Preliminary data show that rainfall in lower Redwood Creek in water year 2002 (October 2001 – September 2002) was 47.52 inches, with 5.52 inches falling within the trapping period (CDWR 2002).

Discharge

A USGS gaging station (#11481500) is located about 8.4 miles upstream of the trap site on Redwood Creek. Stream flow records cover the periods of 1953 – 1958, 1972 – 1993, and 1997 – 2002, (USGS 2002) to total 31 years. Following the pattern of rainfall, most of the high flows occur in the months of November through May, and typically peak in February (USGS 2002; see Flow Events in text). Low flows usually occur from July through October. Using all years' data, mean monthly discharge is 235 cfs, and ranges from 8 – 564 cfs (USGS 2002). Preliminary data for water year 2002 show that the mean monthly discharge was 205 cfs, and ranged from 2 – 727 cfs. The average monthly flow during the trapping season was about 60 cfs, and ranged from 5 – 145 cfs (USGS 2002).

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*).

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*), braken fern (*Pteridium aquilinum*), blackcap raspberry (*Rubus spp*.), and elderberry (*Sambucus spp*.), among other species.

Redwood Cr History

Redwood Creek watershed has experienced extensive logging of Redwood and other commercial tree species. In conjunction with associated road building, geology types, and flood events in 1955, 1964, 1972, and 1975, large amounts of sediments were delivered into the stream channel with a resultant loss of stream habitat complexity such as filling in of pools and flattening out of the stream channel. Currently, Redwood Creek within the study area appears to be experiencing channel incision in flood gravel deposits, scouring of pools to increase depth, riparian growth, and input of woody debris, which collectively increase stream complexity.

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 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 (NOAA 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 belong to the Southern Oregon/Northern California Coasts ESU and are classified as "threatened" (NMFS 1997). Steelhead trout fall within the Northern California Steelhead ESU, and are also listed as a "threatened" species (NOAH 2000). Coastal cutthroat trout of Redwood Creek fall within the Southern Oregon/California Coasts Coastal Cutthroat Trout ESU, and were determined "not warranted" for ESA listing (NOAA 1999). Despite ESU classification of Redwood Creek anadromous salmonid populations, relatively little data exists concerning abundance and population sizes, particularly for juvenile life history stages.

Purpose

The purpose of this project is to describe juvenile salmonid downstream migration in upper Redwood Creek, and to determine out-migrant population sizes for wild 1+ (between 1 and 2 years old) steelhead, 2+ (between 2 and 3 years old) steelhead, and 0+ (young of year) chinook salmon. The primary long term goal is to determine the status and trends of out-migrating juvenile salmonids in upper Redwood Creek. An additional goal is to document the presence or absence of juvenile coho salmon. Specific study objectives were as follows:

1) Determine the temporal pattern and species composition of downstream migrating juvenile salmonids.
2) Enumerate species out-migration.
3) Determine population estimates for downstream migrating 1+ steelhead, 2+ steelhead, and 0+ chinook salmon.
4) Record fork length (mm) and weight (g) of captured fish.
5) Collect and handle fish in a manner that minimizes mortality.
6) Statistically analyze data for significance and trends.
7) Compare data between study years.

METHODS AND MATERIALS

Trap Operations

A modified E.G. Solutions (5 foot diameter cone) rotary screw trap was placed in upper Redwood Creek (RM 33) on March 28, 2002 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. A perforated plate was then used to close the downstream end where the debris wheel once was located. Perforated plates with 2 mm holes were 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 velocities, allowed for less fish crowding during peak catches, and enabled the trap to continue trapping under higher flows as compared to the stock model.

The rotary screw trap operated continually (24hrs/day, 7 days a week) in the thalweg of the stream from March 29 through August 5 2002, except for two days near the end of July when the stream flow was too low and the cone had to be raised (see flow events). Similar to past year's trapping, a rock weir was constructed on the right bank side of the stream to direct more flow into the cone area of the trap. On April 2, screened weir panels were placed on the left bank side to ensure high trap efficiencies. The weir was set to fall down under high stream flows. During periods of increased flows, scientific aides carefully removed debris from within the livebox every night. Weir panels were re-set after high flow events from April 9 through May 4 2002, and thereafter left in place throughout the trapping period. On May 17, a left bank rock weir was placed about 20 m upstream of the trap to force more water into the area of the thalweg. On April 28 and May 31, the trap was moved about 10 feet upstream into faster water to keep catches, trap efficiencies, and cone revolutions relatively high. On June 4, plastic drop cloths were used to line the rock weirs to further increase flow into the cone area; and on June 12, the trap's front end was slightly aligned to ensure that the center of the thalweg traveled straight into the cone. Beginning June 17, streambed cobbles and rocks below the rotary screw trap cone, pontoons, and livebox area were periodically dug out or removed to give adequate clearance. On June 26, the screen mesh weirs on the left bank side were replaced with plywood weirs to increase cone revolutions. After 26 June, individual rocks were strategically placed just upstream of the cone to direct water and increase cone revolutions. On July 27, 2002 the rotary screw trap was no longer functional (due to low flows and low cone revolutions), and a pipe trap similar to that used in 2001 was set. The system worked very well, and enabled trapping to the end of the season (August 4). Throughout the trapping season, efforts were continually made to maximize trap efficiencies and trap catches, and to minimize trap mortalities.

The livebox was emptied at 08:00 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. During parts of June and July when stream and air temperatures were high, crushed ice was sparingly used to cool the water in the ice chest and recovery buckets. Hand held temperature gages were used to keep the water about 2 ^{o}C cooler than the stream water. Ice was not used as frequently compared to the past two years of study because the continuous fresh water kept water temperatures relatively cool.

Random samples of each species at age (eg 0+ KS, 0+ SH, etc.) were netted from the ice chest for enumeration and biometric data collection.

Fork Lengths/Weights

Fish were anesthetized with MS-222 prior to data collection in 2 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), and 2+ steelhead trout (2+ SH). Only fork lengths were taken for 0+ steelhead trout (0+ SH). A 350 mm measuring board ($\pm$ 1 mm) and an Ohaus Scout ll digital scale ($\pm$ 0.1 g) were used in the study. Fork lengths were taken every day of trap operation, and fork length frequencies of 0+ and older steelhead and chinook salmon were used to determine age-length relationships at varying times throughout the trapping period. 0+ chinook salmon and 1+ steelhead weights (g) were taken 2-3 times per week. 2+ steelhead and 1+ chinook salmon 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+ and 2+ steelhead 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, 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**.**

After biometric data was collected, fish were recovered in buckets of continuously aerated fresh water. Young of year fish were kept in separate recovery buckets from age 1+ and older fish to decrease predation, or injury. Crushed ice was sparingly added to the recovery buckets to reduce water temperatures during June-August.

After recovery, 0+ juvenile salmonids were transported 157 meters downstream of the trap into edge-water of a riffle. 0+ juveniles were placed into a circular rock weir with a downstream facing escape exit, which served as a final recovery and release station. Branches with leaves were placed within the rock weir to provide additional cover. The low velocity, pool like habitat allowed more time for recovery and stream re-orientation. In addition, we were able to monitor any potentially immediate negative effects associated with handling and water temperature acclimation.

1+ and 2+ steelhead were released 160 meters downstream of the trap into the edge of the main riffle current. The older juvenile fish were generally much more alert than young-of-year fish, and could handle the stronger current (i.e. could swim wherever they wanted to). There was no concern of fish predation due to their size, and avian predators were not seen at the release location.

Population Estimates

The number of fish captured by the trap represented only a portion of the total fish moving in that time period. Total salmonid out-migration estimates (by age and species) were determined on a weekly basis for 0+ chinook salmon, 1+ steelhead trout, and 2+ steelhead trout using mark-recapture methodology described by Carlson et al. (1998). The approximately unbiased estimate equation for a 1-site study was used to determine total population size (U_h) in a given capture and trapping efficiency period (h). Variance was computed, and the value was used to calculate 95% confidence intervals (CI) for each weekly population estimate. The weekly population estimate (U_h) does not include marked releases in the "C" component to the equation, and any short term handling mortality was subtracted (Carlson et al. 1998). Trap efficiency trials were conducted three times a week for 0+ chinook salmon and 1+ steelhead, and five times a week for 2+ steelhead. Data was combined and run through the equation to determine the weekly estimate. Partial fin clips were used to identify trap efficiency trial fish. Clips were stratified by week such that marked fish of one group (or week) would not be included in the following week(s) calculations. If a marked fish was captured out of the week strata it was clipped and released, the number originally marked for that particular strata was reduced by the number caught out of the strata. For example, if 100 fish were clipped and released for the week's population estimate and one fish was recaptured the following week (eg out of strata capture), the number originally marked would be reduced to 99. The rationale is for each week we are attempting to estimate the number of out-migrants passing the trap. If an efficiency trial fish is caught out of strata, then that fish did not pass the trap with the previous week's group that we are estimating.

If a week's trapping efficiency for a particular species at age was less than 10%, that week's data was pooled with the previous or following week's data to determine a bi-weekly estimate of total population size. Chi-square (or Fisher's Exact Test) was used to determine if trap efficiencies of pooled weeks differed from one-another. If not different ($p > 0.05$), pooling was allowed (Carlson et al. 1998). The pooling procedure tends to smooth out inflation of population size due to low recapture probability. Week and bi-weekly estimates were summed to determine the total out-migrant population estimate for the entire trapping period. Variance for the estimate was determined in a similar way (i.e. adding weekly and bi-week variances), and used to calculate 95% CI for the final total population estimate (Carlson et al. 1998). If the pooling process did not appreciably reduce the estimate or confidence intervals (e.g. 5 %), pooling was not used, so that estimate resolution on a weekly basis would not be lost. Additional population estimate models (e.g. Peterson, Darr) were also used for comparison.

Clip types for 1+ and 2+ steelhead were kept on different time schedules to later aid in identifying the correct age group of the recaptured fish; if there was any doubt or question, we would re-measure the fish, and count it for the appropriate age group. Trap efficiency trial fish were given partial fin clips while under anesthesia, and later recovered in 5 g buckets which received fresh stream water. 0+ chinook salmon were given upper or lower caudal fin clips, 1+ steelhead were given upper or lower caudal fin clips, and 2+ steelhead were given the same fin clips as 1+ SH, in addition to right or left pectoral partial fin clips. Once recovered, the fish were placed in mesh cages in the stream for 1 - 2 hrs to test for short term delayed mortality (Carlson et al 1998). Fin clipped 0+ chinook salmon were released 260 m upstream of the trap, and clipped 1+ and 2+ steelhead were released 160 m upstream of the trap. All fin clipped fish were released upstream of the trap after the livebox was emptied. Due to low trap efficiencies for 2+ steelhead, night releases of 2+ steelhead efficiency fish began on April 24, 2002. A live cage with a battery operated mechanism opened a trap door which allowed for night releases of 2+ efficiency fish at any given time (eg 2200). Differences in efficiency of night and day release marked 1+ steelhead and 0+ chinook salmon were also investigated (see Additional Experiments).

Assumptions of Mark/Recapture

The following assumptions apply to the Carlson et al (1998) population estimates:

1) The population remains closed, and mortality observed during marking, capturing, and handling is accounted for.
2) All smolts have the same probability of being marked, or of being examined for marks
3) Probability of capture between marked and unmarked fish is constant.
4) Marks are not lost between release and recovery, and survival of marked fish is tested.
5) All marked smolts are reported on recapture.
6) All marked smolts released are either recovered or pass by the downstream capture site.

We attempted to satisfy or test the requirements of the mark-recapture assumptions using the following rationale, or experiments:

Assumption 1: We considered the population to be closed and assumed juvenile fish from watersheds other than Redwood Cr do not swim into the Redwood Cr basin; fish captured in Redwood Creek originated from Redwood Creek. Additionally, mortality was monitored throughout the trapping season.

Assumption 2: By using randomly drawn individuals for marking this assumption was met. Fish used in marking were of varying sizes for each species and age class, and hence, possible variability in recapture due to size was accounted for. We assumed that marked fish randomly mixed with the unmarked population because upstream release distances for marked fish were greater than 100 m; this distance of upstream release was considered adequate for mixing. Additionally, the daily numbers of unmarked fish captured were much higher than marked fish recaptured. For example, on any given day we might catch 1,000 0+ chinook salmon, with up to 60 being marked fish.

Assumption 3: Although this assumption was not tested explicitly, methods of using multiple groups of marked fish per week to determine a weekly population estimate should provide a population estimate that takes into account variable flows and capture probabilities within the given week. Carlson et al (1998) suggest that by using more than one sample to estimate a weekly population size, the assumption is less restrictive. We assumed probability of capture for marked and unmarked smolts was the same. In general, we feel the rotary screw trap location and use of weirs decreased the likelihood of marked fish purposely avoiding the trap. However, for 2+ steelhead, equal probability of capture may not be an easy assumption to meet. Equal probability of capture is likely to be the most important assumption to be met, and has the biggest impact upon population estimates.

Assumption 4: Partial fin clips were used because they are relatively long lasting, easy to apply, and do not harm the fish if correctly applied. Every efficiency fish was held in a live car in the stream for a period of 1 – 2 hr prior to upstream release to document any immediate mortality due to fin clipping and handling. Delayed mortality tests (24hr) of fish handled or clipped were conducted for 0+ chinook salmon and 1+ steelhead. 2+ steelhead were given delayed mortality clipping tests as well (see Additional Experiments).

Assumption 5: Each member of the field crew was specifically trained in identifying partial fin clips used for each species at age. All fish captured by the rotary screw trap were anesthetized with MS-222; and individually observed for fin clips in a clear, flat Tupperware © container. We found that we did not have to totally anesthetize the fish to observe clips, which decreased processing time.

Assumption 6: Using stratified marks by week allowed for discriminating groups of marked fish on a weekly basis; and for determining population estimates by week. Marked fish released in a given week were not counted for the population estimate of the following week, unless the two week's data were pooled. The majority of recaptures occurred 1 d after release, with few captured on the second day of release. Nearly all of the recaptures fell within the correct strata, and indicated that marked fish did pass the trapping site.

Marked fish of one week were only occasionally captured the following week. The numbers were very low (e.g. < 9 individuals per species at age over the course of trapping) and considered negligible when compared to the numbers originally released and recaptured in the previous week. This year the 1+ steelhead showed 'straggling' more so than 0+ chinook or 2+ steelhead. Most of the 1+ steelhead straggling (e.g. 5 of 9) occurred near the end of the trapping season when stream temperatures were high. It is possible that the fish found thermal refugia. Of a total of 822 marked 1+ SH recaptures, 98.9% were captured in the correct strata. 1+ SH stragglers represented 1.1% of the total 1+ SH marked recaptures (or 0.46% of total marked fish released). We periodically conducted snorkel surveys in the reach upstream of the trap site to possibly detect straggling or hold over efficiency fish (see Additional Experiments).

Additional Experiments

We marked and released 20 2+ steelhead with two partial fin clips downstream of the trap site on May 3, 2002 to see if any would be caught by the trap a second time. If the steelhead were moving upstream instead of passing by the trap site, we might catch a few if they then moved downstream.

We snorkeled the stream upstream of the trap site to the efficiency release location to see if any of the fin clipped fish were not passing the trap site after a given strata. Snorkel dives were in an upstream manner, and occurred from April 13 to June 23, 2002.

Last year (2001) we marked 374 1+ steelhead with a plastic elastomer, and each fish captured this year was examined for the elastomer mark. If we caught any of the elastomer marked fish, it would give evidence that some of the 1+ steelhead were not migrating to the ocean during last year's out-migration.

On May 11, 2002 we marked 100 0+ chinook salmon with the partial lower caudal (LC) fin clip, and 50 different individuals with the upper caudal (UC) fin clip. The 100 LC efficiency fish were released upstream of the trap during the day, whereas the 50 UC fish were released upstream of the trap during the night. A Chi-square statistical test was used to determine if any significant differences in recapture occurred. A similar test for 1+ steelhead was conducted on May 15 to determine if recapture percentages varied due to day or night release.

Delayed mortality experiments (handling or fin clipping) were conducted on 0+ chinook salmon (n = 3 tests), 1+ steelhead (n = 8 tests), and 2+ steelhead (n = 5 tests) throughout the trapping period. Handling tests were for fish that were anesthetized, measured, and weighed. Fin clip tests were for fish that were anesthetized and given a partial fin clip. Fish were held in mesh cages in the stream for a period of 24 hrs during each test. Sample sizes ranged from 1 – 60 individuals.

Physical Data Collection

A staff gage with increments in hundredths of a foot was used to measure the relative stream surface elevation (hydrograph) at the trap site from March 29 – August 4, 2002. The gage was read every morning at 0800 to the nearest one-hundredth of a foot prior to biometric data collection.

Continual stream temperatures were recorded with an Optic StowAway Temp Probe (Onset computer corporation, 470 MacArthur Blvd. Bourne, MA 02532) placed nearby the rotary screw trap. The probe was deployed from March 29 – August 4, 2002, and recorded stream temperature (^{o}C) every hour. Data was later downloaded into Microsoft Access© to determine daily mean, maximum, and minimum water temperatures.

Data of fraction of the moon illumination at midnight was gathered from the Astronomy Applications Department, US Naval Observatory, Washington, DC 20392-5420.

In response to a request by NOAA (Diane Ashton, Fisheries Biologist, Arcata, Ca), stream turbidity (NTU) was recorded daily at the trap site and further upstream at the US HWY 299 from June 13 – July 1, 2002. These dates corresponded to periods before, during, and after the construction of Chezum Dam. The US HWY 299 site, about 1.4 miles upstream of Chezum Dam, served as a location to obtain background turbidity measurements of upper Redwood Creek. We used a DRT-15 LE turbidity meter (HF Scientific, INC. Fort Meyers, FL), and took three water samples at each place per sample day. The three measurements were then averaged to determine a single value for either the trap site or US HWY 299 site. Measurements at US HWY 299 were also used to determine the maximum exceedence level (base level plus 20% of the base level).

Statistical Analyses

Numbers Cruncher Statistical System Software (NCSS) (Hintze 1998) was used for descriptive statistics, ANOVA, correlation, and linear regression/ANOVA output. Descriptive statistics were used to characterize the mean fork length (mm) and weight (g) of each species at age on a weekly and season basis. ANOVA was used to test if two populations of data were present with respect to 1+ and 2+ SH fork lengths (mm), and for differences in size of each species among study years. Linear regressions or correlations were used to test for significant relations of biological data with physical or temporal data (Table 1). Regression slope was used to determine if population size of species at age was increasing, decreasing, or remaining stable for the three years of study.

If data violated tests of assumptions, data was transformed with Log (x+1), where x = the independent variable. When transformations did not work for ANOVA, non-parametric equivalents were used. Power is defined as the ability of the test to detect differences that truly exist, or put another way, 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.

Table 1. Linear regressions and correlations used in the study.

Test	Dependent Variable (y)	Independent Variable (x)
Regression	Daily catches of salmonids	Daily staff gage reading
Regression	Daily catches of 0+ KS	Daily staff gage reading
Regression	Daily catches of 0+ SH	Daily staff gage reading
Regression	Daily catches of 1+ SH	Daily staff gage reading
Regression	Daily catches of 2+ SH	Daily staff gage reading
Regression	Daily catches of salmonids	Lunar phase
Regression	Daily catches of 0+ KS	Lunar phase
Regression	Daily catches of 0+ KS	Lunar phase
Regression	Daily catches of 1+SH	Lunar phase
Regression	Daily catches of 2+ SH	Lunar phase
Correlation	Average week fork length 0+ KS	Week number
Correlation	Average week fork length 0+ SH	Week number
Correlation	Average week fork length 1+ SH	Week number
Correlation	Average week fork length 2+ SH	Week number
Correlation	Average week weight of 0+ KS	Week number
Correlation	Average week weight of 1+ SH	Week number
Correlation	Average week weight of 2+ SH	Week number
Regression	Weekly 0+ KS trap efficiencies	Average of weekly staff gage
Regression	Weekly 1+ SH trap efficiencies	Average of weekly staff gage
Regression	Weekly 2+ SH trap efficiencies	Average of weekly staff gage
Correlation	Weekly 0+ KS trap efficiencies	Week number
Correlation	Weekly 1+ SH trap efficiencies	Week number
Correlation	Weekly 2+ SH trap efficiencies	Week number
Regression	Daily catches of all salmonids	Average daily stream temperature C
Regression	Daily catches of 0+ KS	Average daily stream temperature C
Regression	Daily catches of 0+ SH	Average daily stream temperature C
Regression	Daily catches of 1+ SH	Average daily stream temperature C
Regression	Daily catches of 2+ SH	Average daily stream temperature C

RESULTS

The rotary screw trap operated from 3/28/02 – 7/26/02 and trapped 120 nights out of a possible 122. The pipe trap operated from 7/28/02 – 8/04/02 and trapped 7 nights out of a possible 7. Using both traps, trapping occurred 127 out of 129 nights possible.

Species Captured

Species captured in the 2002 study year included: juvenile chinook salmon (*Oncorhynchus tshawytscha*), juvenile steelhead trout (*O. mykiss*), cutthroat trout (*O. clarki clarki*), sculpin (*Cottus* spp.), sucker (*Catostomidae* family), speckled dace (*Rhinichthys osculus*), and three-spined stickleback (*Gasterosteus aculeatus*). No juvenile coho salmon (*O. kisutch*) were captured. A total of 361,426 juvenile salmonids were captured in 2002 (Figure 2.). Juvenile (ammocoete) and adult Pacific Lamprey (*Entosphenus tridentatus*), and an unidentified lamprey that might be river lamprey (*Lampetra ayres*) were also caught (Table 2). Amphibian catches included Pacific Giant Salamander (*Dicamptodon ensatus*), Rough Skinned newt (*Taricha granulosa granulosa*), Painted Salamander (*Ensatina eschscholtzii*), Red Legged frog (*Rana aurora*), Yellow Legged frog (*Rana muscosa*), and Tailed Frog tadpole (*Ascaphus truei*) (Table 2).

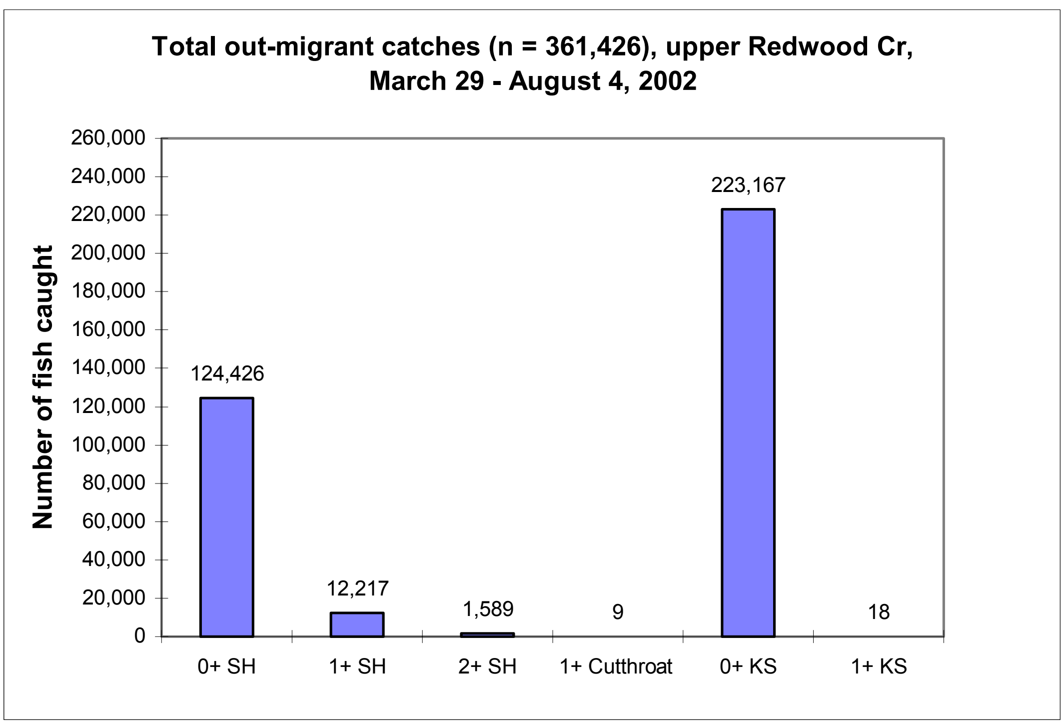

Figure 2. Total juvenile salmonid catches from March 29 through August 4, 2002, upper Redwood Creek, Redwood Valley, Humboldt County, California.

Catches of 0+ chinook salmon were considerably higher in 2002 as compared to study years 2001 and 2000 (Table 2). 0+ SH and 2+ SH catches in 2002 were slightly higher than in 2001, and considerably higher than catches in 2000. 1+ SH catches in 2002 dropped from catches in 2001, and were about the same as in 2000. 1+ chinook salmon catches in 2002 were slightly less than in 2001. No 1+ chinook salmon were caught in study year 2000. Juvenile coho salmon were not captured in 2002, 2001, and 2000. Speckled dace were caught for the first time in 2002. Considerably more adult and juvenile pacific lampreys were caught in 2002 compared to 2001 and 2000.

Table 2. Trap catches of various species in study years 2002, 2001, and 2000.

	Study Year		
Species Captured	2002	2001	2000
0+ Steelhead Trout	124,426	102,408	55,126
1+ Steelhead Trout	12,217	14,775	12,263
2+ Steelhead Trout	1,589	1,360	736
Adult Steelhead	1	3	6
0+ Chinook Salmon	223,167	120,692	123,633
1+ Chinook Salmon	18	21	0
Coho Salmon	0	0	0
Cutthroat Trout	9	6	2
Prickly Sculpin	10	8	3
Coast Range Sculpin	283	67	145
Sucker	3	7	3
3-Spined Stickleback	104	85	144
Speckled Dace	6	0	0
Adult Pacific Lamprey	91	5	16
Juvenile Pacific Lamprey	3,920	1,103	597
Possible River Lamprey	1	16	0
Pacific Giant Salamander	111	28	30
Painted Salamander	1	0	0
Rough Skinned Newt	56	19	NA
Red-Legged Frog	1	1	NA
Yellow-Legged Frog	17	9	NA

Captures

Catches of 0+ KS, 1+ KS, 0+ SH, 1+ SH, and 2+ SH were variable over time, with apparent multiple peak catch distributions for most species at age. 0+ chinook salmon daily catches ranged from 0 – 9,375, and averaged 1,757 per day (Appendix 1). Daily 0+ chinook salmon captures in 2002 expressed as a percentage of total 0+ chinook catch ranged from 0.0 – 4.2%. 0+ steelhead daily catches ranged from 0 – 6,088, and averaged

980 individuals per day (Appendix 2). Daily 0+ steelhead captures in 2002 expressed as a percentage of total 0+ steelhead catch ranged from 0.0 – 4.9%. 1+ steelhead daily catches ranged from 0 – 442, and averaged 96 per day (Appendix 3). Daily 1+ steelhead captures in 2002 expressed as a percentage of total 1+ steelhead catches ranged from 0.0 – 3.6%. 2+ steelhead daily catches ranged from 0 – 41, and averaged 12 individuals per day (Appendix 4). Daily 2+ steelhead captures in 2002 expressed as a percentage of total 2+ steelhead catches ranged from 0.0 – 2.6%.

Missed Trapping Days

Two days were not trapped (7/27 and 7/28) during the course of the study because of low flows which could not spin the rotary screw trap cone. Days missed trapping did not influence the total catch to any large degree because not many fish were out-migrating during this period, and any given catch day did not equate to a large percentage of total catches.

0+ Chinook Salmon

Low numbers of 0+ chinook salmon were caught (n = 13) the day following trap placement, unlike yr 2001 when no 0+ chinook salmon were caught for the first 23 d of trapping. In 2000, chinook salmon were caught on the first day following trap placement. Peak catches in 2002 occurred during April (n = 54,123), May (n = 77,947), and June (n = 86,319) 2002, and accounted for 24, 35, and 39% of the total 0+ chinook salmon catches. Catches in May and June 2002 accounted for 74% of the total 0+ chinook catch, as compared to 96% and 81% in 2001 and 2000, respectively. April, May and June were important months for 0+ chinook salmon out-migration in upper Redwood Creek.

0+ chinook salmon catches by week in 2002 had three noticeable peaks (Figure 3). The peaks in April and late April/early May 2002 occurred when no large peaks were observed in previous study years. The largest peak in 2002 (n = 35,629) was noticeably higher than peaks in 2001 and 2000, and occurred two weeks after the largest peak in 2001, and two weeks before the largest peak in 2000. Data for all years show out-migration by week was considerable until July 8, when out-migration tapered to relatively low values (e.g. < 2,000/week).

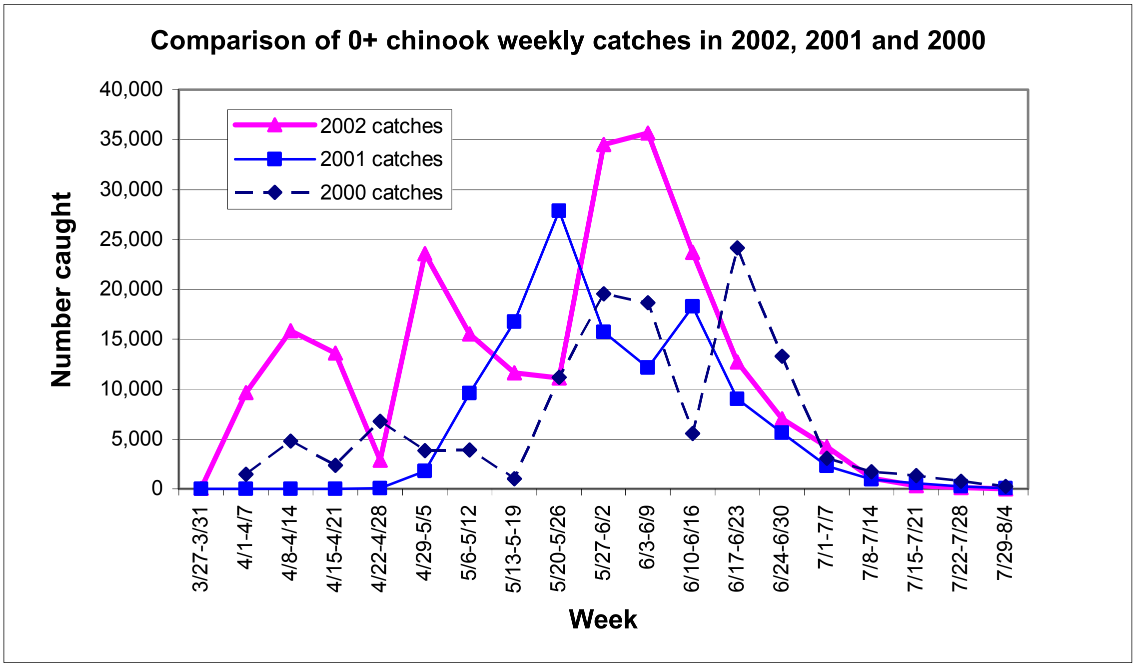

Figure 3. 0+ chinook salmon captures by week, study years 2002, 2001, and 2000.

1+ Chinook Salmon

One year old chinook salmon (n = 18) were caught from 3/29/02 - 5/06/02; in 2001, 21 1+ chinook were captured from 3/27/01 - 5/05/01. Fork lengths (mm) were originally used to differentiate 1+ from 0+ chinook salmon at the trap site. In the laboratory, scale analyses confirmed annuli present on the larger chinook salmon juveniles.

0+ Steelhead Trout

0+ steelhead were first caught on the third day (3/31/02) following trap placement, unlike in 2001, when they were first caught 37 d after trap placement (5/02/01). In 2000, 0+ steelhead were also caught three days after trap placement (4/07/00). Peak 0+ steelhead trout catches in 2002 occurred during May and July, with considerable catches in June as well (Figure 4). Catches in May (n = 24,309), June (n = 57,208), and July (n = 41,596) were 19, 46, and 33% of total 0+ steelhead catches in 2002. Catches in June and July in 2002 accounted for 79% of total catches, as compared to May-June catches in 2001 that equaled 85% of the total catch. In 2000, catches in June and July accounted for 87% of the total catch. May, June, and July were important months for 0+ steelhead downstream migration, or stream re-distribution within the three study years.

0+ steelhead catches by week in 2002 had one small and two large peaks (Figure 4). The second peak in 2002 occurred one week later than the first peak in 2001; and at the same time as the first, albeit small, peak in 2000. The third and largest peak in 2002 was six weeks later than the highest peak catch in 2001, and two weeks after the highest peak catch in 2000. The largest peak in 2002 (n = 23,567) was higher than any peak in 2001 and 2000. Peak catches by week also show that May, June, and July were important months for stream re-distribution (Figure 4). Data for all years show that catches drop considerably from the end of July and the beginning of August.

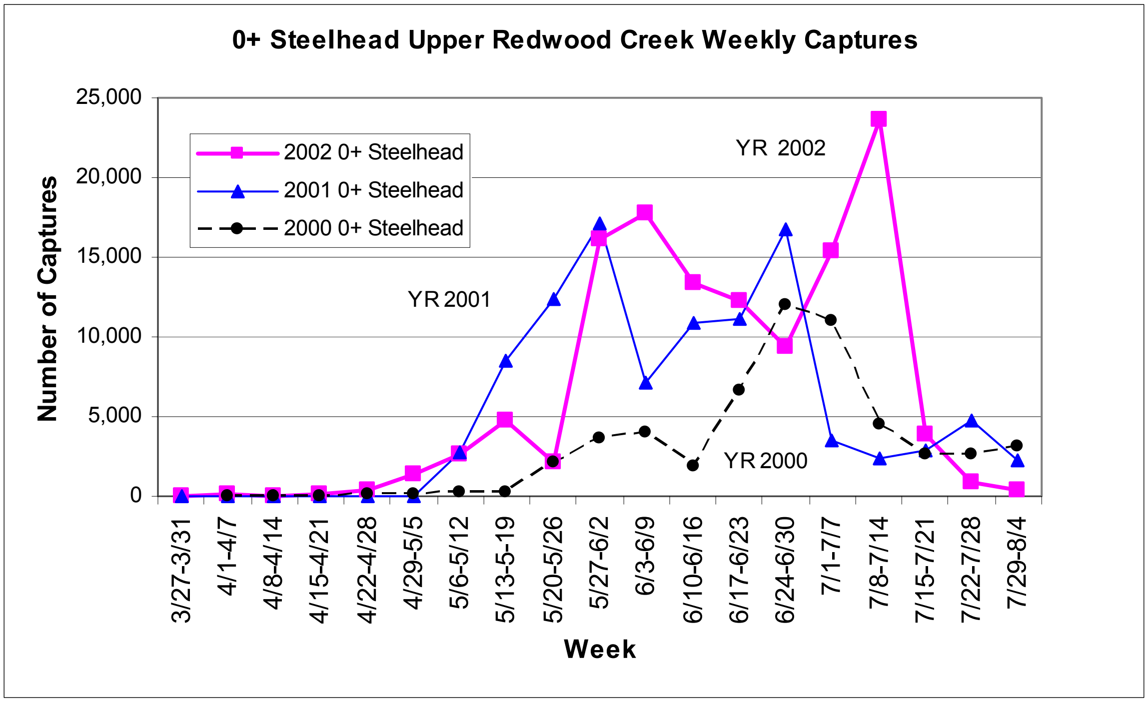

Figure 4. 0+ steelhead captures by week, study years 2002, 2001, and 2000.

1+ Steelhead Trout

The catch distribution of 1+ steelhead trout in 2002 approximated a normal bell shaped curve with a single weekly peak catch (Figure 5). The months of April and May, 2002 accounted for 80% of the total catch, compared to 79.7 and 77% in 2001 and 2000, respectively. April and May were important months for 1+ steelhead downstream migration in study years 2002 - 2000. 1+ steelhead catches by week peaked later in 2002 than in previous study years (Figure 5). The peak catch by week in 2002 occurred three weeks after the greatest peak in 2001, and two weeks later than the peak catch in 2000. Catches by week in 2002 also show the trapping period covered the majority of downstream migration (e.g. the peak catch occurred seven weeks after trap placement). 1+ steelhead catches by week also show that out-migration drastically decreased from July 1 through August 4.

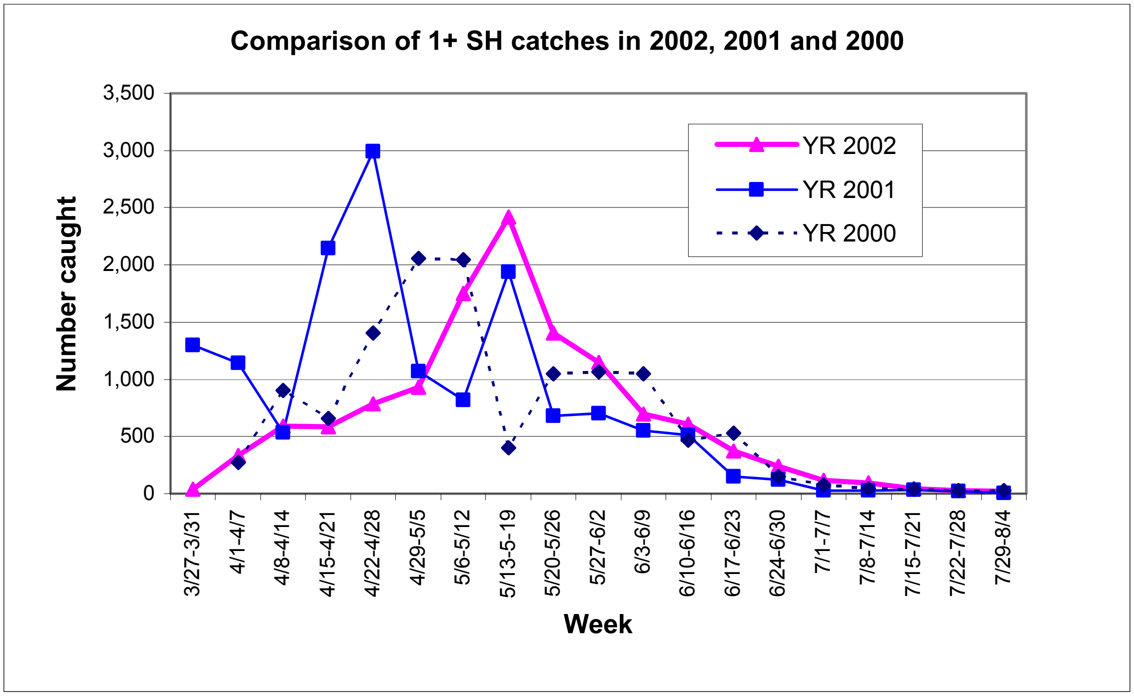

Figure 5. 1+ steelhead captures by week, study years 2002, 2001, and 2000.

<u>2+ Steelhead Trout</u>

Peak 2+ steelhead catches in 2002 occurred during April and May, with small peaks in June and July (Figure 6). The months of April and May accounted for 78.2% of the total catch in 2002, as compared to 64.3 and 81.0% in 2001 and 2000, respectively. Although April and May are important months for out-migration, data in 2001 showed March and July were also important.

2+ steelhead catches by week in 2002 show the trapping period probably encompassed the majority of out-migration (Figure 6). Catches by week were variable over study years, and the peaks in 2002 occurred at times when in 2001 and 2000, no peaks were present. The largest peak in 2002 took place four weeks after the first peak in 2001; and five weeks after the largest peak in 2000. The 2002 2+ SH peak was also at the same time as the 1+ SH peak in 2002. Similar to study year 2001, a small 2+ SH peak occurred in June, 2002. Catches by week for all study years show out-migration tapered off from July 22 – August 4.

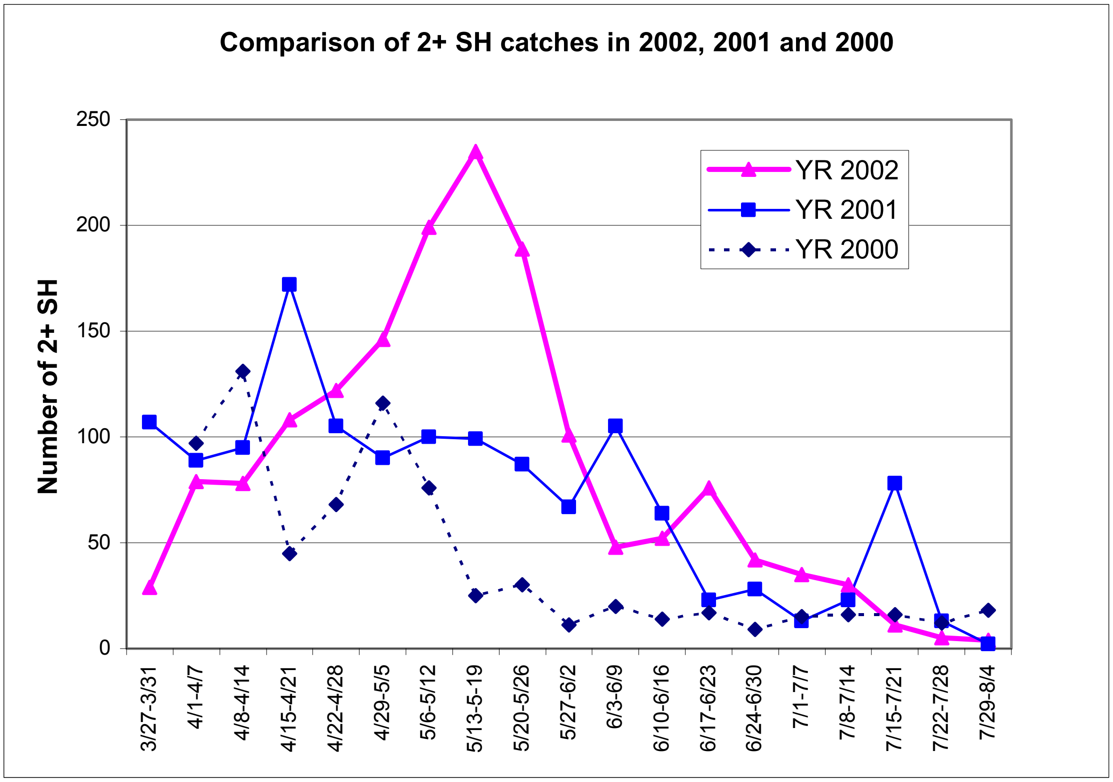

Figure 6. 2+ steelhead captures by week, study years 2002, 2001, and 2000.

Pacific Lamprey

Adult pacific lamprey (*E. tridentatus*) were observed spawning just above the trap site on 5/9/02. The lampreys basically appeared overnight, and the next day we counted 5 lamprey redds. One of the redds was very large, and we at first thought it was a fresh steelhead redd. Upon closer inspection, I observed that the lampreys had cleared a large area free of surface cobbles, some of which they had placed at the downstream section (tail) of the disturbed area to presumably form an egg pocket. Minutes later I observed a pair of lamprey actively spawning at the head of the redd, just upstream of another small clump of cobbles. Four other lampreys were observed on or near redds in the same general area. Total lamprey catches in 2002 equaled 91, with the majority caught from 5/12 – 6/22 (Figure 7). Catches of ammocoetes (n = 3,920) peaked in almost every month of trap operation (April, May, June, July).

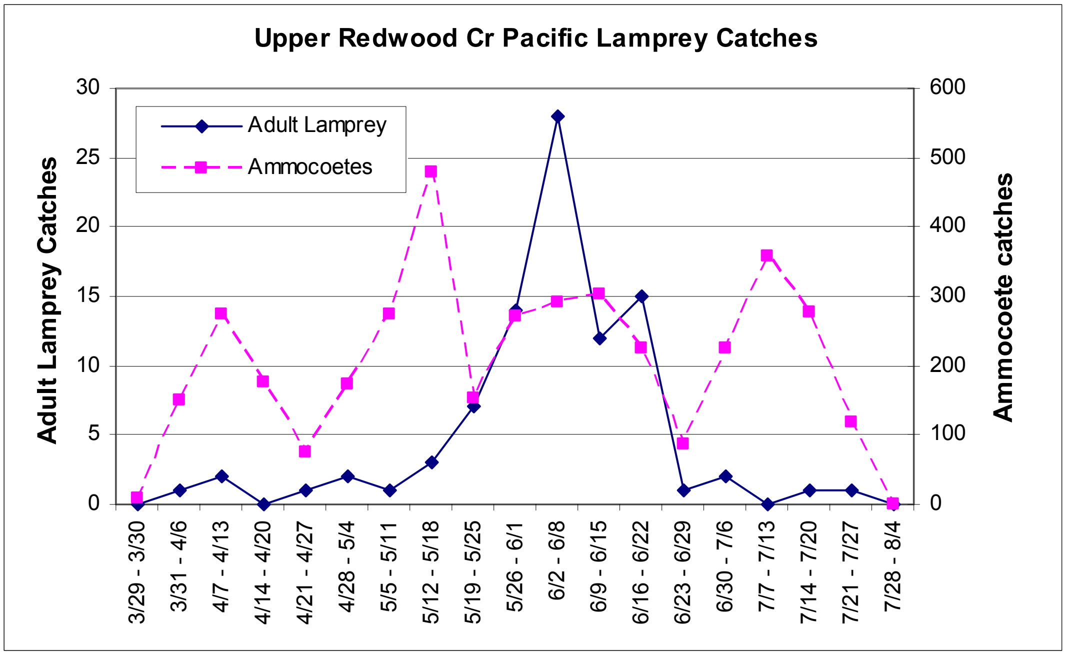

Figure 7. Adult and juvenile (ammocoete) Pacific Lamprey catches in upper Redwood Creek, 2002.

Flow Events

Stream discharge in upper Redwood Creek in water year 2001-02 (October 2001-September 2002) was higher than average in December and January (Figure 8); however mean discharge (Qcfs) in the remaining months were below average.

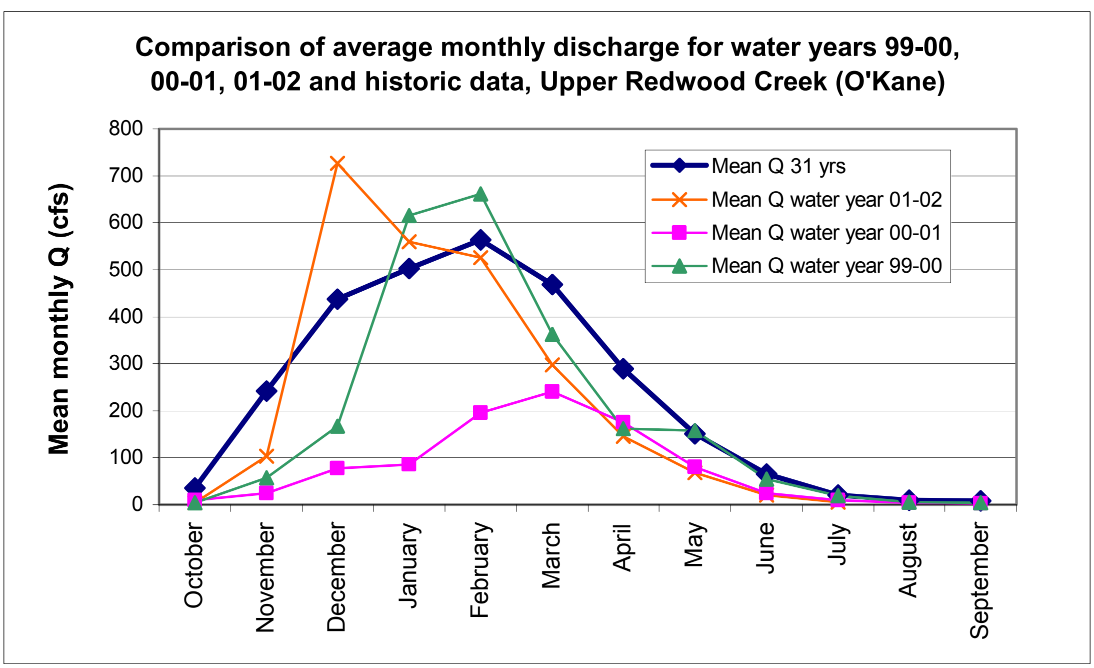

Figure 8. Average monthly discharge in upper Redwood Creek, Humboldt County, Ca. (USGS 2002).

Although more water was present in water year 2002 compared to 2001, flows during the trapping season were less than previous study years, and historic values (Figure 9). The lack of significant spring rainfall was probably the reason.

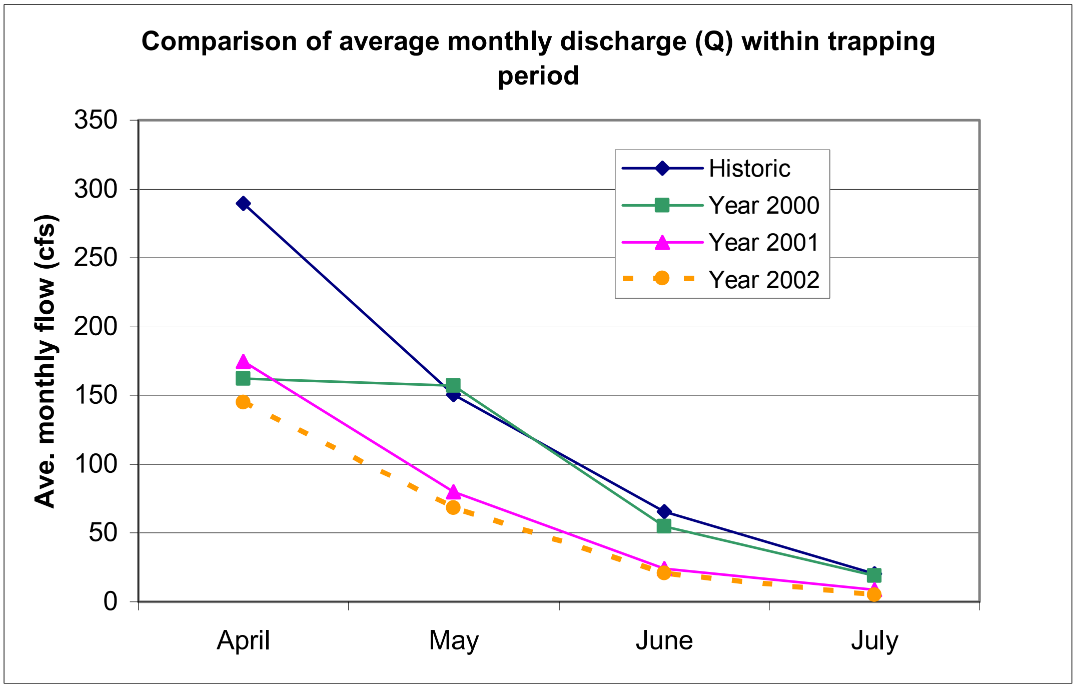

Figure 9. Average monthly discharge in upper Redwood Creek during out-migrant trapping, 2002-2000 (USGS 2002).

Flows during the 2002 season were moderate, with less high flow events than previous study years. Three discernable peaks at the trap site occurred in 2002 (Figure 10). The largest daily increases in gage height in 2002 were on 4/17/02 (0.49 ft), 5/01/02 (0.36 ft), and 5/20/01 (0.14 ft). The largest daily increases in gage height in 2001 were 0.56, 0.34, and 0.72 ft, as compared to 1.14 and 0.60 ft in 2000.

Similar to study year 2001, the trap in 2002 was positioned in the middle of the thalweg throughout all flow events. Low flows in 2002 required trapping adjustments on a weekly, and at times, daily basis (e.g. increase weir paneling, increasing cone clearance with streambed, etc.).

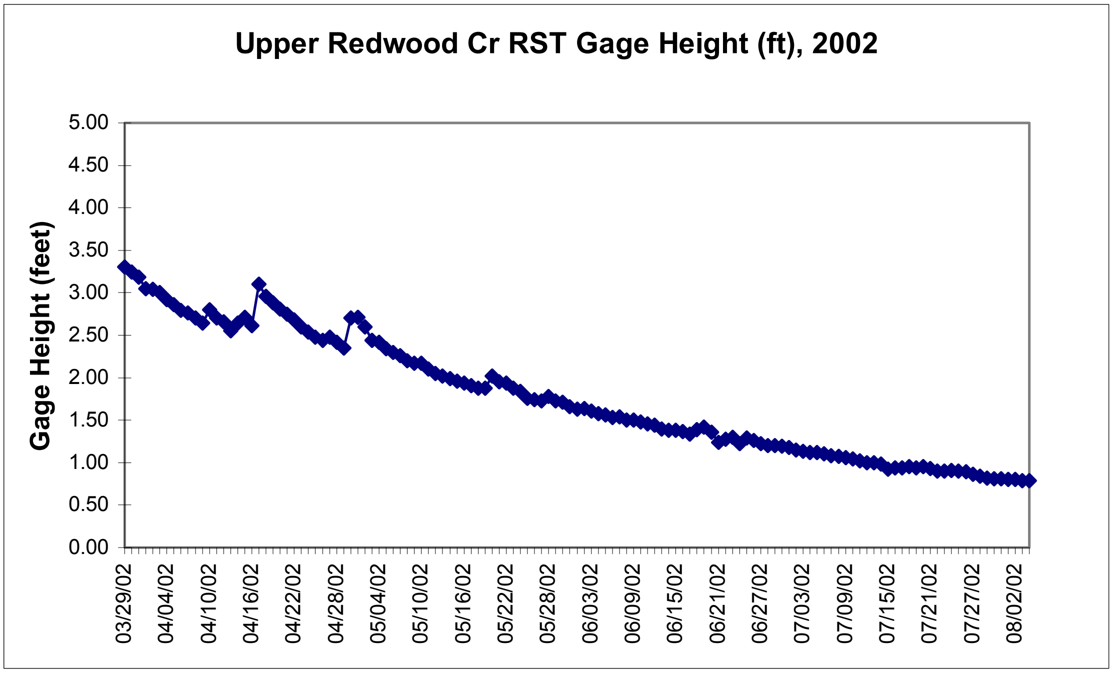

Figure 10. Staff gage at RST site, upper Redwood Creek, Humboldt County, Ca., 2002.

Chezum Dam

Influences on Stream Gage Height

The construction of Chezum Dam, located about 5.6 mi upstream of the trap site, began on June 15, 2002. Chezum Dam is an earthen impoundment with a gravel spillway used to pass fish. According to Mike Chezum, operator of Chezum Dam, the dam was filled with water in about four days in 2002, compared to one day in 2001 (pers comm. 2002). In 2000, Chezum Dam was not installed. The filling phase impacts the stream flow at the trap site, as evidenced by changes in staff gage measurements (Figure 11). Changes in gage height attributable to the dam occurred from 6/18/02 – 6/27/02. The largest drop from one day to the next occurred on 6/21/02, with a decrease of 1.44 inches; the largest two day drop was 2.16 inches. The largest single day drop in 2001 was 1.7 inches, and from 6/19/01 – 6/23/01, the stream dropped 3.12 inches. Not all hydrograph changes in 2002 were negative (Figure 11). Man-made changes in gage height in 2002 did not halt trapping, unlike study year 2001.

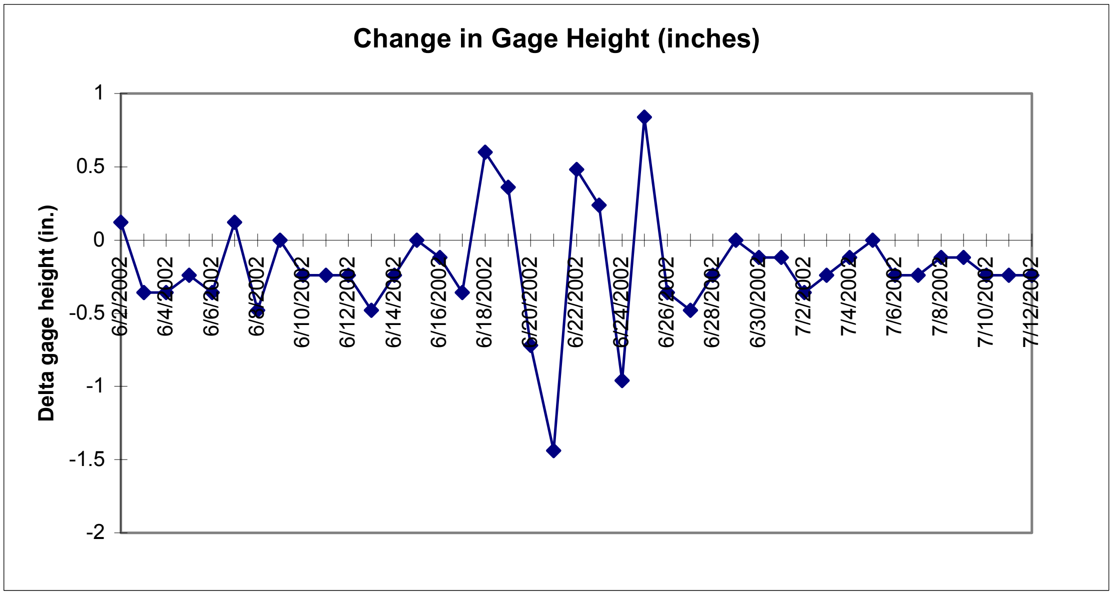

Figure 11. Change in gage height (in.) at the trap site during Chezum Dam operations, 2002.

<u>Influences on Stream Turbidity</u>

Stream turbidity at the trap site and control site (US HWY 299 stream section) was monitored from 6/13/02 – 7/01/02 (Figure 12). Stream turbidity in nephelometric turbidity units (NTU) did not vary between the trap site and control site from 6/13/02 - 6/17/02, prior to major dam construction (Kruskall-Wallace, $p > 0.05$). However, stream turbidity (NTU), as expected from the graph below, significantly varied between the trap site and control site from 6/18/02 – 7/01/02 (Kruskall-Wallace, $p < 0.0001$). The median turbidity at the trap site and control site was 0.62 and 0.22 NTU's, respectively. The average turbidity at the trap site and control site was 1.41 and 0.23 NTU's, respectively. Turbidity measured at the trap site was assuredly less than what would be expected immediately below Chezum Dam.

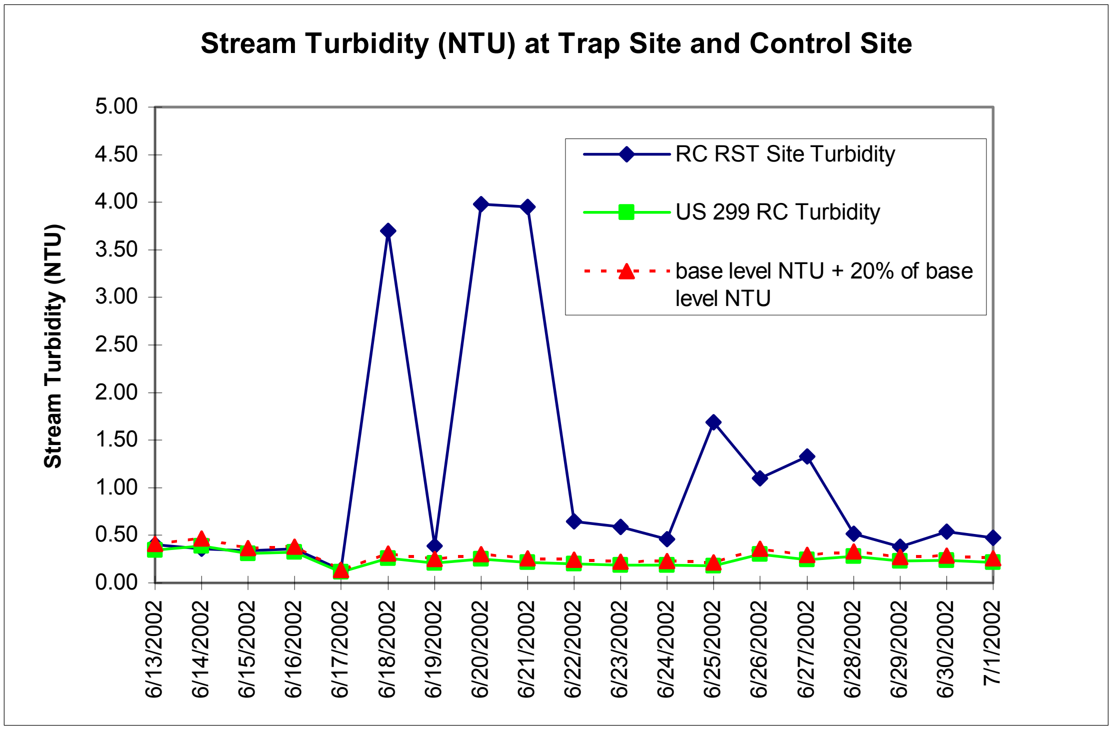

Figure 12. Comparison of stream turbidity above and below Chezum Dam, 2002.

Linear Relations of Catch with Staff Gage Height

Linear regression of daily gage height (ft) on daily catches for all salmonids combined in 2002 showed no significant relationship ($p > 0.05$, power = 0.05). In study year 2001, a moderate negative relationship was found ($p < 0.001$), and in 2000, no relationship was found ($p > 0.05$). Using average gage height by week and total species catch by week, regression determined no significant relationship in 2002 ($p > 0.05$).

Regression of daily gage height (ft) on 0+ chinook salmon daily catches (log (x+1) transformation) in 2002 showed a significant, yet weak positive linear relationship ($p < 0.001$, R2 = 0.24; power = 1.0). In study year 2001 and 2000, no relationships were found ($p > 0.05$). Two peak chinook salmon catches occurred during gage height increases (e.g. 4/30/02 and 5/20/02), and the remaining peak catches occurred during the descending limb of the hydrograph. The regression of average gage height (ft) by week on 0+ chinook salmon catches by week in 2002 also showed a significant positive relationship ($p = 0.01$; R2 = 0.34; power = 0.77).

Regression for 0+ SH daily catches (log (x+1) transformation) showed a significant, yet weak negative relationship with daily gage height ($p < 0.001$, R2 = 0.31; power = 1.0), similar to that found in 2001 and 2000. None of the peak catches in 2002 were associated with peaks in the hydrograph. The regression of average gage height (ft) by week on 0+

steelhead catches by week in 2002 also showed a weak, yet significant negative relationship ($p = 0.04$; R2 = 0.24; power = 0.57).

Regression of 1+ SH catches (log (x+1) transformation) showed a weak, yet significant positive relationship with gage height ($p < 0.001$, R2 = 0.35; power = 1.0). The relationship was similar to study year 2001 and 2000; however, the R2 in 2001 (0.59) was higher than in 2002 (0.35) and 2000 (0.34). Three small 1+ SH daily catch peaks in 2002 were associated with small peaks in gage height (ft). The regression of average gage height (ft) by week on 1+ steelhead catches by week (log (x+1) transformation) in 2002 also showed a significant positive relationship ($p < 0.001$; R2 = 0.45; power = 0.92).

Regression of 2+ SH daily catches and gage height (ft) in 2002 violated regression assumptions even when data was transformed with log (x+1), however, two peak catches did correspond to peaks in gage height (ft). In 2001, regression assumptions were violated even with transformation, and only one peak corresponded with an increase in the hydrograph. In study year 2000, 2+ SH daily catches were positively related to gage height ($p<0.05$). In 2002, average gage height (ft) by week and weekly 2+ SH catches (log (x+1) transformation) passed regression assumption tests. The regression of average gage height by week (ft) on catch by week was significant and positive ($p = 0.0009$, R2 = 0.36; power = 0.80).

Linear Relations of Catch with Lunar Phase

Linear regressions of daily fraction of moonlight on daily catches for all salmonids, and each species violated assumptions of normality, and results were not valid. Although statistical parametric relations were not warranted, some generalizations can be made.

Similar to 2001 data, 0+ chinook salmon catches in 2002 generally decreased with a full moon. However, the two largest daily peak catches in 2002 occurred at moon illumination fractions of 0.87 and 0.75. A smaller peak occurred at a fraction of 0.01. In 2001 peak catches occurred at illumination factors less than 0.51. In 2000, peak catches occurred during a moon illumination of 0.30 – 0.84.

0+ SH catches in 2002 generally decreased with a full moon. The two largest daily 0+ SH peak catches occurred at moon illumination of 0.75 and 0.01. In 2001, the peak catch occurred at 0.41 with catches greater than 3,000 per day occurring at fractions of 0.13 – 0.41. In 2000, peak 0+ SH catches did not occur at moon illumination fractions greater than 0.17.

1+ SH catches in 2002 were variable with respect to moon illumination. Two of the smaller peaks in 2002 were associated with a full moon; however, the largest peak catch occurred during a 0.01 moon illumination. In 2001, the majority of high catches were below a moon illumination fraction of 0.50; however, one peak catch occurred at a moon illumination of 0.99. Aside from the peak catch at 0.99 in 2001, results in 2001 and 2000 were similar (eg higher catches below 0.50 moon illumination).

For all three trapping seasons, 2+ steelhead were the most variable of all salmonids with respect to catches and moon illumination fractions. High catches in 2002, 2001, and 2000 occurred at full and new moon phases, with no clear pattern.

Stream Temperatures

The average daily (24 hr period) stream temperature from 3/29/02 - 8/04/02 was 15.8 ^{o}C (95% CI 15.0 - 16.5), and ranged from 7.7 - 22.9 ^{o}C (Figure 13). The average daily stream temperature (^{o}C) exceeded 20 ^{o}C for 34 d out of 129 d (26%) of record. In 2001, exceedence was 30 d of 120 d (25%) of record. Relations of average stream temperature ^{o}C and gage height (ft) in 2002 were significantly negative ($p < 0.001$, R2 = 0.89; power = 1.0). Gage height (ft) explained 89% of the variation in average stream temperatures (^{o}C). The maximum and minimum daily temperatures ranged from 8.7 - 27.5 ^{o}C, and 6.7 - 20.3 ^{o}C, respectively (Figure 13). Maximum temperatures (^{o}C) occurred in mid to late afternoon, well after the trapped fish were processed and released. The dip in stream temperatures from 8/02/02 onward was probably due to smoke in the atmosphere from forest fires in Southern Oregon and Northern California, which decreased solar radiation.

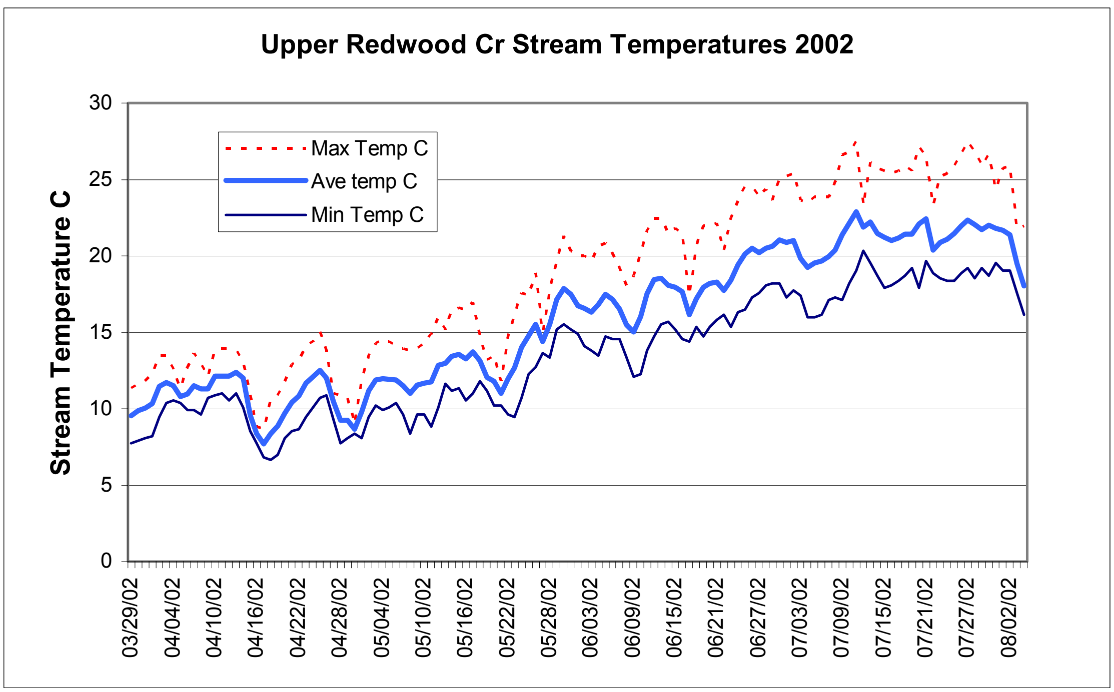

Figure 13. Upper Redwood Creek stream temperatures during the trapping period (^{o}C), 2002.

The average stream temperature in 2001 and 2000 was 16.26 and 15.88 ^{o}C, respectively. Similar to 2002 data, stream temperatures in 2001 and 2000 increased over time ($p < 0.001$), and were negatively related to gage height ($p < 0.001$). Using daily data for the same time period in all study years (i.e. truncating the 2001 and 2002 data to match 2000 data), Kruskall-Wallace One Way ANOVA on Ranks determined no significant variation among treatment medians ($p > 0.05$).

<u>Linear Relations of Catch with Average Stream Temperature</u>

Linear regressions of average stream temperature ^{o}C by day on daily catches of all salmonids combined, 0+ chinook salmon, 0+ steelhead trout, and 1+ steelhead trout violated regression assumptions (even with log(x+1) transformations), and results were not valid. 2+ steelhead daily catches (log (x+1) transformation) passed regression assumption tests, and a negative relationship with average stream temperature was found ($p < 0.001$, R2 = 0.58, power = 1.0). Regression of average stream temperature by week ^{o}C on catches of all salmonids by week was not significant ($p > 0.05$, power = 0.05); however, significant relations were found for 0+ chinook salmon, 0+ steelhead trout, 1+ steelhead trout, and 2+ steelhead trout (Table 3).

Table 3. Linear regression of average stream temperature ^{o}C by week on catches by week, 2002.

	Average weekly temperature ^{o}C			
Age/species	p	R2	power	relationship
All species	> 0.05	na	na	na
0+ KS*	0.0060	0.38	0.84	-
0+ SH	0.0300	0.26	0.62	+
1+ SH*	0.0002	0.60	0.99	-
2+ SH*	0.00005	0.65	1.0	-

* Denotes log (x+1) transformation

In 2001, no significant relationship was found for 0+ chinook salmon weekly catches and average temperature ^{o}C; in 2000, a positive relationship was determined ($p < 0.05$). 0+ steelhead weekly catches were not related to temperature ^{o}C in 2001, but were positively related in 2000 ($p < 0.05$). Similar to 2002 data, 1+ steelhead weekly catches in 2001 and 2000 were negatively related to average week temperatures ^{o}C ($p < 0.05$). 2+ steelhead weekly catches in 2001 were negatively related to average stream temperature ^{o}C, and in 2000, no relationship was found.

Negative relationships of catches with increasing stream temperatures may suggest that the fish prefer or have evolved to migrate prior to periods of higher temperatures; positive relationships with increasing stream temperatures may indicate the fish are leaving because temperatures are higher than desired. Low R2's or coefficients of determination (e.g. < 0.40) indicate other variables besides temperature are influential.

Variables that are not addressed in this study with respect to attempting to explain the pattern of catches (by species at age) include: upstream food availability, upstream habitat space, degree of smoltification, and genetics, among other factors. Only 2+ steelhead catches by week were significantly related to trap efficiencies for species at age (p < 0.05, + relationship). An increase in trap efficiency does not necessarily mean higher catches from one week to the next; at the population level, significantly less fish could be moving downstream during periods of increased efficiencies.

Fork Length and Weight

<u>0+ Chinook Salmon</u>

This year we measured (FL mm) 3,517 and weighed (g) 1,545 0+ chinook salmon. Overall, fork lengths ranged from 34 – 85 mm, and averaged 52.4 mm; the standard error of the mean (SEM) was 0.2 mm. Weights in 2002 ranged from 0.3 – 7.2 g, and averaged 1.70 g. 0+ chinook salmon average fork length in 2002 was greater than study year 2001, and less than study year 2000 (Table 4). Average weight in 2002 was less than average weight in 2001 and 2000. The greatest difference in average fork lengths and weights between study years was minimal (3.6 mm; 0.33 g).

Table 4. 0+ chinook salmon average fork length (mm) and weight (g) by study year, 2002-2000.

	0+ Chinook Salmon							
	Fork Length (mm)				Weight (g)			
Study Year	MIN.	MAX.	AVE.	SEM	MIN.	MAX.	AVE.	SEM
2002	34	85	52.4	0.2	0.3	7.2	1.70	0.03
2001	34	81	51.9	0.2	0.3	5.3	1.73	0.04
2000	36	85	55.5	0.2	0.3	6.3	2.03	0.04

<u>1+ Chinook Salmon</u>

Seventeen fork length (mm) and weight (g) measurements were taken for 1+ chinook salmon in 2002 (Table 5). Fork lengths ranged from 70 – 148 mm, and averaged 108.5 mm (95% CI 100 – 117). 1+ chinook salmon average fork length and weight in 2002 was greater than study year 2001(Table 5); no 1+ chinook salmon were captured in 2000. Differences in average fork lengths and weights between study years were slight (4.1 mm; 3.32 g).

Table 5. 1+ chinook salmon average fork length (mm) and weight (g) by study year, 2002-2000.

	1+ Chinook Salmon							
	Fork Length (mm)				Weight (g)			
Study Year	MIN.	MAX.	AVE.	SEM	MIN.	MAX.	AVE.	SEM
2002	70	148	108.5	3.9	4.3	41.5	16.70	2.0
2001	86	133	104.4	2.8	6.6	28.6	13.38	1.7
2000	-	-	-	-	-	-	-	-

0+ Steelhead Trout
A total of 3,228 fork length (mm) measurements were taken for 0+ steelhead trout in 2002. Overall, fork lengths ranged from 24 – 69 mm, and averaged 38.7 mm. 0+ steelhead trout average fork length in 2002 was less than the average in 2001 and 2000 (Table 6). Similar to 0+ chinook salmon, differences in average 0+ steelhead fork lengths between study years were minimal (eg 2.2 mm).

Table 6. 0+ steelhead trout average fork length (mm) by study year, 2002-2000.

	0+ Steelhead Trout							
	Fork Length (mm)				Weight (g)			
Study Year	MIN.	MAX.	AVE.	SEM	MIN.	MAX.	AVE.	SEM
2002	24	69	38.7	0.2	-	-	-	-
2001	25	69	39.0	0.3	-	-	-	-
2000	25	75	40.9	0.2	-	-	-	-

1+ Steelhead Trout
A total of 3,049 fork length (mm) and 1,356 weight (g) measurements were taken for 1+ steelhead trout in 2002. In 2002, fork lengths ranged from 51 – 119 mm, and averaged 86.7 mm; weights ranged from 1.3 – 21.3 g, and averaged 7.79 g (Table 7). For all three study years, the smallest fish were captured in the beginning of the trapping season. 1+ steelhead trout average fork length and weight in 2002 was less than averages in 2001 and 2000 (Table 7). The largest difference between average fork lengths (2002 vs. 2000) and weights (2002 vs. 2001) was 5.7 mm and 1.48 g, respectively.

Table 7. 1+ steelhead trout average fork length (mm) and weight (g) by study year, 2002-2000.

	1+ Steelhead Trout							
	Fork Length (mm)				Weight (g)			
Study Year	MIN.	MAX.	AVE.	SEM	MIN.	MAX.	AVE.	SEM
2002	51	119	86.7	0.3	1.3	21.3	7.79	0.11
2001	55	124	91.9	0.3	2.0	26.6	9.27	0.14
2000	48	138	92.4	0.3	1.3	30.7	8.29	0.13

2+ Steelhead Trout
This year we measured (FL mm) 1,528 and weighed (g) 1,463 2+ steelhead, or 92% of the 2+ steelhead catch. In 2002, fork lengths ranged from 120 – 274 mm, and averaged 147.5 mm; weights ranged from 12.8 – 229.6 g. 2+ steelhead trout average fork length and weight in 2002 was less than averages in 2001 and 2000 (Table 8). The largest

difference between average fork lengths (2002 vs. 2000) and weights (2002 vs. 2000) was 16.9 mm and 11.25 g, respectively.

Table 8. 2+ steelhead trout average fork length (mm) and weight (g) by study year, 2002-2000.

	2+ Steelhead Trout							
	Fork Length (mm)				Weight (g)			
Study Year	MIN.	MAX.	AVE.	SEM	MIN.	MAX.	AVE.	SEM
2002	120	274	147.5	0.6	12.8	229.6	37.87	0.51
2001	125	218	151.2	0.5	18.6	110.1	39.17	0.43
2000	136	220	164.4	0.6	25.1	116.1	49.12	0.61

Kruskal-Wallis One Way ANOVA on Ranks (ANOVA non-parametric equivalent) determined significant variation among 1+ and 2+ steelhead weekly fork lengths ($p = 0.000001$), and support fork length cutoffs used to separate these two age classes throughout the trapping period. Median fork length for 1+ and 2+ steelhead trout was 83.4 and 146.4 mm, respectively.

Fork Length and Weight Over Time

Data in 2002 was tested for significant relationships with time (week) using linear correlation. Single factor ANOVA was used to determine if significant variation in average fork length (mm) and weight (g) existed between study years. The lack of data in some weeks is due to 1) differences in trap placement time among study years, 2) no catches occurred, or 3) sample size was too low to generate a reliable average.

The average fork lengths (mm) by week of out-migrating 0+ chinook salmon and 0+ steelhead trout increased over the sampling period for the three study years (Figure 14).

Correlation of week on average 0+ chinook fork length (mm) in 2002 showed a highly significant positive relationship ($p = 0.0000001$, $r = 0.99$; power = 1.0), similar to tests in 2001 and 2000. Chinook salmon fork lengths steadily increased over time, and indicate growth was taking place. 0+ chinook salmon average week fork lengths (mm) in 2002, 2001, and 2000 were not significantly different from one another (ANOVA, $p > 0.05$; power = 0.12). The difference in average fork length (mm) from the first week of captures and the last week in 2002, 2001, and 2000 equaled + 36.0 mm, + 24.7 mm, and + 30.2 mm, respectively.

The correlation test for 0+ steelhead trout showed a highly significant positive relationship of fork length (mm) with time ($p = 0.000007$, $r = 0.93$; power = 1.0), very similar to data in 2001 and 2000. 0+ steelhead trout fork lengths increased over time, and indicate growth was taking place. As expected from the graph below, ANOVA found no significant differences in 0+ SH average week fork length (mm) among study years 2002, 2001, and 2000. The difference in average fork length (mm) from the first week of captures and the last week for 2002, 2001, and 2000 equaled + 22.9 mm, + 13.6 mm, and + 21.1 mm, respectively.

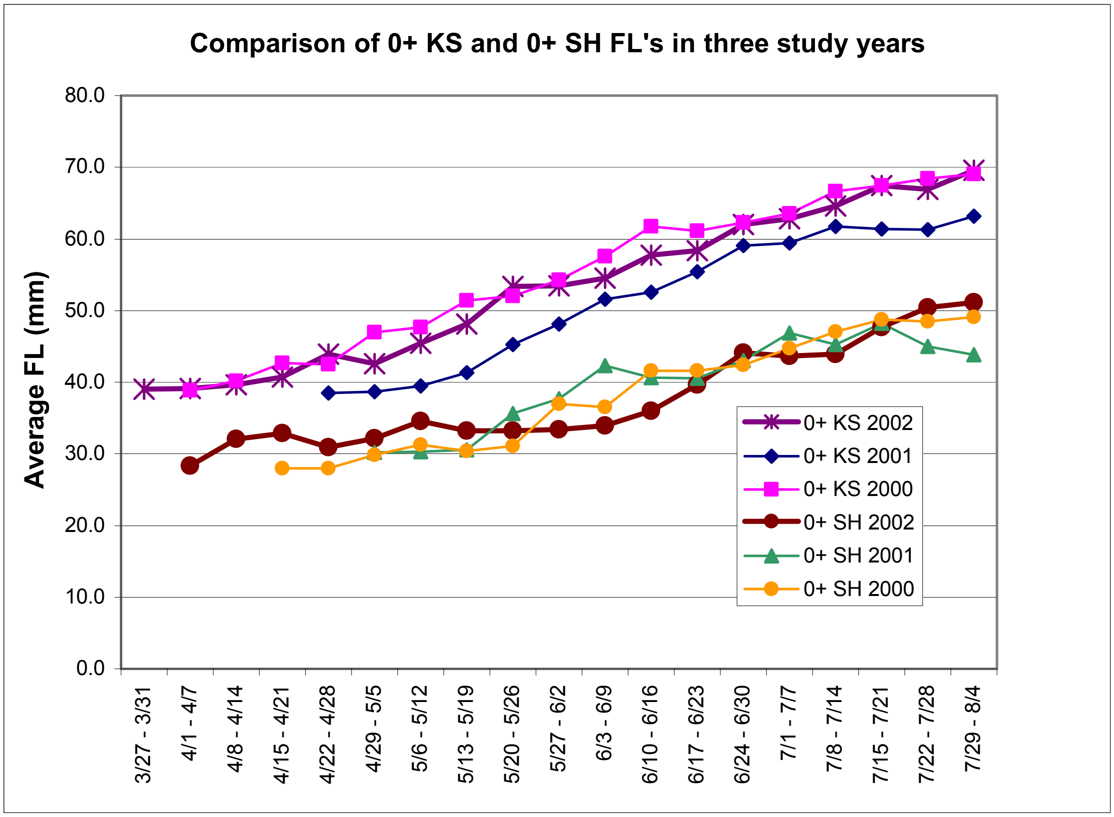

Figure 14. 0+ chinook salmon and 0+ steelhead trout average fork lengths (mm) by week for study years 2002-2000.

The correlation of 1+ steelhead trout average fork lengths (mm) by week and time (week) in 2002 showed no significant relationship was present ($p > 0.05$), unlike in study year 2001 and 2000 when significant positive relationships occurred ($p < 0.01$; $r = 0.61, 0.97$). Fork lengths by week for 2002, 2001, and 2000 were similar until week 10 (5/27 – 6/2), when values diverged (Figure 15). Kruskal-Wallis One Way ANOVA on Ranks determined significant differences existed between study year median fork lengths ($p < 0.001$). Scheffe's Multiple-Comparison tests determined fork lengths in 2002 were significantly less than 2001 and 2000 ($p < 0.05$); the test additionally determined fork lengths in 2000 were significantly greater than 2001 ($p < 0.05$). The difference in average fork length (mm) from the first week of captures and the last week in 2002, 2001, and 2000 equaled 0.00 mm, + 11.8 mm, and + 28.6 mm, respectively.

The correlation of 2+ steelhead trout average fork length (mm) on week showed a significant negative relationship ($p = 0.02$; $r = 0.51$; power = 0.64). In 2001 and 2000, no relationships were found ($p > 0.05$). Average fork lengths by week in all study years show a general trend of starting high in the beginning of the season, decreasing in the middle of the season, increasing towards the end of the season, and decreasing at the very end of the season (Figure 15). It appears that, on average, larger 2+ steelhead smolts out-migrate earlier than others. Near the end of the season (7/1 – 7/14), two year old smolts increase in length, probable due to increases in food availability (eg predation on young of year salmonids, invertebrates, etc). Kruskal-Wallis One Way ANOVA on Ranks determined significant differences between study year median fork lengths ($p < 0.05$). Scheffe's Multiple-Comparison tests determined fork lengths in 2002 were significantly less than 2001 and 2000 ($p < 0.05$); the test additionally determined fork lengths in 2000 were significantly greater than 2001 ($p < 0.05$). The difference in average fork length (mm) from the first week of captures and the last week in 2002, 2001, and 2000 equaled (-) 28.0 mm, (-) 3.0 mm, and (-) 13.8 mm, respectively.

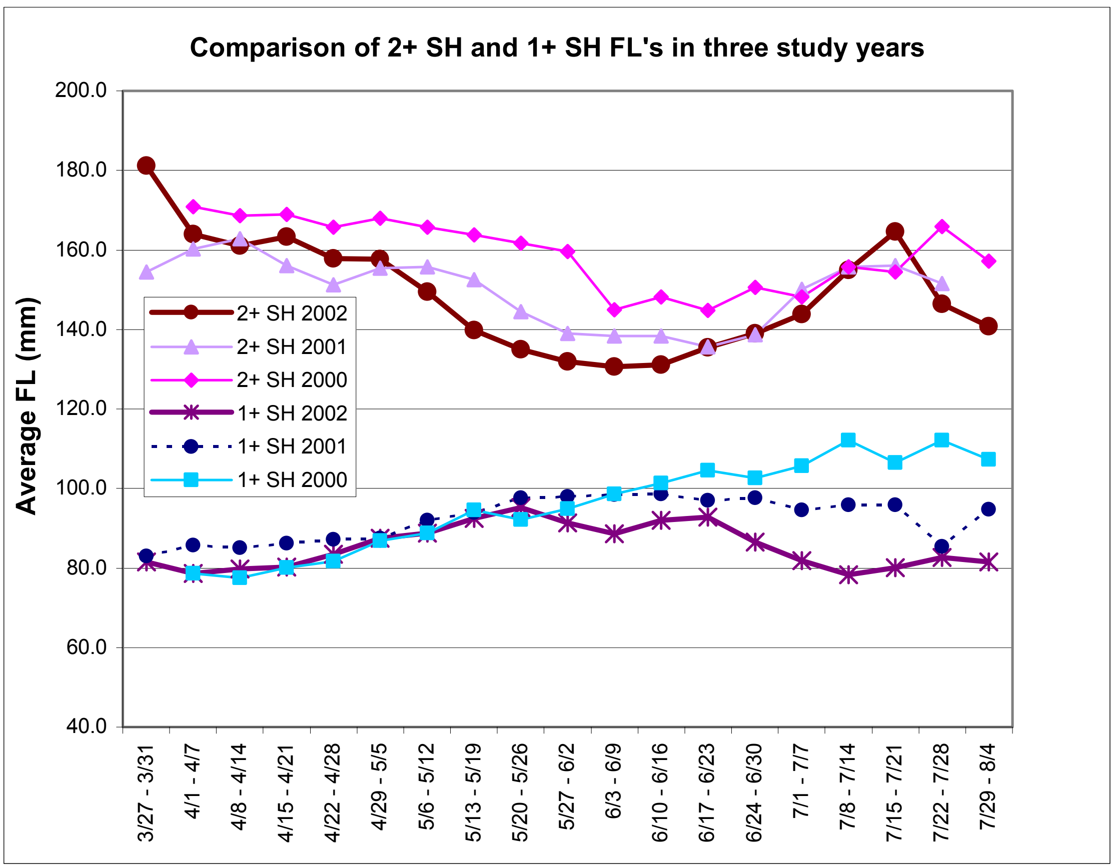

Figure 15. 1+ and 2+ steelhead trout average fork lengths (mm) by week for study years 2002-2000.

The correlation of week number of average weight (g) for 0+ chinook in 2002 showed a highly significant positive relationship ($p = 0.000001$; $r = 0.96$; power = 1.0), similar to data collected in 2001 and 2000 ($p < 0.0001$). Chinook salmon weights steadily increased over time, and indicate growth was taking place in the three study years (Figure 16). 0+

chinook salmon average week weights (g) in 2002, 2001, and 2000 were not significantly different (ANOVA, $p > 0.05$; power = 0.12), similar to fork length relationships. The difference in average weight (g) from the first week of captures and the last week in 2002, 2001, and 2000 equaled + 4.04 g, + 2.14 g, and + 2.80 g, respectively.

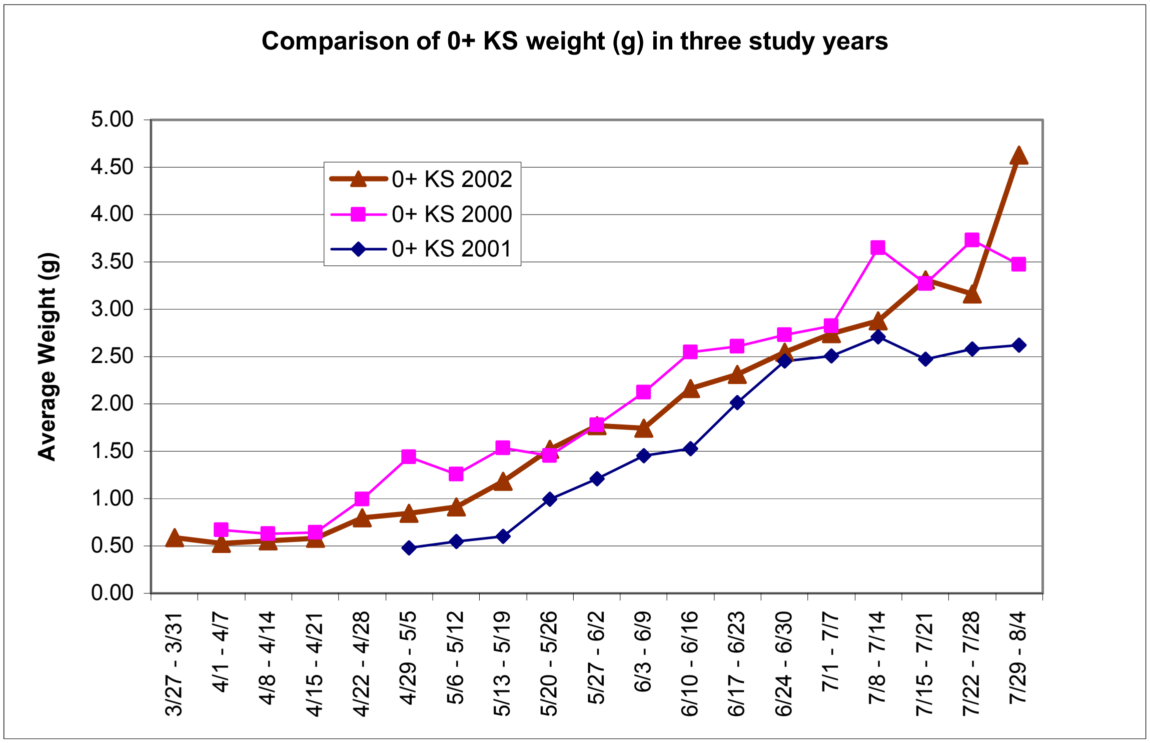

Figure 16. 0+ chinook salmon average weight (g) by week for study years 2002-2000.

The correlation of 1+ steelhead trout average weight (g) by week and time (week) showed no significant relationship was present ($p > 0.05$), unlike in study year 2001 and 2000 when significant positive relationships occurred ($p < 0.01$; $r = 0.62, 0.92$). Weights (g) by week for 2002, 2001, and 2000 were similar until week 11 (6/3 – 6/9)), when values started to diverge (Figure 17). Single factor ANOVA determined significant differences between study year average weekly weights ($p = 0.001$). Scheffe's Multiple-Comparison tests determined weights in 2002 were significantly less than 2001 and 2000 ($p < 0.05$); the test additionally determined weights in 2001 were significantly greater than 2000 ($p < 0.05$). The difference in average weight (g) from the first week of captures and the last week in 2002, 2001, and 2000 equaled (-) 0.74 g, + 4.27 g, and + 11.05 g, respectively.

The correlation of 2+ steelhead trout average weight (g) on week was not significant ($p = 0.07$), similar to 2001 and 2000 weight data ($p > 0.05$). Average 2+ SH weights by week in all study years show the same trend as for fork lengths; however, average weight in 2000 during the decreasing period (valley) spiked upward (Figure 17). The pattern of average weight also suggests larger 2+ steelhead out-migrate earlier than others, however, in July 2002 average weight approached the weight in the first week of April. Kruskal-Wallis One Way ANOVA on Ranks determined no significant differences between study year median weights ($p > 0.05$). The difference in average weight (g) from the first week of captures and the last week in 2002, 2001, and 2000 equaled (-) 28.03 g, (+) 0.35 g, and (–) 12.08 g, respectively.

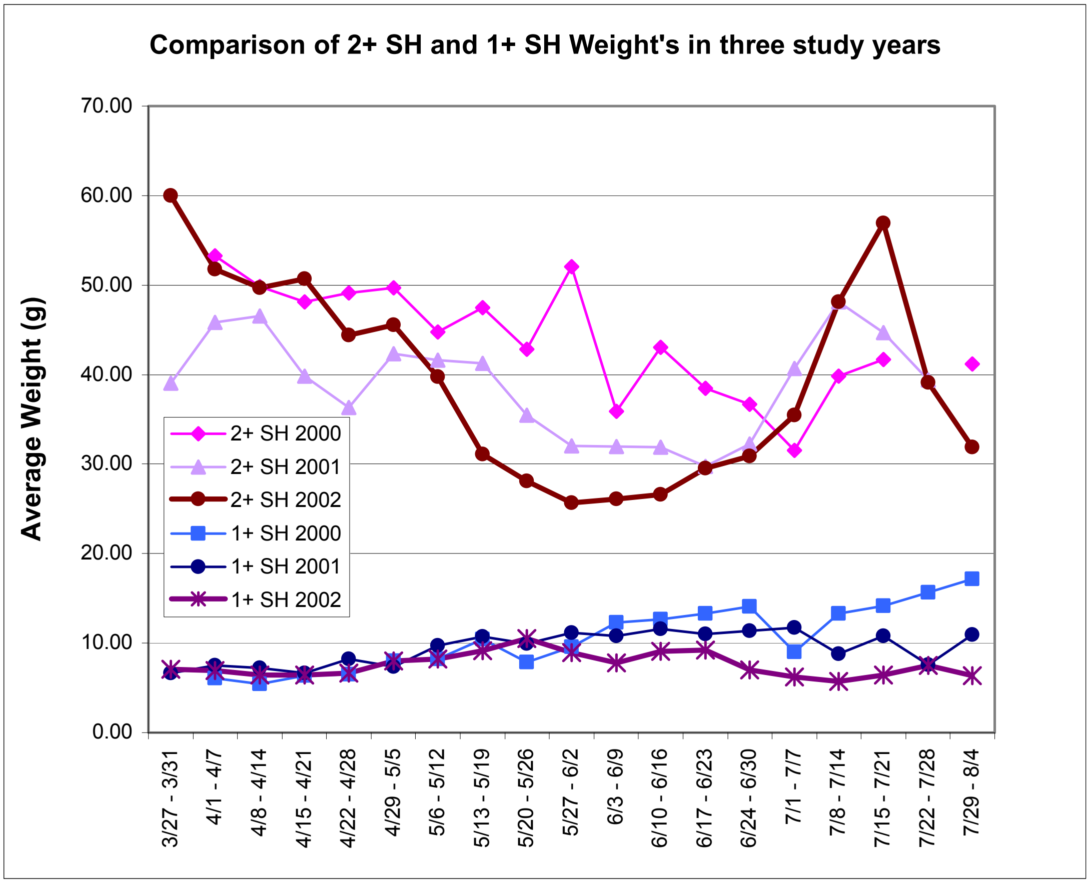

Figure 17. 1+ and 2+ steelhead trout average weight (g) by week for study years 2002-2000.

Developmental Stages

All 1+ and 2+ steelhead trout captured were observed for developmental stages. Few 1+ and 2+ steelhead were in a parr developmental stage in 2002 (Table 9). Differences in developmental stages among study years could be “real” (e.g. differing degrees of smoltification or lack of) or due to variability among observers. Observer variation was minimized by having the same individuals determine developmental stages over the three study years. The most difficult stages to separate are pre-smolt and smolt. The combined percentage of pre-smolt and smolt in 2002 for 1+ steelhead and 2+ steelhead was 98.9 and 100.0%, respectively. For 1+ steelhead, there was a drop from 99% combined pre-smolts and smolt to 94% during week 10, and a drop from 97.8 to 95.8% in week 13.

There was no apparent relationship in 2002 for 2+ steelhead combined pre-smolt and smolt designations with trap catches (i.e. 100% throughout season).

Table 9. Developmental stage for captured 1+ and 2+ steelhead, by study year 2002-2000.

	Developmental Stage (Percentage)					
	1+ Steelhead Trout			2+ Steelhead Trout		
Year	Parr	Pre-smolt	Smolt	Parr	Pre-smolt	Smolt
2002	1.1	91.9	7.0	0.0	53.4	46.6
2001	1.0	84.0	15.0	0.2	37.0	62.8
2000	19.0	59.0	22.0	0.3	13.6	86.1

Trapping Efficiencies

<u>0+ Chinook salmon</u>

We fin clipped and released 4,921 young-of-year chinook salmon upstream of the trap site during 54 efficiency trials. The average number of 0+ chinook salmon used in our weekly trials (includes 3 efficiency trials) was 273, and ranged from 14 – 400 (per week). The majority of recaptures (96%) occurred within one day following release.

Average weekly trapping efficiencies in 2002 (mean = 50.6%, range = 21.4 – 78.6%) were slightly less than 2001 (mean = 55.3%, range = 3.2 – 96.3%); and greater than study year 2000 (mean = 31.3%, range = 5.8 – 56.3%). Overall trap efficiency (combining all mark/recapture data) for 0+ chinook salmon in 2002 was 47.3%, as compared to 52.0% in 2001 and 33.9% in 2000. Weekly trap efficiencies in 2002 were negatively related to the week's average gage height ($p < 0.001$, R2 = 0.78, power = 1.0), similar to study year 2001 ($p < 0.001$, R2 = 0.77, power = 1.0) and 2000 ($p < 0.001$, R2 = 0.58, power = 1.0). Gage height in 2002 explained 78% of the variation in 0+ chinook salmon trap efficiencies. As the gage height (ft) dropped, efficiencies increased.

Trap efficiencies increased over time, and correlation analysis determined a statistically significant positive correlation with week ($r = 0.86$, $p < 0.001$, power = 1.0), very similar to study years 2001 ($r = 0.86$, $p < 0.001$, power = 1.0) and 2000 ($r = 0.84$, $p < 0.001$, power = 1.0).

The majority of fin clipped 0+ chinook salmon released upstream were recovered in the 'correct' strata. Out of 2,329 recaptured fin clipped chinook, only nine (0.39%) were caught in the following week's strata. Expressed as a percentage of total number of marked chinook salmon, the stragglers (n=9) represented 0.16%. Clearly, the assumption of passing the trap site soon after upstream release based upon time of recapture was met.

1+ Steelhead Trout

We fin clipped and released 1,936 one-plus year old steelhead upstream of the trap site during 51 efficiency trials. The average number of 1+ steelhead trout used in our weekly trials was 102, and ranged from 2 – 150 (per week). The majority of recaptures (95%) occurred within one day following release.

Average weekly trapping efficiencies in 2002 (mean = 42.3%, range = 26.7 – 57.0%) were considerably greater than 2001 (mean = 24.0%, range = 0.0 – 46.3%) and 2000 (mean = 16.9%, range = 5.3 – 42.0%). Overall trap efficiency (combining all mark/recapture data) for 1+ steelhead trout in 2002 was 42.5%, as compared to 29.9% in 2001 and 20.0% in 2000.

To test relationships of trap efficiencies with time and gage height, week 18 was not included because only one trial with two fish was conducted. Trap efficiencies decreased over time in 2002, and correlation analysis determined a statistically significant negative relationship with week ($r = 0.53$, $p = 0.02$, power = 0.63), similar to test results in 2001 ($r = 0.68$, $p < 0.001$, power = 1.0) and 2000 ($r = 0.48$, $p = 0.04$, power = 0.55). Weekly trap efficiencies in 2002 were positively related to the week's average gage height ($p = 0.01$, R2 = 0.34, power = 0.74), similar to study year 2001 ($p < 0.001$, R2 = 0.88, power = 1.0) and 2000 ($p < 0.05$, R2 = 0.26, power = 0.58). Gage height in 2002 explained 34% of the variation in 1+ steelhead trap efficiencies. As the gage height (ft) increased, efficiencies increased.

As mentioned in the mark/recapture assumption section of methods, 1+ SH showed straggling more so than 2+ steelhead; however, the amount was very low, and considered negligible. For example, of 822 marked 1+ SH recaptures, 98.9% were captured in the correct strata. Expressed as a percentage of total number of marked steelhead trout, the stragglers (n=9) represented 0.46%. Clearly, the assumption of passing the trap site soon after upstream release based upon time of recapture was met.

2+ Steelhead Trout

Trap modifications (eg re-positioning the trap, weir panels, etc) were generally made to increase 2+ steelhead trap efficiencies. Adequate 2+ SH efficiencies resulted in higher than necessary efficiencies for other species at age. We fin clipped and released 1,038 two-plus steelhead upstream of the trap during 83 efficiency trials. The average number of 2+ steelhead used in our weekly trials (includes 5-6 weekly trials) was 61, and ranged from 1 – 161 (per week). The majority of recaptures (96%) occurred within one day following release.

Average weekly (un-pooled) trapping efficiencies in 2002 (mean = 20.4%, range = 5.6 – 48.8%) were considerably greater than 2001 (mean = 10.9%, range = 0.0 – 20.7%) and 2000 (mean = 11.7%, range = 0.0 – 25.8%). Overall trap efficiency (combining all mark/recapture data) for 2+ steelhead trout in 2002 was 24.4%, as compared to 12.6% in 2001 and 15.9% in 2000. To test relationships of trap efficiencies with time and gage height, week 18 was not included because only one trial with one fish was conducted. Trap efficiencies for 2+ SH in 2002 were more variable than 0+ KS and 1+ SH, and no significant correlation with week was detected ($p > 0.05$, $r = 0.08$, power = 0.19), similar to study years 2001 and 2000 ($p>0.05$).

2+ SH efficiencies were probably much higher in 2002 because we shifted to night releases using an automated timer fastened to a trip door on a live-car. The difference in 2+SH recaptures was readily apparent, with average efficiency for night release trials equaling 22.4%, compared to average day release efficiency of 13.7%. As mentioned in the population estimate assumption section, equal probability of capture between marked and unmarked fish may be difficult to meet with 2+ SH, especially since we have evidence that release times (eg night vs. day) of marked fish can result in different capture probabilities. An inaccurate and low recapture probability will positively bias the population estimate. Unfortunately, we do not know for sure if night vs. day releases would have changed the population estimates in 2000 and 2001. We do know that it did for 2002 data. Data also show that night releases and subsequent recaptures gave more realistic trap efficiencies.

Weekly 2+ SH trap efficiencies in 2002 were not significantly related to the week's average gage height ($p > 0.05$, $R2 = 0.01$, power = 0.07); however, when tested with a dummy variable denoting day (0) or night release (1), significant positive relations were found for 2+ SH trap efficiencies on average week gage height, and night releases ($p = 0.006$, adj. $R2 = 0.44$, power = 0.58). In 2001, trap efficiencies were positively related to gage height ($p < 0.05$), and in 2000, no relationships were found ($p > 0.05$).

The majority of fin clipped 2+ steelhead trout released upstream were recovered in the 'correct' strata. Out of 253 recaptures, only one (0.40%) was caught in the following week's strata. Expressed as a percentage of total number of marked 2+ steelhead trout, the stragglers (n=1) represented 0.10%. Clearly, the assumption of passing the trap site soon after upstream release based upon time of recapture was met.

Population Estimates

<u>0+ Chinook salmon</u>

Comparisons of population model estimates for 2002 data show Carlson et al. (1998), Peterson (Ricker 1975), and Darr (personnel com. Bjorkstedt) gave somewhat similar results (Table 10). I chose to use the Carlson et al (1998) estimate because it is usually more conservative, and has been field tested with a counting fence.

Table 10. 0+ chinook salmon population estimate model comparisons, 2002.

Model	0+ Chinook Salmon
Carlson et al. 1998	518,189 $\pm$ 4.5%
Peterson (Ricker 1975)	521,367 $\pm$ 5.6%
Darr (Bjorkstedt)	497,168 $\pm$ 4.7%

We estimate that 518,189 (95% CI 494,834 – 541,543) 0+ chinook salmon migrated past the trap site in 2002, compared with 378,063 (95% CI 335,290 – 420,835) in 2001, and 427,542 (95% CI 390,096 – 464,988) in 2000 (Figure 22).

Over the three years of study, linear regression/correlation determined a positive relationship of yearly population estimates with time; 0+ chinook salmon population estimates increased from study year 2000 to 2002 (Figure 18). Reasons for the increase could be: 1) more adults spawned above the trap site, 2) spawning and gravel conditions improved over time, 3) better stream survival, or 4) some combination of factors 1 – 3.

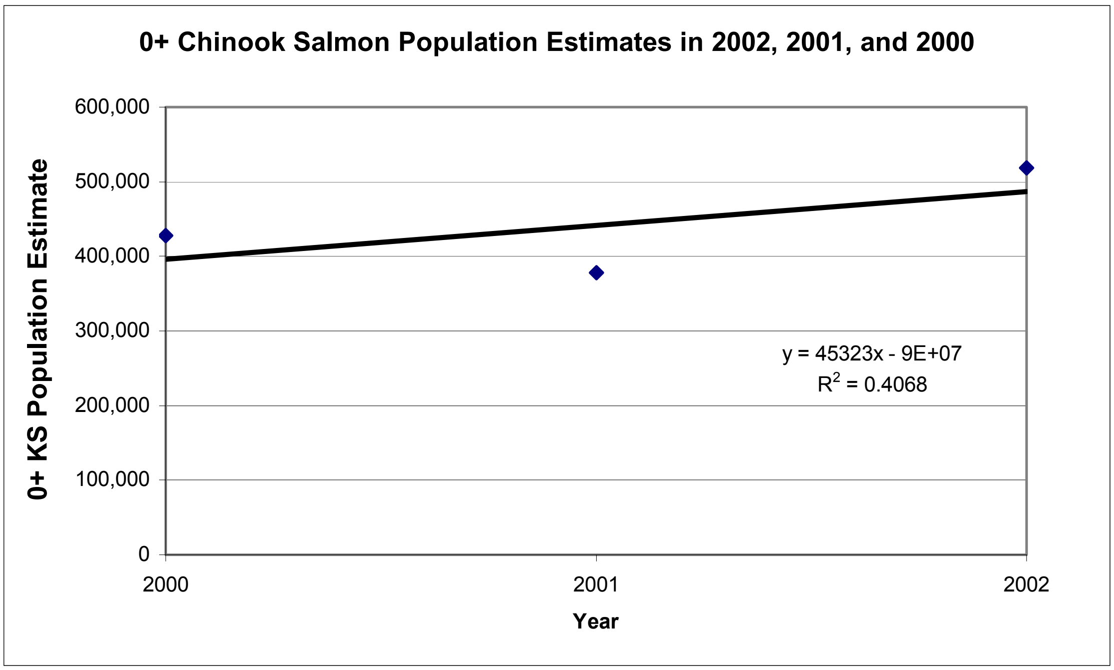

Figure 18. 0+ chinook salmon population estimates for study years 2002, 2001, and 2000.

The total population estimate in 2002 divided by anadromous stream miles (37) and watershed area upstream of the trap site (65,000 acres) equaled 14,005 fish/mi and 8 fish/acre (Table 11).

Table 11. 0+ chinook salmon population estimates divided by anadromous stream miles and watershed area above trap site, 2002-2000.

Study year	0+KS/mi	0+KS/acre
2002	14,005	8
2001	10,218	6
2000	11,555	7

In 2002, April (n = 194,041), May (n = 159,544), and June (n = 149,506) were important months for population out-migration, and accounted for 97.1% of the total population estimate. In 2001, May and June accounted for 98.2% of the 2001 estimate; and in 2000, April, May, and June accounted for 95.8% of the 2000 estimate.

0+ chinook salmon population estimates in 2002 varied over time, with peak out-migration corresponding to 4/8 - 4/14 (n = 64,798), 4/29 - 5/5 (n = 55,221), and 6/3 - 6/9 (n = 73,961). The pattern of population out-migration varied among study years (Figure 19). It should be noted that weekly population estimates in 2002 tracked very well with weekly catches. In 2002 and 2001, out-migration was very low in the beginning of trapping, and in 2000, out-migration was on-going with trap installation. Out-migration by week in 2002 and 2000 was more spread out over time compared to 2001 data. Although there were more peaks in 2002 and 2000 than in 2001, the peak in 2001 (n = 83,278 was higher than other study years. The first peak in 2002 (4/8 - 4/14) was four weeks before the first peak in 2001, and two weeks before the first peak in 2000. In study year 2000, a peak occurred on 6/17 – 6/23, when in 2002 and 2001, no peaks were observed. All three population lines show downstream migration tapered off from 7/8 onward.

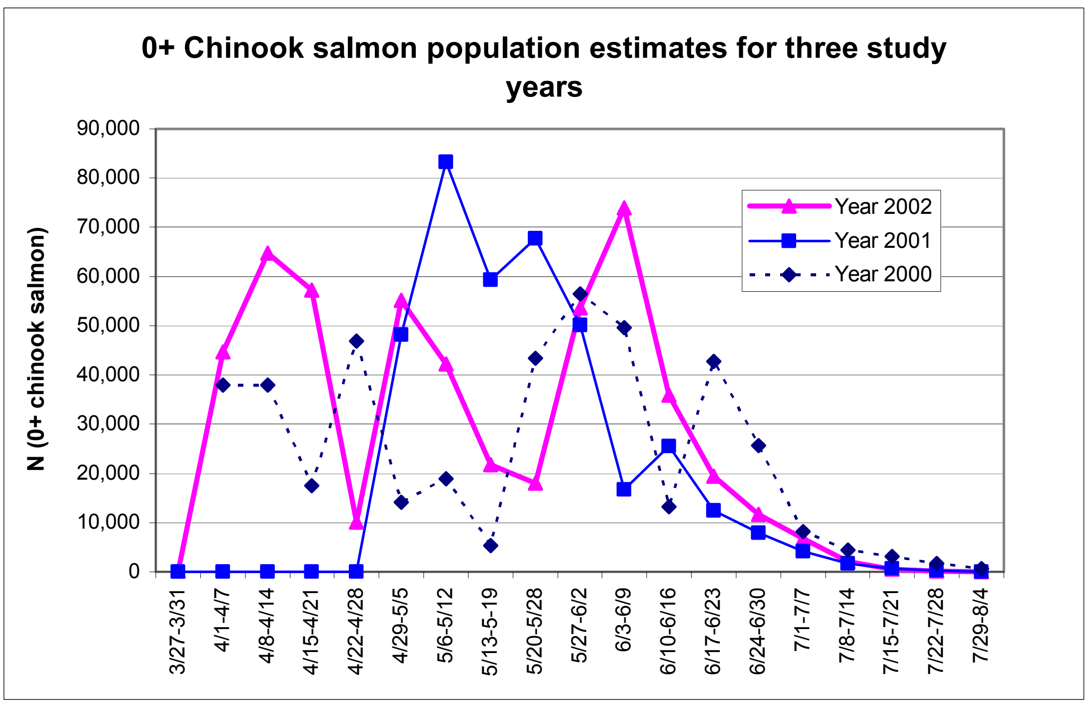

Figure 19. 0+ chinook salmon population estimates by week for three study years.

1+ Steelhead trout

Comparisons of population model estimates for 2002 data show Carlson et al. (1998), Peterson (Ricker 1975), and Darr (personnel com. Bjorkstedt) gave similar results (Table 12).). I chose to use the Carlson et al (1998) estimate because it is usually more conservative, and has been field tested with a counting fence, (albeit with young of year juvenile salmonids).

Table 12. 1+ steelhead trout population estimate model comparisons, 2002.

Model	1+ Steelhead Trout
Carlson et al. 1998	28,501 ± 6.3 %
Peterson (Ricker 1975)	30,200 ± 7.6 %
Darr (Bjorkstedt)	28,772 ± 6.3 %

We estimate 28,501 (95% CI 26,701 – 30,300) 1+ steelhead trout migrated past the trap site in 2002, compared with 50,654 (95% CI 45,571 – 55,736) in 2001, and 68,328 (95% CI 59,055 – 77,601) in 2000 (Figure 20). Over the three years of study, linear regression/correlation determined a negative relationship with time; 1+ steelhead population estimates decreased from study year 2000 to 2002. Reasons for the decrease could be: 1) less recruitment to one year old age because high numbers of young of year steelhead out-migrated the year before, 2) less habitat space for rearing due to decreases in stream discharge, 3) reduced habitat quality within study years, and 4) some combination of factors 1-3.

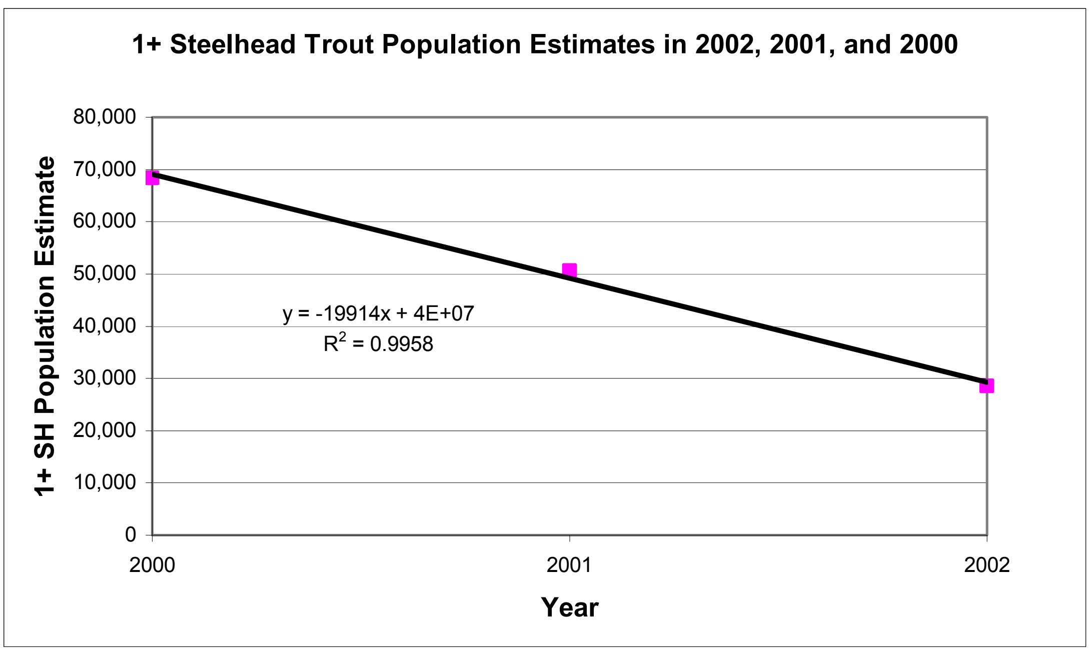

Figure 20. 1+ steelhead trout population estimates for study years 2002, 2001, and 2000.

The total population estimate in 2002 divided by anadromous stream miles (37) and watershed area upstream of the trap site (65,000 acres) equaled 770 fish/mi and 0.44 fish/acre (Table 13).

Table 13. 1+ steelhead trout population estimates divided by anadromous stream miles and watershed area above trap site, 2002-2000.

Study year	1+SH/mi	1+SH/acre
2002	770	0.44
2001	1,369	0.78
2000	1,847	1.05

In 2002, May (n = 17,572), and June (n = 5,472) were important months for 1+ SH population out-migration, and accounted for 80.9% of the total population estimate. In 2001, April and May accounted for 74.9% of the 2001 estimate; and in 2000, April, May, and June accounted for 97.0% of the 2000 estimate.

The pattern of population out-migration by week varied among study years (Figure 21). 1+ steelhead population estimates by week in 2002 show a bell shape curve distribution, with two noticeable peaks occurring 5/13 – 5/19 (n = 4,620) and 5/27 – 6/2 (n = 4,221). In 2002 out-migration was very low in the beginning of trapping, and in 2000 and 2001, some out-migration was on-going prior to trap installation. Weekly out-migration in 2002 was considerably less than study years 2001 and 2000. The first peak in 2002 occurred three weeks after the first peak in 2001, and one week after the first peak in 2000. The second peak in 2002 occurred at the same time for the second peak in 2001, and both were one week later than the second peak in 2000. All three population lines show population out-migration tapered off from 7/1 onward.

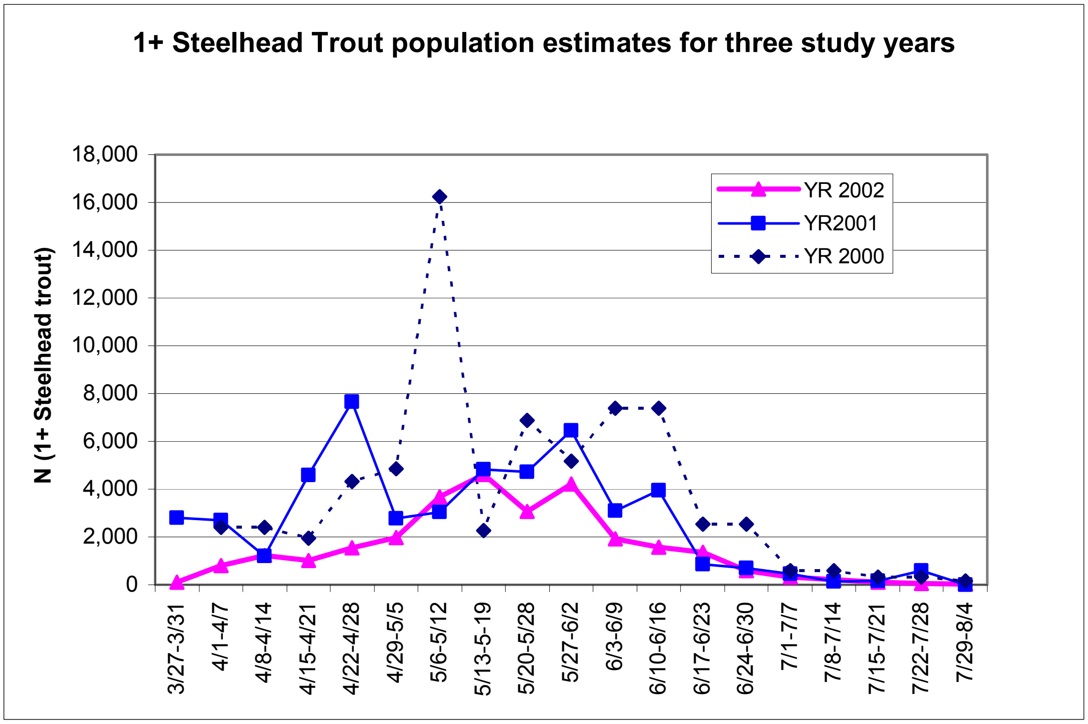

Figure 21. 1+ steelhead trout population estimates by week for three study years.

2+ Steelhead Trout

A chi-square test determined weeks A and 1, and 3 and 4 trap efficiency data could be pooled ($p > 0.05$). Weeks A and 1, and 3 and 4 were combined (A-1, 3-4) because pooling reduced an otherwise inflated population estimate for those periods. Pooling these weeks decreased the total population estimate by 851 fish, and the 95% CI by 7%. There was no need to pool other weeks because trap efficiencies were acceptable (> 10%). Comparison of population model estimates for 2002 data show Carlson et al. (1998) was more conservative than the Peterson (Ricker 1975) and Darr (Bjorkstedt pers. com.) estimates (Table 14). Closer inspection of the Darr estimate showed the program failed to pool weeks 3 and 4, which probably caused the positive bias to the population estimate, with wider 95% CI's. However, all population point estimates fell within the confidence intervals of any given model. I chose to use the Carlson et al (1998) estimate because it is usually more conservative, and has been field tested with a counting fence, (albeit with young of year juvenile salmonids).

Table 14. 2+ steelhead trout population estimate model comparisons, 2002.

Model	2+ Steelhead Trout
Carlson et al. (1998)	7,370 ± 14.7 %
Peterson (Ricker 1975)	8,286 ± 14.1 %
Darr (Bjorkstedt)	9,006 ± 26.1 %

The total 2+ steelhead trout Carlson et al. (1998) population estimate over the course of the trapping period in 2002 equaled 7,370 (95% CI 6,286 – 8,455), compared to 12,668 (95% CI 9,786 – 15,550) in 2001, and 4,739 (95% CI 3,669 – 5,808) in 2000 (Figure 22). Over the three years of study, linear regression/correlation determined a positive relationship with time; 2+ steelhead population estimates increased from study year 2000 to 2002 (We currently need more data to assess this apparent increase).

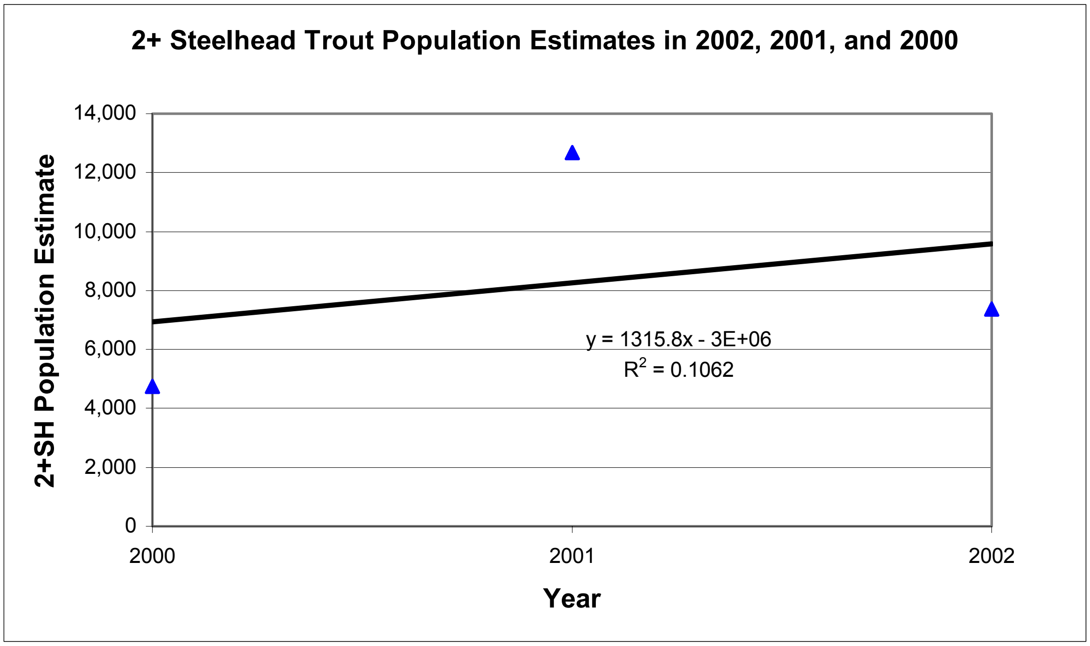

Figure 22. 2+ steelhead trout population estimates for study years 2002, 2001, and 2000.

The total population estimate in 2002 divided by anadromous stream miles (37) and watershed area upstream of the trap site (65,000 acres) equaled 199 fish/mi and 0.11 fish/acre (Table 15).

Table 15. 2+ steelhead trout population estimate divided by anadromous stream miles and watershed area above trap site, 2002-2000.

Study year	2+SH/mi	2+SH/acre
2002	199	0.11
2001	342	0.19
2000	128	0.07

In 2002, April (n = 2,956), and May (n = 2,508) were the important months for 2+ SH population out-migration, and accounted for 74.1% of the total population estimate. In 2001 and 2000, April and May were also important months for population out-migration; and accounted for 66.8% and 76.2%, respectively, of the total population estimates. In 2002 and 2001, June accounted for 18.4%, and 23.0%, respectively.

The pattern of population out-migration by week varied among study years (Figure 23). 2+ steelhead population estimates in 2002 were in-between population estimates in 2001 and 2000. Out-migration in 2000 was high in the beginning of trapping, and in 2002 and 2001, out-migration increased weeks after trap placement. The highest peak in 2002 (5/13 - 5/19) occurred two weeks before the highest peak in 2001, and five weeks after the first peak in 2000. Except for week 7/15 – 7/21 in 2001, out-migration tapered off from 7/8 onward.

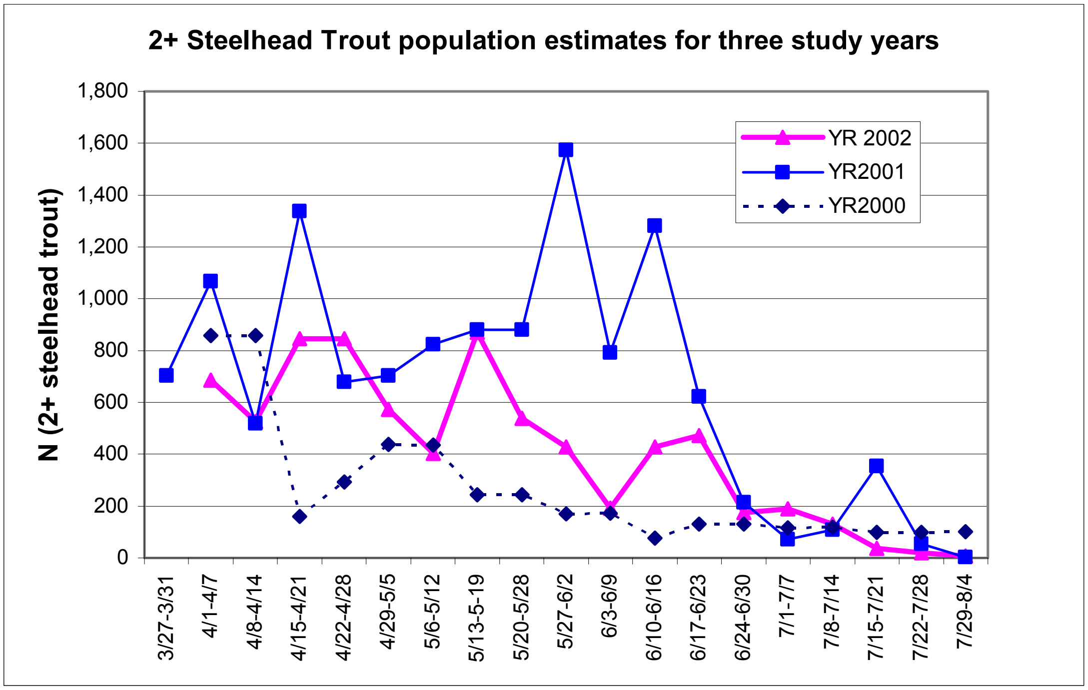

Figure 23. 2+ steelhead trout weekly population estimates for three study years.

Additional Experiments

Zero of the 20 marked 2+ steelhead released downstream of the trap site were captured by the rotary screw trap a second time.

Ten snorkel surveys were conducted upstream of the trap site to determine if any efficiency fish held over from one strata (week) to the next; only one fish was observed with a clip, and it fell within the correct strata. Snorkel survey results indicate efficiency fish were passing the trap site within the correct strata.

We did not re-capture any of the 374 1+ steelhead that were given elastomer marks in 2001. Although the sample size was small, results indicate that these fish did not travel back upstream of the trap site (in 2001 or 2002) to be later recaptured as 2+ steelhead in 2002.

Chi-square statistical tests showed re-capture of 0+ chinook salmon and 1+ steelhead trout released in the day or night upstream of the trap site did not differ ($p > 0.05$). The percent re-capture of 0+ chinook salmon released upstream of the trap in the day was 52%, compared with 56% for night releases. Percent re-capture of 1+ steelhead released in the day was 54%, and for night release was 44%.

Zero percent of the 24 hr delayed mortality study fish died from fin clipping or handling (Table 16). Study results also show these fish were able to withstand stream temperatures as high as 21 ^{o}C for the 24 hr period.

Table 16. Delayed mortality test results, 2002.

				# Fin clipped		# Handled	
Date	Spp.	(n)	Ave. Temp C	Morts/total	Percent Mortality	Morts/total	Percent Mortality
4/14 – 4/15	0+ KS	50	10.80	0/50	0.00	-	-
6/13 – 6/14	0+ KS	60	18.30	-	-	0/60	0.00
7/14 – 7/15	0+ KS	50	21.34	0/50	0.00	-	-
4/09 – 4/10	1+ SH	30	11.71	-	-	0/30	0.00
5/17 – 5/18	1+ SH	25	13.45	0/25	0.00	-	-
6/13 – 6/14	1+ SH	50	18.30	0/50	0.00	-	-
6/19 – 6/20	1+ SH	50	18.07	0/50	0.00	-	-
7/14 – 7/15	1+ SH	8	21.34	0/8	0.00	-	-
7/17 – 7/18	1+ SH	9	21.29	0/9	0.00	-	-
7/29 – 7/30	1+ SH	12	21.85	0/12	0.00	-	-
7/30 – 7/31	1+ SH	3	21.90	0/3	0.00	-	-
5/02 – 5/03	2+ SH	16	11.52	0/16	0.00	-	-
6/13 – 6/14	2+ SH	7	18.30	0/7	0.00	-	-
6/19 – 6/20	2+ SH	11	18.07	0/11	0.00	-	-
7/17 – 7/18	2+ SH	1	21.29	0/1	0.00	-	-
7/29 – 7/30	2+ SH	2	21.85	0/2	0.00	-	-

Trapping Mortality

The mortality of fish that were captured in the trap and handled was closely monitored over the course of the trapping period. Mortality by species at age ranged from 0.00 – 0.51%, and using all species was 0.41% of the total juvenile salmonid catches (Table 17). The larger, modified livebox and removing debris from the livebox at night helped minimize trap mortalities.

Table 17. Trapping mortality for juvenile salmonids, 2002.

Age/Species	Number captured	Number of mortalities	Percent mortality
0+ steelhead	124,426	632	0.51%
1+ steelhead	12,217	6	0.05%
2+ steelhead	1,589	0	0.00%
0+ chinook	223,167	842	0.38%
1+ chinook	18	0	0.00%
Cutthroat trout	9	0	0.00%
Total:	361,426	1,480	0.41%

DISCUSSION AND RECOMMENDATIONS

This was the third consecutive year of a study designed to quantify the numbers of out-migrating juvenile salmonids in upper Redwood Creek, Humboldt County, California.

This is a very exciting study because as we continue to collect data over multiple years, we will be able to detect trends in downstream migrating juvenile salmonid abundance with good degrees of confidence. We attribute the success of this project to a near perfect trapping site, a very dedicated crew, and methods that are carefully planned and carried out. The upper Redwood Creek study can provide valuable, and often unattainable information that can be used to assess status and trends of juvenile steelhead trout and chinook salmon upstream of the trapping site. I therefore recommend the study be carried out for as many consecutive years as possible (10+ years) to encompass as much environmental and biological variability as possible. Examples of environmental variability among study years may include: watershed and riverine conditions, hydrology, and climatic conditions such as El Nino, La Nina, and Pacific Decadal Oscillations. Biological variation among study years may result as a response to environmental variability over time.

Although I could just analyze data on the population level, I chose to include catch data because not all downstream migration trapping can produce realistic population estimates. In such cases, actual catches may prove more meaningful for comparison to other data sets than a high population estimate with wide confidence intervals. Assessing whether a population estimate is realistic involves more than observing the width of a confidence interval; the careful investigator must somewhat subjectively decide if a given efficiency is reasonable. If the investigator just plugs the data into a population model without any *a priori* knowledge of the trap site and configuration, then model input and output errors can occur, unless the model allows for user flexibility (ie Carlson et al. 1998; Peterson from Ricker 1975). Fortunately with the Redwood Creek study, efficiencies are usually good and believable. In relatively rare cases when efficiencies are unrealistically low, pooling is used to crop the positively biased population spike, after statistical tests are run to show pooling is allowed (Carlson et al. 1998). On the other hand, if a given trap is in a very large river system (Klamath, Trinity, etc), trapping efficiencies are expected to be low because the trap can only catch a small portion of the river.

0+ Chinook Salmon

Catch data of 0+ chinook salmon in 2002 (n = 223,167) was considerably higher than catches in 2001 (n = 120,692) and 2000 (n = 123,633), and definitely suggests either more chinook salmon adults spawned above the trap site in 2001/02 spawning season, or redd and stream survival was higher in 2002 compared to previous study years. Trap efficiencies in 2002 for 0+ chinook salmon were slightly lower than in 2001, therefore, the increase in catches was not due to "better or more efficient trapping".

Three noticeable groupings of chinook salmon catches are discernable in the catch distribution in 2002. This pattern is not necessarily attributable to different run and spawning timing of adult chinook in 2001/02 because juvenile fish in later groups were larger than the earlier groups. The later migrating juvenile chinook salmon could have emerged from redds near the same time as earlier out-migrants, and stayed above the trap site, growing as time went by.

The period of out-migration between study years was markedly different; in 2002, catches were spread out over more of the season compared to 2001 and 2000 data. In 2001, catches were more compressed over time than 2002 and 2000. Based upon the low discharge within the trapping period in 2002, I initially suspected out-migration would be compressed, similar to 2001 data; however, the 'wet' winter in 2001/02 most likely allowed for further upstream migration by spawning adults, which could translate to a longer time period for some of the juveniles to reach the trap site. Nevertheless, 0+ chinook catch data for all study years shows April, May, and June are important months for out-migration. Using all three years of catch data, June was the most important month for out-migration, and represented 43% of total catches.

The length (mm) and weight (g) of 0+ chinook salmon significantly increased over the course of time within each study year ($p<0.05$), and indicates growth occurred. We currently do not know what constitutes the diet of young of year chinook in upper Redwood Creek. One individual with a very large stomach that died in the livebox was dissected to reveal 25+ small mayfly nymphs. On average, increases in average weekly length (mm) and weight (g) in 2002 (+ 36mm, + 4.04 g) were greater than in 2001 and 2000. The overall average fork length in 2002 was slightly greater than 2001 data (+ 0.5 mm) and less than 2000 data (- 3.1 mm); average weight in 2002 was less than 2001 average weight by 0.03 g and less than 2000 data by 0.27 g. These differences were not statistically significant (ANOVA, $p>0.05$) and in addition, probably will not have an overall biological effect on survival to adulthood.

<u>0+ Chinook Salmon Population Size</u>

Trap efficiencies for 0+ chinook salmon in 2002 were slightly less than 2001 because we used a pipe trap for a longer period of time in 2001. Efficiencies in 2002 were greater than 2000 because of lower flows in 2002 compared to 2000. Within the three study years, gage height explained 58 – 78% of the variation in 0+ chinook trap efficiencies. The recapture of marked chinook salmon in 2002 occurred within the correct strata, and provided more evidence that the assumption of marked fish passing the trap site within the correct strata was met. Additionally, marked fish were released into calm water upstream of the trap site within ten feet of the streambank. Marked fish had to actively migrate from calm water to the river current, and then downstream to the trap site. The probability that migration was passive was ruled out due to release site, and high recaptures which generally occurred one day after release.

The trend of the 0+ chinook salmon population out-migrating over the three study years was positive. Similar to catch data, the population estimate in 2002 was considerably higher than 2001 estimate. The population in 2002 was about 37% (or 140,126 individuals) higher than the 2001 estimate, and about 21% (or 90,647) higher than the 2000 estimate. Differences in estimates among years could be due to: 1) variation in the number of adults spawning upstream of the trap, 2) variation in redd survival, 3) variation in stream survival, and 4) some combination of factors 1-3. I speculate the juvenile population increase was due to an increase in adult spawners above the trap site because positive changes to habitat probably take more than a couple of years to occur.

Similar to catch distributions over time, population out-migration by week varied among study years. Population out-migration in 2002 showed discernable peaks in April, May, and June, similar to catches by week. The highest out-migration in any given week equaled 73,961 $\pm$ 12%, and occurred 6/3/02 – 6/9/02. For all three study years combined, May and June were the most important months for population out-migration, and accounted for 71% of the estimated 1,323,793 individuals. I therefore recommend in-stream structures (eg. summer dams) should not be placed in upper Redwood Creek during May and June. The three study years' population estimates by week show that 0+ chinook salmon downstream migration tapered off from July 8 onward.

1+ Chinook Salmon

Eighteen yearling chinook salmon were caught in 2002 from time of trap installation on 3/27/02 through 5/6/02. The majority of captures occurred in April 2002. It is unknown how many were in the upper Redwood Creek system because peak emigration could have occurred before trapping commenced (eg February). In 2001, 21 1+ chinook salmon were caught, with the last individual captured on 5/5/01.

Fork lengths (mm) were originally used to separate the 1+ chinook from 0+ chinook salmon. Fork length (mm) differences between 0+ and 1+ chinook salmon in 2002 were readily apparent (1+ range 70 to 148 mm, mean = 109 mm; 0+ chinook range 34 to 60, mean = 42 mm) during the same capture periods. In 2002, 1+ chinook salmon were on average larger (FL_{mean} = 109mm; Wt_{mean} = 42 g) than 1+ chinook salmon in 2001

(FL_{mean} =104mm; Wt_{mean} = 29 g). Scale annuli were positively identified in the larger 'stream type' chinook salmon juveniles, and supported age determination using fork lengths.

The 1+ stream life history pattern may be important for increased ocean survival, and general species diversity. Although in coastal streams the 1+ chinook salmon juvenile life history appears relatively rare, 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 SRAMP out-migrant studies on the Mad River in 2002 and 2001 also report captures of 1+ chinook salmon (Sparkman 2002).

0+ Steelhead Trout

0+ steelhead trout catches in 2002 (n = 124,426) were higher than catches in 2001 (n = 102,408), and considerably higher than catches in 2000 (n = 55,126). Large numbers of 0+ steelhead trout were also observed in stream margins near the trap site, and in the later part of the season 0+ steelhead were observed using thermal refugia where sub-gravel water entered the stream. Periods of increased downstream migration in 2002 occurred in May, June, and July, which collectively accounted for 98% of captures. Combining all study year data (2002-2000), June (47%) and July (28%) accounted for 75% of the total catch of 281,960 individuals. Catches dropped considerably from late July to early August in the three study years. Population estimates were not made for young-of-year steelhead because: 1) many are too small to effectively mark without harming the fish, and 2) their movements are considered stream re-distribution, and not migration to the estuary and ocean.

Increases in year to year catches may be attributable to: 1) increases in adult steelhead spawning above trap site, 2) good redd gravel conditions, 3) reduced carrying capacity of stream habitat due to lower flows and possibly increased temperatures, which could 'force' fish downstream, 4) passive downstream migration or 5) some combination of factors 1, 2, 3, and 4. Catches of 0+ steelhead in a given year may influence catches of 1+ steelhead the following year. If the 0+ steelhead do not re-migrate upstream of the trap site, then fewer 1+ steelhead will be produced (assuming 1+ SH carrying capacity is not met).

The large numbers of 0+ steelhead trout redistributing in a downstream manner May through July suggest over-summer electro-fishing densities of 0+ steelhead would be inaccurate with respect to how many fish were produced in a given locale. In conjunction with hydrology and the life history of redistribution, numbers electro-fished during June, July, and August would not include those that have previously migrated downstream. The over-summer densities would be a measure of habitat carrying capacity at that time and place. To project from the density of fish captured in small tributaries to adults that produced them could have serious flaws because of these accounting errors. To project forward (i.e. from 0+ steelhead densities to adult steelhead) would be tenuous at best because of high mortality often associated with young of year fish. Additionally, the lack of including 0+ steelhead that out-migrated prior to sampling would once again be an accounting error.

1+ Steelhead Trout

Catch data for 1+ steelhead trout in the three study years ranged from 12,217 – 14,775, and suggest stability, when in fact population data shows a negative trend. Daily catches were positively related to stream gage height (ft) in the three study years ($p < 0.05$), and indicate more 1+ steelhead moved downstream during higher flow events. April and May were months of greater downstream migration for the three study years, and accounted for about 79% of the total catch (n = 39,255). The weekly peak catch in 2002 occurred three weeks later than the peak in 2001, and two weeks later than the peak in 2000. The 1+ steelhead catch distribution in 2002 approximated a bell shaped curve, and suggest the trapping period covered significant out-migration. In addition, the peak catch by week in 2002 occurred about seven weeks after trap placement. 1+ steelhead catches dropped considerably from July 1 onward in all study years.

1+ steelhead median fork length among study years was significantly different. The length of 1+ steelhead in 2002 (86.7 mm) was less than 2001(91.9 mm), which was less than 2000 (92.4 mm) ($p<0.05$). A difference of 5 millimeters may have an affect on survival, but really more data and research is needed.

<u>1+ Steelhead Trout Population Size</u>

Trap efficiencies for 1+ steelhead were considerably higher in 2002 than 2001 and 2000. Based upon the three years of data, there appears to be an upper and lower limit of gage height and 'good' trap efficiencies for 1+ steelhead. Trap efficiencies and gage height were positively related for all study years ($p < 0.05$; 2002 R2 = 0.34; 2001 R2 = 0.88, 2000 R2 = 0.26). Trap efficiencies for the three study years also significantly decreased over the trapping period, probably due to decreasing flows ($p<0.05$). The majority of marked fish recaptures in 2002 occurred within the correct strata, and provided more evidence the assumption of marked fish passing the trap site within the correct strata was met. In addition, snorkel survey dives did not observe marked fish residing above the trap after release.

The trend of 1+ steelhead trout population out-migration over the three study years was negative. Population data is considered to reflect the 'true' trend of 1+SH numbers, unlike catch data. The population in 2002 was about 44% (or 22,153 individuals) less than the 2001 estimate, and about 58% (39,827 individuals) less than the 2000 estimate. Differences among years could be due to a variety of factors such as: 1) number of adults that produced the cohorts, 2) survival from egg to emergent fry, 3) the number of 0+ fish that left upper Redwood Creek the prior year, 4) over-summer survival, 5) over winter survival, and 6) some combination of factors 1-5. Although more data is required to answer why the population is decreasing, it could be due to increasingly more 0+ steelhead leaving upper Redwood Creek in the previous study year(s).

The graphical lines of population out-migration by week suggest the trapping periods covered the majority of downstream migration in 2002-00. Similar to catch distributions, the months of April and May were very important times for population migration, and accounted for 78% (YR 2002), 75% (YR 2001) and 68% (YR 2000) of the population estimates. In 2002 and 2000, June was also an important time of population out-migration (e.g. 21% and 29 %, respectively). Using all years' population data combined, April and May accounted for 71% of the estimated 147,143 individuals.

The three years' population estimates by week show downstream migration tapered off by July 1. Large numbers of 1+ steelhead emigrating in April and May (prior to over-summer electro-fishing studies) would not be included in electro-fishing surveys conducted in July or August. The number of 1+ steelhead encountered during those times may not reflect the true numbers originally present in that habitat, reach, or stream.

Adult steelhead scale analyses are recommended to determine the freshwater age of returning adults in upper Redwood Creek. Currently we are unsure what percentage of the 1+ steelhead trout are actually entering the ocean. In 2002, we collected two adult steelhead carcasses in Redwood Creek, one of which had entered the ocean as a 1+ steelhead. Although not a large percentage, one study reports that eight percent of the returning adults of a given sample (n = 116) had spent one year in freshwater as juveniles (Shapovalov and Taft 1954). We also know that 1+ steelhead are present in the Redwood Creek estuary during summer sampling (Dave Anderson pers. comm.). Further recommendations include marking 1+ steelhead with elastomere to determine if any are caught the next season as two-year-old fish. In 2002, none of the 374 1+ steelhead trout marked with elastomere in 2001 were caught.

2+ Steelhead Trout

The number of 2+ steelhead may very well be the most important group of juvenile steelhead that contribute to future adult populations.

Catches (within the study years) were positively related to stream gage height (ft) ($p < 0.05$), and generally indicate more 2+ steelhead migrated downstream during higher flow events. April and May were months of greater downstream migration in 2002, 2001, and 2000, and accounted for 78, 64, and 81% of total catches, respectively. In 2001, March, June, and July were also important months. Using all years' catch data combined, April and May accounted for 74% of the total, with the greatest catches occurring in May (39%). Weekly peak catches were variable over study years. The largest peak catch in 2002 was four weeks after the largest peak catch in 2001, and five weeks after the largest peak catch in 2000. 2+ steelhead catch data in 2002 approximated a bell shape curve distribution, and suggests the trapping period covered the majority of out-migration. In addition, the peak catch by week in 2002 occurred seven weeks after trap placement. Catch data in 2001 and 2000 was skewed to the right, and suggested some out-migration occurred prior to the trapping period. 2+ steelhead catches in all study years dropped considerably from July 15th onward, except for 2001 when catches spiked upward during 7/15-7/21. Dependent upon stream flows, installing and operating the trap in February or early March is highly recommended for a potentially more complete estimate. In 2002, we planned on trapping in early March, however, snow melt and rain, with subsequent high flows, prevented trap installation.

Average fork lengths in 2002 significantly decreased over time, unlike 2001 and 2000 data when no significant changes occurred. In 2002, 2001, and 2000, weight did not significantly change over time. Median fork lengths among study years were significantly different; median fork lengths in 2002 were 5.6 mm less than 2001, which were 8.6 mm less than 2000. We currently do not know if these statistical differences will have biological meaning. No significant differences in weight were found among study years.

2+ Steelhead Trout Population Size

2+ steelhead trap efficiencies in 2002 were nearly twice the efficiencies in 2001 and 2000. Reasons for the increase could be because peak flow events in 2002 were less than other study years, and also because in 2002, efficiency fish were released at night. Night releases of efficiency fish were most likely the reason for better trap efficiencies. Differences in recapture rates among night and day released 2+ steelhead were readily apparent; with much higher and more realistic efficiencies for night releases.

The population model assumption of equal probability of capture between marked and un-marked fish is likely to be the most important assumption to meet, especially with 2+ steelhead. Put another way, the recapture rate of marked fish needs to be very close to the recapture rate of un-marked fish. Population models (eg Darr) that attempt to correct for the assumption of fish not passing the trap site within the correct strata, are trying to fix a problem that does not exist to any large degree with our rotary screw trap data because the large majority of recaptures occurs within the correct strata. Additionally, in 2002, snorkel survey dives confirmed efficiency fish were not staying above the trap site. In the 2001 data set, Darr produced an estimate that was 1.6 times higher than Carlson et al. (1998) and Peterson (Ricker 1975), and with much wider confidence intervals. The higher Darr estimate was likely due to the 12 stragglers (or 8.7% of total recaptures) caught out of the correct strata. Biologically, it seemed unreasonable that 12 fish could account for 7,486 more fish than Carlson et al. (1998) and Peterson (Ricker 1975) when trap efficiencies were above a 10% average, and errors in the field (e.g. incorrect fin clipping, incorrectly recording fin clip type) were potentially possible. Additionally, it seemed un-likely that 20,000 2+ steelhead (Darr 2001 estimate) could migrate past the trap site with only 1,360 captured. The best model to use for 2+ steelhead will take time to determine. Besides being statistically sound, the model must be reasonable and believable with respect to field observation and experience.

Currently, the best 2+ SH model appears to be Carlson et al. (1998) because it allows for fine tuning by the researcher, produces the most conservative 2+ steelhead population estimate, and has been field tested (albeit with a different juvenile salmonid) with a downstream counting weir. The point of fine tuning by the observer warrants further discussion. Darr does not allow for fine tuning based upon trapping experience with regard to believable efficiencies and catches. The observer simply plugs in the data, and

Darr produces an estimate which uses ranking, algorhythms, and iterations. The model does not know what is 'real' and 'believable' based upon the researcher's experience, type of trap used, trap configurations, and current flow regimes. Carlson et al (1998) and Peterson (Ricker 1975) allow the user to pool weeks (strata) if efficiencies are unrealistically low. By pooling a 'bad' efficiency week with a 'good' efficiency week, the positive bias can be reduced. For example, in 2002 week #3, 2+SH efficiency was unrealistically low; week 2 efficiency was 18% and week 3 dropped to 6%. Based upon a relatively steady hydrograph, trap efficiencies should not have changed that much, and most likely, the assumption of equal probability of capture for marked and un-marked fish was violated to some degree. Darr did not pool weeks 3 and 4, and instead produced an unbelievable week 3 estimate of about 2,300 fish. The trap caught 108 individuals in week 3. Based upon stable flows, and a trap through which most of the water flowed, I found it very unlikely that 2,300 fish could have passed the trap with only 108 catches. The biased estimate in week 3 was probably why the Darr total estimate was higher than other models in 2002. By using the Carlson et al. (1998) model, I was able to run statistics (Chi-square) to show pooling was allowed (weeks 3 and 4); and produced an estimate of about 1,694 individuals for weeks 3 and 4 combined. This does not really fix the problem (which no model to date can); however, it does minimize the bias, and that is the best we can currently do in such cases. Although there was once again model output discrepancy between Darr, and Carlson et al. (1998) and Peterson (Ricker 1975) in 2002, all population model point estimates for 2+SH fell within confidence intervals of any given model.

The overall trend of 2+ steelhead population out-migration over the three study years (using Carlson et al. 1998 estimates) was positive. The population estimate in 2002 was 42% (or 5,296 individuals) less than 2001, and about 56% (or 2,632 individuals) greater than 2000. Currently there are too many potential variables for explaining the increase in population size over the three year period. I hope that by having more than 10 years of trapping data, we will be able to more accurately assess the status and trend of 2+ steelhead.

The graphical lines of population out-migration by week varied between study years. Population out-migration was relatively high in the beginning of trapping in 2000, and in 2001 and 2002, out-migration was highest weeks after trap placement.

Similar to catch distributions in 2002, April and May were important months for 2+ steelhead population out-migration, and accounted for 74% (YR 2002), 67% (YR 2001), and 76% (YR 2000) of the population estimates. In 2001, June was also an important month (26%). Using all years' population data combined, April and May accounted for 69% of the estimated 24,777 individuals. The most important month was April, which accounted for 36% of the population estimate, followed by May (33%). Population out-migration tapered off from 7/8 onward, except for study year 2001, when a small peak (n = 354 2+SH) emigrated from 7/15 – 7/21.

Coho Salmon

Although one adult coho salmon was observed in the spawning surveys in 2001 (which suggests more might be present) above the trap site, no juvenile coho salmon were caught in 2001, or in 2002 or in 2000. It is highly probable that the trapping effort would catch some juveniles if present above the trap site. Historic records of coho salmon in areas above the trap site are anecdotal; however, do warrant mentioning. Bill Chezum (long time resident in Redwood Valley, per comm. 2001) observed schools of adult coho salmon in areas upstream of the current trap site while growing up in Redwood Valley. He particularly mentioned seeing coho in the 1940's and early 1950's. Every year he watched the fish swim past him during their spawning run, and around the time of the 1954 flood event, the coho seemingly disappeared. Marlin Stover (pers. comm. 2000) who is also a long time resident in Redwood Valley, collaborates Bill Chezum's observations of adult coho in upper Redwood Creek. One stream near the trap site (Minor Creek) supposedly supported runs of coho salmon. I recommend in 2003 we electro-fish or snorkel sections of Minor Creek to determine if juvenile coho are present.

Cutthroat Trout

A low number of cutthroat trout were captured in all three study years. An unknown number of cutthroat trout will residualize in the stream for varying years, and not out-migrate to the estuary and ocean. The low trap catches may not necessarily reflect a low population size in upper Redwood Creek. However, if there were large numbers present, we would probably catch more than we do, as they re-distribute or migrate downstream. Electro-fishing or snorkel surveying tributaries and mainstem reaches of Redwood Creek is recommended to determine the current spatial structure of cutthroat trout in the Redwood Creek watershed.

Operation of Chezum Dam

Chezum dam serves multiple purposes: 1) source of water for fire fighting, 2) place for the local community to meet and swim, and 3) area of cold water refugia for juvenile and adult salmonids (pers. comm. Chezum 2001). According to Chezum, he originally built the dam to offer cold-water refugia for salmon and steelhead because of massive fish kills he eye-witnessed during summer low flow months (pers comm. Chezum 2001). The dam does have a spillway to allow both adults and juveniles passage; however, professional biologists and engineers need to oversee spillway configuration. In 2002, Diane Ashton (NOAA, Protected Resources, Arcata, CA.), Jon Mann (NOAA, Habitat Conservation Division, Santa Rosa), and I critiqued the spillway for adult and juvenile passage with Bill Chezum's son, Mike Chezum. We instructed Mike (who was very amenable) to add rocks and small boulders to break up the flow in places, and to offer backwater refugia for upstream migrating fish.

Operating and filling the dam in June is a time when 0+ chinook salmon and 0+ steelhead trout downstream migration is considerable. I recommend that dam construction and filling does not occur until the end of June (28th onward). With respect to just 0+ steelhead, the dam may cause increased mortality in July because there is less margin areas of the ponded water compared with the area that is pooled. The ponded water allows easy access for 1+ and 2+ steelhead to prey upon 0+ steelhead. The placement of woody debris alongside parts of the margin water may reduce young-of-year-predation by offering places to hide.

According to Mike Chezum, the dam took four days to fill in 2002, and is needed for use (eg swimming, etc) by July 4th. I believe that if they started the dam on June 28th (instead of June 15) they could meet the July 4th deadline. I also recommend the time to fill the dam should take no less than five days. If they fill the dam within 1-4 days, regular stream flow will be adversely affected. For example, in 2001 the dam was filled in one day, and the stream flow dropped considerably (1.7 to 3.1 inches). At a time of already low flows (June/July), a decrease in stream height could strand fish in side channels and alcoves. In 2002, the dam took four days to fill, and the stream dropped 1.44 inches in one day, and 2.16 inches in two days. If the dam was filled in 5+ days, drops in stream flow might be minimized. Every effort should be made to minimize the vertical and horizontal drop in stream flow during dam construction and filling to prevent juvenile salmonid stranding and habitat loss. I also recommend stream temperatures above and below the dam should be monitored to insure the spilled water does not thermally pollute sections of upper Redwood Creek.

Turbidity measurements were taken during the construction and filling phase of Chezum Dam in 2002. Our data show that even 5.6 miles downstream of the dam, significant turbidities were recorded. I recommend studies should be undertaken to monitor turbidity associated with all summer dams within Redwood Creek during and after dam construction, and decommissioning. Fine tuning dam construction and decommission may minimize turbidities and subsequent sediment deposition, and minimize negative consequences to the threatened salmonids that inhabit upper Redwood Creek.

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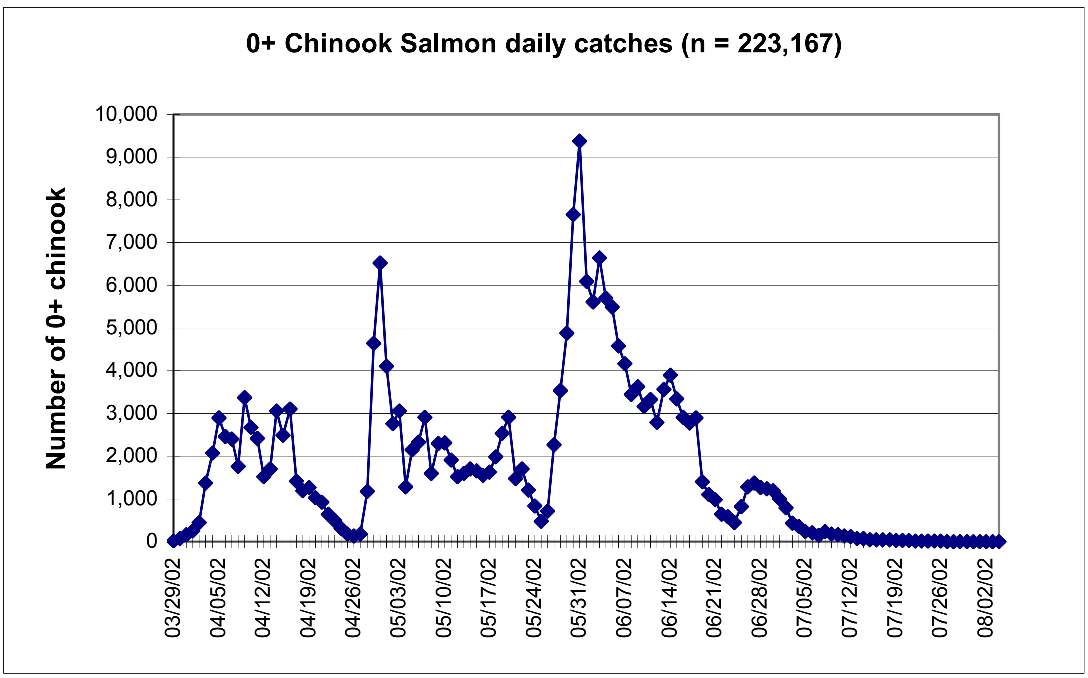
APPENDICES

Appendix 1. Daily catch distribution for 0+ chinook salmon, 2002.

The daily catch distribution for 0+ chinook salmon showed three distinct groupings in 2002 (see figure below). Peak daily 0+ chinook salmon catches in 2002 occurred on April 9 (n = 3,370), April 30 (n = 6,516), May 31 (n = 9,375), and June 3 (n = 6,635), whereas peak catches in 2001 occurred on May 13 (n = 3,993), May 15 (n = 4,682), May 24 (n = 6,204), June 9 (n = 3,374), and June 10 (n = 3,359). In 2000, peak catches occurred on May 27 (n = 4,232), June 7 (n = 3,832), and June 21 (n = 5,457).

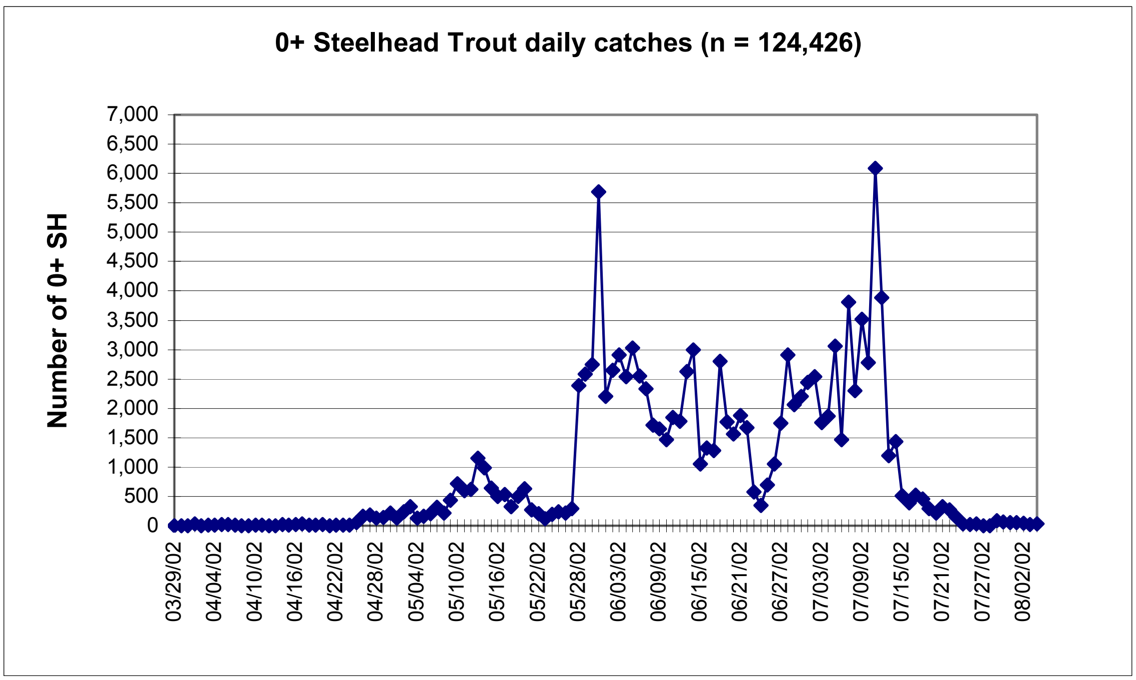
The pattern of catches in 2002 show the trapping period encompassed downstream migration (see figure below). Very low catches on the right tail of the distribution show that out-migration substantially decreased to values near zero. Daily captures in 2002 ranged from 0.0 – 4.2%, and suggest nights missed trapping (n = 2) did not influence the total catch to any large degree. Additionally, the two days missed trapping occurred during the end of July, when out-migration clearly tapered off.



Appendix 2. Daily catch distribution for 0+ steelhead trout, 2002.

The two highest daily 0+ steelhead peak captures in 2002 occurred on May 31 (n = 5,684), and July 11 (n = 6,088) (see figure below), whereas the two highest peak catches in 2001 occurred on May 27 (n = 4,457), and June 27 (n = 6,993). In 2000, the highest peak catches occurred on June 28 (n = 2,439), and July 2 (n = 2,282).

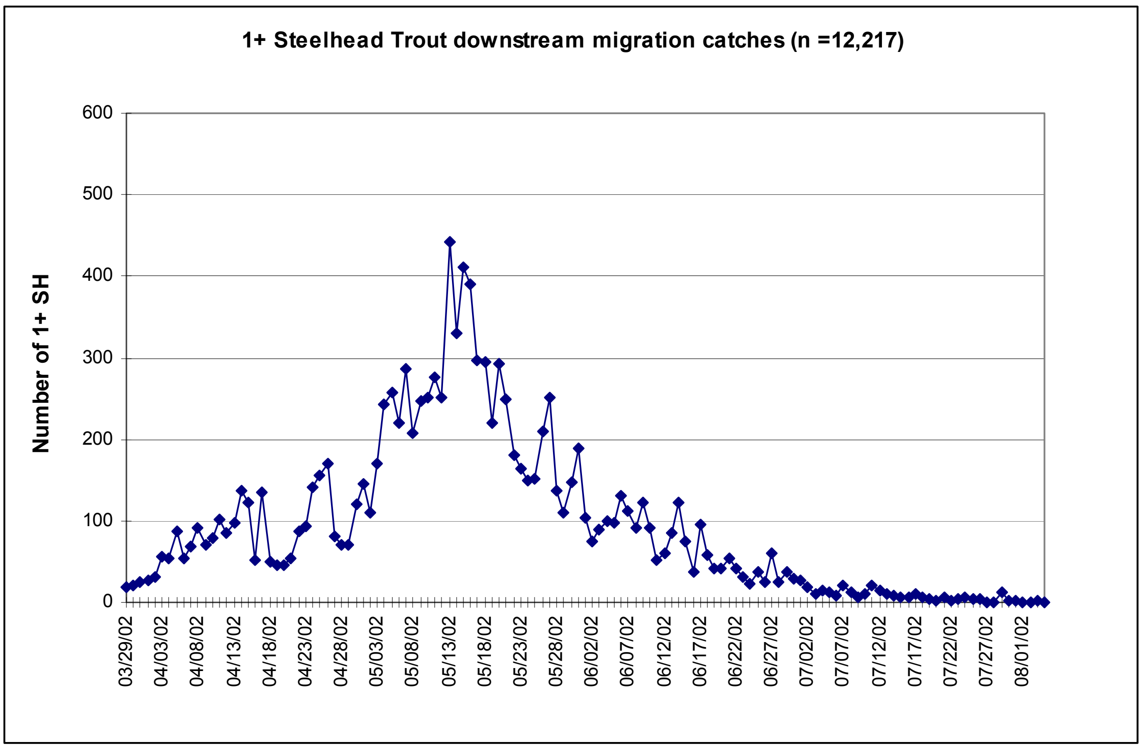
The pattern of daily catches in 2002 show the trapping period encompassed downstream migration or stream re-distribution (see figure below). Zero catch days to the left on the catch distribution correspond to times when fry have not emerged from redds, or moved downstream. Low catches on the right tail of the distribution show out-migration substantially decreased to values near zero. The daily captures in 2002 expressed as a percentage of the total catch ranged from 0 – 4.9%, and suggest that nights missed trapping (n = 2) did not influence the total catch to any large degree.



Appendix 3. Daily catch distribution for 1+ steelhead trout, 2002.

The catch distribution of 1+ steelhead trout in 2002 approximated a normal bell shaped curve with a single peak catch (see figure below). The highest daily peak catch in 2002 (n = 442) was much less than the highest daily peak catch in previous years (YR 2001 n = 710, YR 2000 n = 544). The peak catch in 2002 occurred on 5/13/02. In 2001 and 2000, the highest daily peak catch occurred on 5/16/01 (n = 710) and 5/10/00 (n = 544), respectively.

The pattern of catches in 2002 show the trapping period encompassed the majority of downstream migration (see figure below). Daily captures within the trapping period expressed as a percentage of the total 1+ steelhead catch, ranged from 0 – 3.6%. Such small percentages suggest that nights missed trapping (n = 2) did not influence the total catch to any large degree. Additionally, the two days missed trapping occurred during the end of July, when out-migration clearly tapered off.



Appendix 4. Daily catch distribution for 2+ steelhead trout, 2002.

2+ steelhead daily catches were variable over time (see figure below), more so than other species at age.

The highest daily peak catch in 2002 occurred on 5/16/02 (n = 41). In 2001, the highest peak catch occurred on 4/7/01 (n = 45); in 2000, the highest peak catch occurred on 4/6/00 (n = 35).

The catch distribution in 2002 was better than previous study years (ie more of a bell shaped curve), however, there is skewness to the left which suggests some fish were out-migrating prior to trap placement (see figure below). Daily 2+ steelhead captures expressed as a percentage of total catch in 2002 ranged from 0 – 2.6%, and suggest the two night's missed trapping did not influence the total catch to any large degree. Additionally, the two days missed trapping occurred during the end of July, when out-migration clearly tapered off.