704

303 (d) Deadline:1/31/06

Barnum Timber Company
P.O. Box 1365
1610 Highland Ave.
Eureka, CA 95502

January 17, 2006

VIA EMAIL

Selica Potter
Acting Clerk to the Board
State Water Resources Control Board
Executive Office
1001 I Street, 24th Floor
Sacramento, CA 95814

RE: REVISION TO FEDERAL CLEAN WATER ACT SECTION 303(d) LIST OF WATER QUALITY LIMITED SEGMENTS FOR CALIFORNIA

REDWOOD CREEK, HUMBOLDT COUNTY

Dear Board Members:

I represent Barnum Timber Company, hereafter "Barnum," a landowner in the Redwood Creek watershed in Humboldt County, California. I am providing information to the State Water Board regarding conditions in Redwood Creek in response to the public solicitation for comments and information on proposed revisions of the federal Clean Water Act section 303(d) list of water quality limited segments.

Barnum has been concerned about the listing of Redwood Creek as an impaired water body under Section 303(d) of the Clean Water Act since its original listing in 1993. Since that time, Barnum has endeavored to gather and assimilate all available information relating to conditions in Redwood Creek. Barnum submits this information to assist you in making better informed decisions regarding Redwood Creek and other North Coast water bodies, particularly in deciding whether, in fact, Redwood Creek should continue to be listed as impaired. Please take the time to fully review the information provided. This compilation of information is likely the most comprehensive ever assimilated regarding conditions of a California water body and has been produced over a time spanning nearly a decade at a cost of several hundred thousand dollars.

We understand that the Board and its staff failed fully to review, consider and employ Barnum's submission in 2001, and claimed that it found the submission confused and not wholly user friendly. Our submission in 2001 was orderly and included an annotated index. We trust that this effort will ensure that full and proper consideration will be given to this submission during this proceeding.

By way of updating and strengthening the evidence in support of Barnum's 2006 submission I have attached the most recent report by the California Department of Fish and Game Anadromous Fisheries Resource Assessment and Monitoring Program documenting the salmonid abundance and productive capacity of Redwood Creek. The evidence provided in this report of the considerable abundance of salmonids being produced in Redwood Creek does not suggest or support a designation of impairment from either sediment or temperature for Redwood Creek.

Barnum believes, based upon the scientific information available, that Redwood Creek is not impaired by sediment, temperature or any other pollutant; that, in fact, Redwood Creek is today in as good a condition as has existed in the historical past and is a healthy and productive water body.

LISTING OF REDWOD CREEK

Section 303(d)(1)(A) of the Clean Water Act (33 USC 1313(d)(1)(A)) provides in relevant part:

> "Each state shall identify those waters within its boundaries for which the effluent limitations required by section 1311(b)(1)(A) and section 1311(b)(1)(B) of this title are not stringent enough to implement any water quality standard applicable to such waters."

The effluent limitation required by 33 USC 1311 are limitations on point sources of pollution. Thus, if limitations on point sources are not adequate to achieve applicable water quality standards, the states must identify the water body as impaired. There are no point sources in the Redwood Creek watershed; therefore, any listing of Redwood Creek must be based solely on conditions resulting from non-point sources.

In October, 1993, the United States Environmental Protection Agency disapproved California's 303(d) list of impaired water bodies and added seventeen additional waters to the list including Redwood Creek. Redwood Creek was then listed due to pollution by sediment. The basis for the listing was that aquatic habitat was impaired by excessive sediment loading caused by historic logging activity which was causing anadromous fish populations to experience significant declines, partly as a result of fisheries habitat degradation. Since the original listing in 1993, California has continued to summarily retain Redwood Creek on the 303(d) list, on the same basis, in each of its subsequent updates.

The water quality standard applicable to sediment in Redwood Creek is contained in the Basin Plan for the North Coast Region. The water quality standard for sediment is as follows:

> "The suspended sediment load and suspended sediment discharge rate of surface waters shall not be altered in such a manner as to cause nuisance or adversely affect beneficial uses."

Even though this narrative standard is extremely vague, in order for Redwood Creek to be listed as impaired due to sediment, there still must be substantial evidence in the record that the suspended sediment load and suspended sediment discharge rate have been altered so as to cause a nuisance or so as to adversely affect beneficial uses.

The evidence that was the administrative basis of the original listing and the subsequent re-listings of Redwood Creek was very limited and mostly anecdotal. The listing was based primarily on a report from the Humboldt Chapter of the American Fisheries Society and a letter from the U.S. Fish and Wildlife Service. Neither contained any scientific data regarding conditions in Redwood Creek. The American Fisheries Society letter amounted to little more than an opinion poll of the group's members without any specific data regarding sediment conditions in Redwood Creek. Similarly, the Fish and Wildlife Service letter was based solely on the opinions of various federal regulators and contained no data on the sediment conditions in Redwood Creek.

The Board's case for its "temperature" listing of Redwood Creek is similarly flawed. The *entire* evidence supporting the Board's 2002 Maximum Weekly Average Temperature ("MWAT") of 14.8 degrees Celsius is a single study of temperatures of rivers in Washington, Oregon, and Idaho – none in California – all scores or hundreds of miles north of Redwood Creek. No evidence exists to suggest that the MWAT is even achievable, much less sustainable, in Redwood Creek.

Conversely, the materials accompanying and incorporated by reference into this letter provide a comprehensive set of both historical and current scientific data and information regarding conditions in the Redwood Creek watershed. This newly provided information should provide the regional and state boards with a much more comprehensive understanding of the actual conditions. The materials accompanying and incorporated by reference into this letter show that Redwood Creek:

1. like all river systems, is naturally dynamic, in a constant state of change;

2. currently has sediment conditions well within the range of historical conditions and not significantly different from the sediment conditions that existed prior to significant timber harvesting occurring in the watershed and prior to the major floods that occurred between the mid 1950s and mid 1970s;

3. currently supports healthy and productive populations of anadromous fish with reproduction levels at or above the carrying capacity of pristine river systems, amongst the highest recorded for West Coast streams;

4. is now subject to land management techniques that have substantially reduced the input and affects of human caused sediment; and,

5. never could under natural circumstances achieve the MWAT prescribed for it.

The materials that accompany this letter and are incorporated by reference provide comprehensive and compelling evidence that Redwood Creek is not an impaired water body. I believe that after an objective review of the information provided, you will conclude that Redwood Creek should be removed from the 303(d) list. The overwhelming bulk of scientific evidence supports this conclusion. There simply is no substantial evidence that suspended sediment loads or discharge rates are causing or threaten to result in any nuisance or adverse affect on the beneficial uses of Redwood Creek.

The information that was previously submitted to the North Coast Regional Water Quality Control Board by Barnum regarding Redwood Creek during the previous 303(d) listing cycle is voluminous. I spoke personally with your staff member Dorena Goding on November 28, 2005, and she informed me that the entire Barnum record supporting delisting of Redwood Creek already submitted to the State Water Board would be included in the current 2006 listing cycle by referencing it herein, as a convenience to the State Water Board to avoid redundant materials being submitted. By way of reminder and guide, the Barnum's 2001-02 cycle submission included:

1. A compilation of the information in a report entitled, "*A Study in Change: Redwood Creek and Salmon*," published by CH2MHill, Inc. for the Redwood Creek Landowners Association in September, 2000. This peer reviewed report (see acknowledgements) presents a comprehensive discussion, with over 350 citations, of the conditions in Redwood Creek with particular emphasis on sediment conditions and fish populations. The materials cited in this report are included in the library submitted by Barnum in its previous submission. The report concludes that Redwood Creek is not now impaired by sediment.

2. A letter from Donald W. Chapman to Mr. Thomas M. Herman dated September 21, 2000, offering his opinions regarding conditions in Redwood Creek. Mr. Chapman is regarded as the premier fisheries scientist with regard to West Coast salmonids. Based on his personal review of conditions in Redwood Creek, review of available literature on Redwood Creek and his vast experience, Mr. Chapman concludes that the production rate of salmonids in Redwood Creek is amongst the highest documented for streams along the Pacific Coast, and that objective review of the available information does not support a conclusion that fine sediments currently impair the aquatic habitat of Redwood Creek.

3. A library of reports, studies, photographs and other materials that includes 479 different sources of information related to conditions in Redwood Creek. Included are the materials cited in "*A Study in Change: Redwood Creek and Salmon*" as well as numerous additional materials. The library is organized in alphabetical order by the primary author's last name or a file name.

4. Reference lists to assist the reviewer in identifying the material in the library by key words. Included is a spreadsheet listing those documents in the library that are related to a number of key subject areas. The relevant documents for each key word are listed by their individual reference ID number. Accompanying the key word spreadsheet are two reference lists showing the author, date, title, reference ID number and file name of each particular reference. One reference list is organized in order of the reference ID number. The other is organized in alphabetical order by author or file name. A reviewer should identify the reference ID number of the references associated with a particular subject area from the spreadsheet, locate the author, date and title from the reference list organized by ID number, and then locate the reference in the library in alphabetical order. If a particular document is not found in the library in alphabetical order, it is contained in a "library file." The library files are also shown on the reference lists and occur within the library in alphabetical order by file name. An example of where a file is necessary is where a scientific report is a part of compendium of many reports by several authors.

5. An electronic bibliography contained in a database constructed using software entitled "*Reference Manager, Version 9.*" The data base file is entitled "redwood creek file2.rmd," and is included on the computer disks provided by Barnum. If the reviewer has access to this particular software, it will be very helpful in review. I can provide assistance in utilizing the database.

6. A report entitled "*Redwood Creek Rotary Screw Trap Downstream Migration Study Redwood Valley, Humboldt County, California April 4 – August 5, 2000,*" prepared by Michael Sparkman for Doug Parkinson. This report documents the results of the operation of a rotary screw trap in Redwood Creek by the Redwood Creek Landowners Association in cooperation with the U.S. Fish and Wildlife Service during the Spring and Summer of 2000 to estimate the population of downstream migrating salmonids. The report documents that large numbers of out migrating Chinook salmon and steelhead trout (much higher numbers than other rivers sampled). This study has continued annually, and additional data is available from the California Department of Fish and Game.

7. A spreadsheet created in "*Microsoft Excel*" that contains the data that was generated from the monitoring of the rotary screw trap in Redwood Creek during 2000. The spread sheet is entitled "RC RST 2000.xls," and is included

on the computer disks that were previously submitted by Barnum. Additionally, an Excel spreadsheet that contains data gathered during 2001 from the monitoring of the rotary screw trap. This spreadsheet is entitled "RC RST 2001.xls." I can provide assistance in utilizing the spreadsheet data.

New information that accompanies this letter includes the following:

1. A report entitled "*2003 Annual Rerport Upper Redwood Creek Juvenile Salmonid Downstream Migration Study, 2000-2003 Seasons Project 2a5,*" prepared by Michael D. Sparkman for the Anadromous Fisheries Resource Assessment and Monitoring Program dated January 27, 2004. Please note that the downstream salmonid migrant monitoring has continued in Redwood Creek annually to this day. Final reports have not yet been distributed by the California Department of Fish and Game, but should be available shortly. Also, draft reports are available. I can assist the State Water Board in obtaining data and draft reports from the California Department of Fish and Game.

If there are any questions regarding the information provided, please contact me. My address and telephone numbers are shown on the letterhead. My email address is s_horner@cox.net.

Thank you for the opportunity to assist you in making fully informed decisions.

Sincerely,

Stephen R. Horner
General Manager

SRH:sh

Attachments:

1. *2003 Annual Rerport Upper Redwood Creek Juvenile Salmonid Downstream Migration Study, 2000-2003 Seasons Project 2a5*

State of California
The Resources Agency
DEPARTMENT OF FISH AND GAME

2003 ANNUAL REPORT
UPPER REDWOOD CREEK JUVENILE SALMONID DOWNSTREAM MIGRATION STUDY, 2000-2003 Seasons
PROJECT 2a5

Prepared by

Michael D. Sparkman
Northern California, North Coast Region

Anadromous Fisheries Resource Assessment and Monitoring Program

January 27, 2004

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

2003 ANNUAL REPORT
UPPER REDWOOD CREEK JUVENILE SALMONID
DOWNSTREAM MIGRATION STUDY, 2000-2003 Seasons
PROJECT 2a5 [1/]

Prepared by

Michael D. Sparkman
Northern California, North Coast Region

ABSTRACT

Juvenile anadromous salmonid trapping was conducted in upper Redwood Creek from March 25 – August 9, 2003 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 138 nights possible, and captured 649 0+ Chinook salmon, 29 1+ Chinook salmon, 102,954 0+ steelhead trout, 7,258 1+ steelhead trout, 623 2+ steelhead trout and 1 cutthroat trout. No juvenile coho salmon were captured. 0+ Chinook salmon catches showed no significant relationship with stream gage height. 0+ steelhead trout catches were negatively related to stream gage height, and 2+ steelhead trout showed a weak positive relationship. Daily catches of 0+ steelhead were positively related to stream temperature, and weekly catches of 2+SH showed a negative relationship with stream temperature. Trap efficiencies for 0+ Chinook salmon, 1+ steelhead trout, and 2+ steelhead trout by week averaged 68.4, 20.8, and 17.9%, respectively. 0+ Chinook salmon, 1+ steelhead trout, and 2+ steelhead trout trap efficiencies were not related to stream gage height. Total population estimates with 95% confidence intervals for 0+ Chinook salmon, 1+ steelhead trout, and 2+ steelhead trout were 987 (900 – 1,074), 30,670 (27,865 - 33,475) and 2,846 (2,291 – 3,401), respectively. Peak population out-migration for 0+ Chinook salmon, 1+ steelhead trout, and 2+ steelhead trout occurred during June, May-June, and April-May-June, respectively, and followed trends of actual catches. 0+ Chinook salmon, 1+ steelhead trout, and 2+ steelhead trout showed a negative trend (preliminary) in population abundance over the four study years. Other comparisons are made with downstream migration data collected in 2002, 2001 and 2000.

[1/] This paper should be referenced as: Sparkman MD. 2004. Upper Redwood Creek juvenile salmonid downstream migration study, 2000-2003. CDFG AFRAMP Annual Report 2a5: 83 p.

INTRODUCTION

This study is the fourth 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, third, and fourth years of study have been a cooperative effort between the California Department of Fish and Game Anadromous Fisheries Resource Assessment and Monitoring Program (AFRAMP) (formerly Steelhead Research and Monitoring Program) and RCLA. AFRAMP and RCLA plan on continuing the study for a longer period of time (>10 yrs) in order to more fully address biological and environmental variability.

Although there is abundant data on Redwood Creek with respect to geology, geomorphology, hydrology, forestry, and wildlife biology, relatively little information exists concerning anadromous salmonids upstream of the estuary. Studies of salmon and steelhead in Redwood Creek include: adult summer steelhead snorkel (dive) survey counts, estuarine juvenile salmonid monitoring, stream habitat typing, juvenile coho salmon presence/absence surveys, late summer juvenile steelhead and coho abundance in selected Redwood Creek tributaries, and upper Redwood Creek out-migrant trapping. New to 2003, the United States Fish and Wildlife Service (USFWS) operated a rotary screw trap in lower Redwood Creek (RM 4) to document juvenile salmonid out-migration (Bill Pinnix pers comm.).

Determining and documenting 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 juvenile life history 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 (Meehan and Bjornn 1991). 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

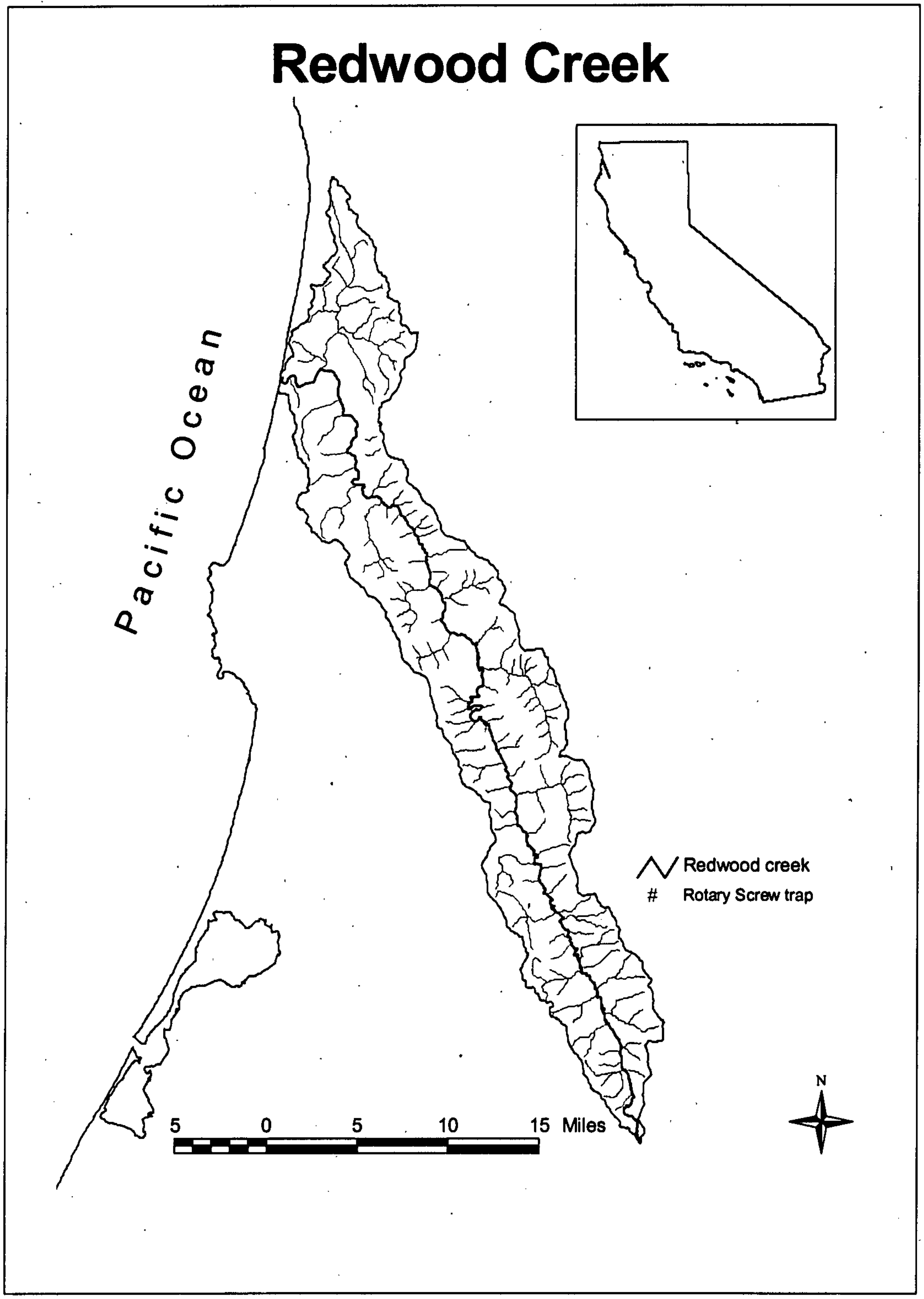


Figure 1. Redwood Creek watershed, Humboldt County, California (scale is slightly inaccurate due to reproduction process; C. Peters pers. comm. 2001).

flow north to northwest to the Pacific Ocean, bisecting the town of Orick in Northern California. The basin of Redwood Creek is 179,151 acres, and about 49.7 miles long and 6.2 miles wide (Cashman et. al 1995). The study area upstream of the trap site encompasses approximately 65,000 acres of upper Redwood Creek watershed, with about 37 stream miles of accessible salmon and steelhead habitat (Brown 1988).

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

A weather station (Davis Vantage Pro Weather Station) is located at the Hinz family residence in Redwood Valley, about 5.25 miles downstream of the trap site. Rainfall records cover the period from 1986 to the present to total 18 years (Redwood National Park, in house data, 2003; Vicki Ozaki pers. comm. 2003). Annual precipitation ranges from 90 cm (35.4 in.) to 238 cm (93.7 in.), and averages 176 cm (69.3 in.). Most (97%) of the rainfall in Redwood Creek occurs from October through May, with peak monthly rainfall occurring in December and January. Rainfall in water year 2003 (2002/03) was about 210 cm (82.7 in.), or 34 cm (13.4 in.) greater than the 18 year average. In 2003, peak monthly rainfall occurred in December (78 cm or 30.7 in.) and April (37 cm or 14.6 in.). The total monthly rainfall during the majority of the trapping season (April – July) in 2003 was 42 cm (16.5 in.) and considerably higher than the average of the three previous study years for the same time period (16 cm or 6.3 in.). Rainfall in April 2003 (37 cm or 14.6 in.) was four times higher than the average rainfall in April for the previous three study years (9.1 cm or 3.6 in.), and about 2.8 times higher than the 18 year average for April (13.3 cm or 5.2 in.) (Redwood National Park, in house data, 2003; Vicki Ozaki, pers comm.).

Discharge

A USGS/CDWR gaging station (Blue Lake O'Kane, #11481500) is located about 8.4 miles upstream of the trap site on Redwood Creek. Stream flow records cover the periods of 1953 – 1958, 1972 – 1993, and 1997 – 2003, to total 32 years (Patricia Shiffer pers. comm. 2003; USGS 2003). Following the pattern of rainfall, most of the high flows occur in the months of November through May, and typically peak in February (USGS 2003; see Flow Events in text). Low flows usually occur from July through October. Using all years' data, mean monthly discharge is 234 cfs, and ranges from 8 – 555 cfs (USGS 2003). Preliminary data for water year 2003 show that the mean monthly discharge was 260 cfs, and ranged from 2 – 762 cfs. The average monthly flow during the majority of the trapping season (April – July) in 2003 (268 cfs; range = 15 – 605 cfs) was noticeably higher than average flows in April – July for previous study years (YR 2002: 60 cfs; YR 2001: 72 cfs; YR 2000: 98 cfs) and the 32 year historic average (136 cfs) (Patricia Shiffer pers comm.).

<u>Overstory</u>

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*).

<u>Understory</u>

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 Creek History

The 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 irideus*), 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 of Redwood Creek fall within the Northern California Steelhead ESU, and are also listed as a "threatened" species (NOAH 2000). Coastal cutthroat trout 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+ (2 years old and greater) 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 and 1+ Chinook 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 deployed in upper Redwood Creek (RM 33) on March 25, 2003 at the same location as in previous study years (i.e. downstream of a moderately high gradient riffle). Modifications to the trap involved using the larger pontoons normally equipped with the 8 foot cone so that a larger livebox could be used. The debris wheel of the E.G. solutions livebox was cut out, and aluminum was added to the livebox to increase the length nearly two-fold (L 218.4 cm x W 121.9 cm x H 55.9 cm). A framed perforated plate was then used to close the downstream end where the debris wheel once was located. Perforated plates with 2 mm holes were also placed in the sides (n = 2, 56 x 31 cm) and bottom (n = 1, 89 x 41 cm) of the livebox to dissipate livebox water velocities. The modifications to the livebox decreased livebox water velocities, allowed for less fish crowding during peak catches, and enabled the trap to continue trapping under higher flows as compared to the stock model.

The rotary screw trap operated continually (24 hrs/day, 7 days a week) from March 25 through July 26 except for 11 days in late March/April when stream flows were too high to trap (see flow events in text). When stream flows were too high to safely operate the trap, we moved the trap to the side of the stream and raised the cone. Flows in late March, April and May were much higher than previous study years (see flow events in text) such that we could not wade nor build a bridge to the trap to check the livebox contents; a winch was used to pull the trap to the left bank side of the stream so that we could safely access the trap and livebox (cone revolutions were kept above 10 per 3 minutes to decrease any likelihood of fish swimming out of the livebox through the cone and into the stream).

Trapping in higher than normal flows in spring 2003 required moving the trap in and out of the thalweg at various times during the high flow periods. In early April, the trap was set partially out of the thalweg to reduce cone revolutions to less than 45 per 3 minutes (considered an upper limit) and to reduce excessive debris loading. We also moved the trap completely out of the thalweg to determine if any fish (primarily 0+ Chinook salmon) were moving along the margin areas of the streams during two of the high flow events. A major benefit to the upper Redwood Creek trapping site is a relatively narrow channel width which causes the stream to rise vertically more than spread out horizontally during high rainfall and stream flow periods. The channel morphology reduces the amount of space fish could pass by the trap without being captured.

On April 26 we added a length of cable to the right bank cable so we could re-position the trap 15 feet downstream of the previous location in order to fish the trap completely in the thalweg during high flow events. This allowed for trapping in flows as high as 1,100 cfs or nearly 4x the 32-year average flow for April. However, in the evening of April 29 the stream rose to 1,350 cfs and the trap was moved to the side of the stream. By the afternoon of April 30, the stream dropped to 950 cfs, and the trap was re-set in the thalweg of the stream at 1500. By May 10th, the stream dropped enough to move the trap eight feet upstream, and on May 16th, the trap was moved 15 feet further upstream. The trap was moved upstream into the faster and more spatially restricted current to ensure good trap efficiencies and catches.

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 when high stream flows subsided. Due to higher than average flows in the early part of the season, left bank weir panels were used later in 2003 than previous study years. On May 22nd, two weir panels were placed just upstream of the left bank trap pontoon, however, on May 30th, the panels were removed and the trap was moved 12 feet upstream in the thalweg. Left bank panels were then re-set. Weir panels were used to: 1) keep the trap's cone revolutions relatively high, and 2) increase trap efficiencies. The panels were set to fall down under high stream flows. On June 5th, a rock weir was built on the left bank side to connect to the left bank weir panels. Beginning June 8th, streambed cobbles and rocks below the rotary screw trap cone, pontoons, and livebox area were occasionally dug out or removed to give adequate clearance. On June 27th, plastic drop cloths were used to line the rock weirs to further increase flow into the cone area, and the trap's front end was slightly aligned to ensure that the center of the thalweg traveled straight into the cone. On July 3rd, a plywood weir panel was set between the two pontoons on the left bank side to increase cone revolutions. On July 9th, plastic screens were used to extend left bank weir paneling to a point just inches upstream of the cone entrance. On July 14th, similar plastic screens were then placed between the pontoons on the right bank side to increase cone revolutions, catches, and trap efficiencies. On July 26, 2003 the rotary screw trap was no longer functional due to low flows and low cone revolutions (less than 9 per 3 minutes), and a pipe trap similar to that used in YR 2001 and YR 2002 was set. The system worked very well, and enabled trapping to the end of the season and catch distribution (August 9).

Scientific aides carefully removed debris (eg. alder cones, leaves, sticks, detritus, large amounts of filamentous green algae, etc) from within the livebox nearly every night to reduce trap mortalities, and on a couple of occasions, stayed overnight to help insure that the trap would not be damaged during high or extreme flow events. The 2003 trapping season, particularly March – May, can be characterized as working in and out of high flow events.

The livebox was emptied at 09:00 every morning by 2 - 4 technicians. Young of year fish were removed first and processed before 1+ and 2+ fish to decrease predation or injury to the smaller fish. Captured fish (0+ fish first, then 1+ and older) were placed into 5 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.

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+ and greater cutthroat trout, 1+ steelhead trout (1+ SH), and 2+ and greater steelhead trout (2+

SH). Only fork lengths were taken for 0+ steelhead trout (0+ SH). A 350 mm measuring board (± 1 mm) and an Ohaus Scout ll digital scale (± 0.1 g) were used in the study. Fork lengths were taken every day of trap operation, and fork length frequencies of 0+ and older steelhead and Chinook salmon were used to determine age-length relationships at various times throughout the trapping period. 1+ steelhead weights 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, showed some blackening of the caudal fin, and were in the process of becoming silver colored smolts. Pre-smolt was considered in-between parr and smolt.

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

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 1 - 2 °C during June-August when stream temperatures reached 20°C or greater. Hand held thermometers were used for monitoring stream and recovery bucket temperatures. Ice was not used as frequently in YR 2003 (and YR 2002) compared to study years 2000 and 2001 because the continuously pumped fresh stream water helped keep water temperatures relatively cool.

After recovery from anesthesia, 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 downstream in that time period. Total salmonid out-migration estimates (by age and species) were determined on a weekly basis for 0+ Chinook salmon, 1+ steelhead trout, and 2+ steelhead trout using stratified mark-recapture methodology described by Carlson et al. (1998). The approximately unbiased estimate equation for a 1-site study was used to determine total population size (U_h) in a given capture and trapping efficiency period (h). Variance was computed, and the value was used to calculate 95% confidence intervals (CI) for each weekly population estimate. The weekly population estimate (U_h) does not include catches of marked releases in the "C" component 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 1+ steelhead, and five times a week for 2+ steelhead and 0+ Chinook salmon (due to low sample sizes). 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 stratum it was clipped and released, the number originally marked for that particular stratum was reduced by the number caught out of the stratum. 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 stratum 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 stratum, 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 0% and catches occurred for that species at age, then the overall seasonal trap efficiency for that particular species at age was used for that week (Oregon Department of Fish and Wildlife 2002).

If a week's trapping efficiency was greater than 0% and 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 significantly differed from one-another. If not different ($p > 0.05$), pooling was allowed (Carlson et al. 1998). Pooling is not an uncommon practice when efficiencies are low (Solazzi et al. 1999; Oregon Department of Fish and Wildlife 2002). The pooling procedure tends to smooth out inflation of population size due to low recapture probability. If the pooling process did not appreciably reduce the estimate or confidence intervals (e.g. by 5 %), pooling was not used so that estimate resolution on a weekly basis would not be lost.

Week and bi-week population 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). Additional population estimate models (e.g. Peterson, Darr) were also used for comparison. During the fall of 2003, a California Department of Fish and Game Biometrician (Phil Law) critically reviewed my population estimate techniques, mark-recapture data, and model choice for the most difficult species at age to estimate (ie 2 plus year-old steelhead) (see appendix 6).

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+ steelhead, 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. Fin clipped 0+ Chinook salmon were released upstream of the trap after the livebox was emptied, and 1+ steelhead and 2+ steelhead were released at night. A live cage with a battery operated mechanism opened a trap door which allowed for night releases of efficiency fish at any given time (eg 2200). Night releases generally occurred from 2000 – 2300.

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 Creek do not swim into the Redwood Creek 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 200 1+ steelhead, with up to 15 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 and un-marked fish purposely avoiding the trap. 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, 1+ steelhead, and 2+ steelhead 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. 0+ Chinook salmon were placed in a clear, flat Tupperware © container with water to facilitate observing partial fin clips. 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 rarely captured the following week. The numbers were very low (e.g. < 3 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 (Sparkman 2002a; Phil Law pers. comm. 2003). This year the number of 'stragglers' or delayed migrants was lower than other study years (1+SH n = 2, 2+SH n = 2, 0+KS n = 1). Of a total of 411 marked 1+ SH recaptures, 99.6% were captured in the correct strata. 1+ SH stragglers represented 0.4% of the total 1+ SH marked recaptures (or 0.10% of total marked 1+SH released). The highest percentage of stragglers in 2003 occurred with 2+SH (2.5%), however, the sample size of recaptures was lower than normal due to a decrease in 2+SH available for mark and recapture experiments. The number of 2+SH stragglers (n = 2) was 0.5% of the total 2+SH marked and released upstream of the trap. The number of 0+KS stragglers (n = 1) was only 0.35% of marked 0+KS recaptures, and 0.23% of the total number of 0+KS marked and released upstream of the trap. These percentages are typical of the Upper Redwood Creek trap data set (study years 2000-03), and clearly show that 'straggling' or the failure of marked fish to pass the trap site within the correct stratum (based upon week of recapture) is not a problem.

Additional Experiments

Beginning this year, we examined the diet of 1+ steelhead and 2+ steelhead trout using standard stomach pumping techniques (Walt Duffy pers. comm. 2003). Sample collection began on April 22 and generally occurred once a week throughout the remainder of the trapping season. 1+ and 2+ steelhead were anesthetized with MS-222 prior to stomach pumping. We also pumped stomachs of juvenile steelhead in the Redwood Creek estuary on one occasion while assisting Redwood National Park Biologist David Anderson (personal communication). Stream water was gently pumped into the stomach of the fish by inserting an appropriately sized tube into the stomach via the mouth. A small hand operated water pump (frequently used for applying pesticides or herbicides in home gardens) pushed the water through the tube into the fish's stomach. A small dish was used to collect the stomach samples as they exited the fish's mouth, and the contents were then placed into a properly labeled jar containing 70% isopropyl alcohol for preservation and later lab analysis. In the laboratory, specimens were viewed under a microscope and enumerated by Order, and in some cases, the genus level. We did not attempt to identify body parts (eg legs) to a particular Order unless the majority of the body was intact. Surprisingly, most of the stomach contents containing invertebrates were fresh and generally intact.

Invertebrate keys were used to classify the food item into the correct Order or genus (Merritt and Cummins 1996). Distinctions of life cycle (pupae, nymph, emerger or subimago, and adult) were made when possible. We conducted a delayed mortality test on every fish whose stomach was pumped by placing the fish in a cage in the stream for 24 hrs. I am only reporting the Order of food items ingested in this report because data analysis is not complete at this time. I plan on writing a separate paper on the food items found in outmigrating 1+ steelhead and 2+ steelhead in upper Redwood Creek at a later date.

Similar to previous study years, delayed mortality experiments (handling or fin clipping) were conducted on 0+ Chinook salmon (n = 5 tests), 1+ steelhead (n = 8 tests), and 2+ steelhead (n = 16 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. Due to the small number of catches in YR 2003, some fin clip test fish were also measured and weighed. Fish were held in mesh cages in the stream for a period of 24 hrs during each test. Sample sizes ranged from 1 – 30 individuals.

The USFWS marked 581 1+ steelhead and 18 2+ steelhead at the upper Redwood Creek trap site (over a period of nine weeks) with a photonic pigment paint to investigate travel time between the upper and lower rotary screw traps in Redwood Creek. The fish were anesthetized with MS-222, and given a mark (blue, pink, violet, yellow) that was stratified for each week by color and mark location (eg upper caudal fin, lower caudal fin, etc). Marked fish were held for 1 hr to test for any immediate mortality, and then released at the downstream release site where all rotary screw trap captured fish were released.

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 25 – August 9, 2003. The gage was read every morning at 0900 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 behind the rotary screw trap in the bottom of a pool. The shallowest depth encountered (during August) was about 2 - 3 feet. The probe was deployed from March 9 – August 9, 2003, and recorded stream temperature (^{o}C) every hour.

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

We did not measure stream turbidity (NTU) because there was no request to do so.

Statistical Analyses

Numbers Cruncher Statistical System Software (NCSS 97) (Hintze 1998) was used for descriptive statistics, chi-square, 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 seasonal 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 at age in YR 2003 compared to the average of the three previous 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 and equation line were used to determine if population size of species at age was increasing, decreasing, or remaining stable for the four years of study.

If data violated tests of statistical assumptions, data was transformed with Log (x+1), where x = the independent variable (Zar 1999). When transformations did not work for ANOVA, non-parametric equivalents were used (ie Kruskal-Wallis One-Way ANOVA on Ranks). Power is defined as the probability of correctly rejecting the null hypothesis when it is false (Zar 1999). The level of significance (Alpha) for all tests was set at 0.05.

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

Model	Dependent Variable (y)	Independent Variable (x)
Regression	Daily and weekly catches of salmonids	Daily or average weekly staff gage reading
Regression	Daily and weekly catches of 0+ KS	Daily or average weekly staff gage reading
Regression	Daily and weekly catches of 0+ SH	Daily or average weekly staff gage reading
Regression	Daily and weekly catches of 1+ SH	Daily or average weekly staff gage reading
Regression	Daily and weekly catches of 2+ SH	Daily or average weekly 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
Regression	Daily and weekly catches of all salmonids	Average stream temperature C by day and week
Regression	Daily and weekly catches of 0+ KS	Average stream temperature C by day and week
Regression	Daily and weekly catches of 0+ SH	Average stream temperature C by day and week
Regression	Daily and weekly catches of 1+ SH	Average stream temperature C by day and week
Regression	Daily and weekly catches of 2+ SH	Average stream temperature C by day and week
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

RESULTS

The rotary screw trap operated from 3/25/03 – 7/26/03 and trapped 113 nights out of a possible 124. The pipe trap operated from 7/27/03 – 8/09/03 and trapped 14 nights out of a possible 14. Using both traps, trapping occurred 127 out of 138 nights possible (92%).

Species Captured

Species captured in the 2003 study year included: juvenile Chinook salmon (*Oncorhynchus tshawytscha*), juvenile coastal steelhead trout (*O. mykiss irideus*), cutthroat trout (*O. clarki clarki*), sculpin (*Cottus* spp.), sucker (*Catostomidae* family), three-spined stickleback (*Gasterosteus aculeatus*), and a brown bullhead (*Ameiurus nebulosus*). No juvenile coho salmon (*O. kisutch*) were captured. A total of 111,514 juvenile salmonids were captured in YR 2003 (Figure 2.). Juvenile (ammocoete) lamprey and adult Pacific Lamprey (*Entosphenus tridentatus*) were also caught (Table 2). Amphibian catches included Pacific Giant Salamander (*Dicamptodon ensatus*), Rough Skinned newt (*Taricha granulosa granulosa*), Red Legged frog (*Rana aurora*), Yellow Legged frog (*Rana muscosa*), Tailed Frog tadpole (*Ascaphus truei*) and American bullfrog (*Rana catesbeiana*) (Table 2).

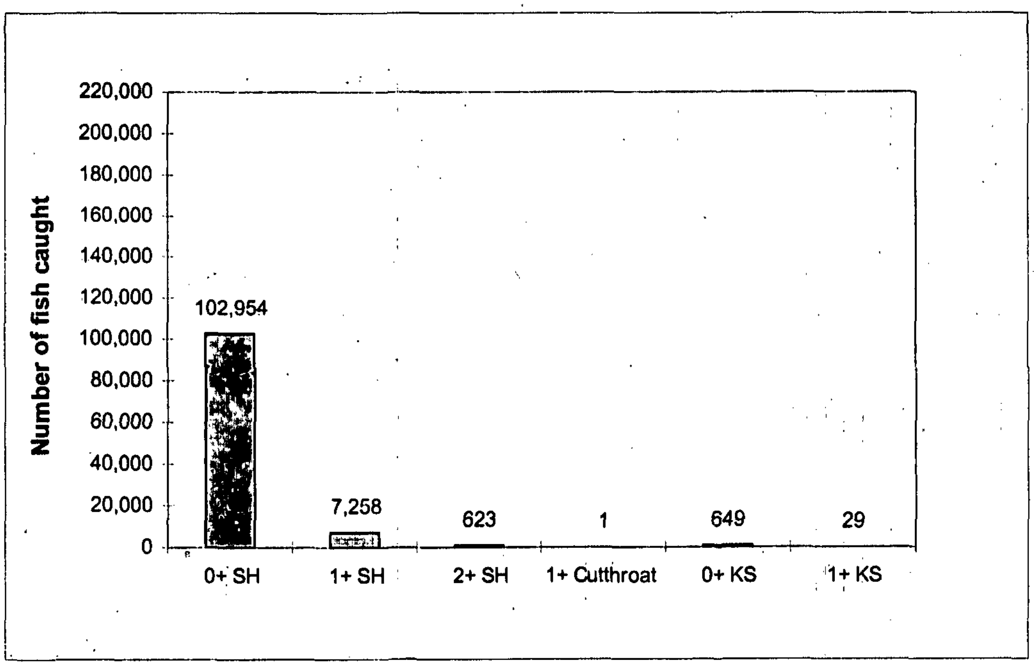


Figure 2. Total juvenile salmonid catches (n = 111,514) from March 25 through August 9, 2003, upper Redwood Creek, Redwood Valley, Humboldt County, California.

0+ Chinook salmon catches were considerably less in YR 2003 as compared with study years 2002, 2001 and 2000 (Table 2), and indicate a year class failure (see appendix 1). 0+ SH catches in YR 2003 were considerable, and greater than the average of the three previous study years (average = 93,987 individuals). 1+SH catches in YR 2003 were 40.6% less than catches in YR 2002, and 44% less than the average of the three previous study years (average = 13,085). 2+ SH catches in YR 2003 were noticeably less than previous study years, and 47.1% less than the previous three year average catch (n = 1,228 individuals). 1+ Chinook salmon catches in YR 2003 were slightly higher than previous study years. No 1+ Chinook salmon were caught in study year 2000. Juvenile coho salmon were not captured in YRS 2003, 2002, 2001, and 2000. A brown bullhead was captured for the first time in YR 2003. Fewer adult pacific lamprey were caught in YR 2003 compared with YR 2002, however, catches in YR 2003 were higher than the previous three year average (n = 37). Juvenile (Pacific?) lamprey catches were lower than catches in YR 2002 and higher than catches in YRS 2001 and 2000.

Table 2. Trap catches of various species in study years 2000 - 2003.

	Study Year			
Species Captured	2003	2002	2001	2000
0+ Steelhead Trout	102,954	124,426	102,408	55,126
1+ Steelhead Trout	7,258	12,217	14,775	12,263
2+ Steelhead Trout	623	1,589	1,360	736
Adult Steelhead	1	1	3	6
0+ Chinook Salmon	649	223,167	120,692	123,633
1+ Chinook Salmon	29	18	21	0
Coho Salmon	0	0	0	0
Cutthroat Trout	1	9	6	2
Prickly Sculpin	0	10	8	3
Coast Range Sculpin	33	283	67	145
Sucker	7	3	7	3
3-Spined Stickleback	69	104	85	144
Speckled Dace	0	6	0	0
Brown Bullhead	1	0	0	0
Adult Pacific Lamprey	58	91	5	16
Juvenile Lamprey	3,096	3,920	1,103	597
Possible River Lamprey	0	1	16	0
Pacific Giant Salamander	170	111	28	30
Painted Salamander	0	1	0	0
Rough Skinned Newt	31	56	19	NC*
Red-Legged Frog	2	1	1	NC*
Yellow-Legged Frog	4	17	9	NC*
American Bullfrog	1	0	0	0

* denotes not counted

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 in YR 2003 (n = 649) ranged from 0 – 56 individuals, and averaged 5 fish per day (Appendix 2). The previous three year daily catch ranged from 0 – 9,375 and averaged 1,233 per day.

0+ steelhead daily catches in YR 2003 ranged from 0 – 3,133 individuals, and averaged 811 per day (Appendix 3). The previous three year daily catch ranged from 0 – 6,993 individuals and averaged 741 per day. Daily 0+ steelhead captures in YR 2003 expressed as a percentage of total 0+ steelhead catch in 2003 (n = 102,954) ranged from 0.0 – 3.0%.

1+ steelhead daily catches in YR 2003 ranged from 0 – 278, and averaged 57 per day (Appendix 4). The previous three year daily catch ranged from 0 – 710 individuals and averaged 103 per day. Daily 1+ steelhead captures in YR 2003 expressed as a percentage of total 1+ steelhead catch in 2003 (n = 7,258) ranged from 0.0 – 3.8%.

2+ steelhead daily catches in YR 2003 ranged from 0 – 18, and averaged 5 individuals per day (Appendix 5). The previous three year daily catch ranged from 0 – 45 individuals and averaged 9 per day. Daily 2+ steelhead captures in YR 2003 expressed as a percentage of total 2+ steelhead catches ranged from 0.0 – 2.9%.

Missed Trapping Days

Eleven days were not trapped (3/26, 3/27, 3/28, 4/5, 4/6, 4/7, 4/13, 4/24, 4/25, 4/26, 4/30) during the course of the study due to high flow events (see flow events in text). For the previous 3 study years we would typically miss two days of trapping each year. Days missed trapping did not influence the total catch to any large degree because not many fish were out-migrating during these periods, and any given catch day did not equate to a large percentage of the total catch.

0+ Chinook Salmon

Low numbers of 0+ Chinook salmon were caught the day following trap placement in YR 2003 (n = 1), similar to study year 2002 (n = 13). In YR 2001, no 0+ Chinook salmon were caught for the first 23 d of trapping, and in YR 2000, 0+ Chinook salmon were caught on the first day following trap placement. Peak catches in YR 2003 occurred during the month of June (n = 597) which accounted for 92% of the total 0+ Chinook salmon catches. Catches in June for the previous three study years averaged 45% of the total catches. Catches in May 2003 only accounted for about 6% of the catches in YR 2003, compared with the average of 39% in May the previous three study years. More Chinook salmon are caught in May and June than other months, and using all year's data (YRS 2000 – 2003) accounted for 87% of the total catches.

Catches by week in YR 2003 were severely reduced from the previous three year average (Figure 3). 0+ Chinook salmon catches by week in YR 2003 climbed to the highest value (n = 211) during 6/18 – 6/24, compared with the previous three year average peak catches which occurred during 4/9 – 4/15 (average = 7,343 individuals), 5/7 – 5/13 (average = 10,434), and 5/28 – 6/3 (average = 25,245)(Figure 3). Data for the previous three year average show out-migration by week was considerable until 7/9 – 7/15, when out-migration tapered to relatively low values (e.g. < 1,200/week). In YR 2003, out-migration was over by 7/9.

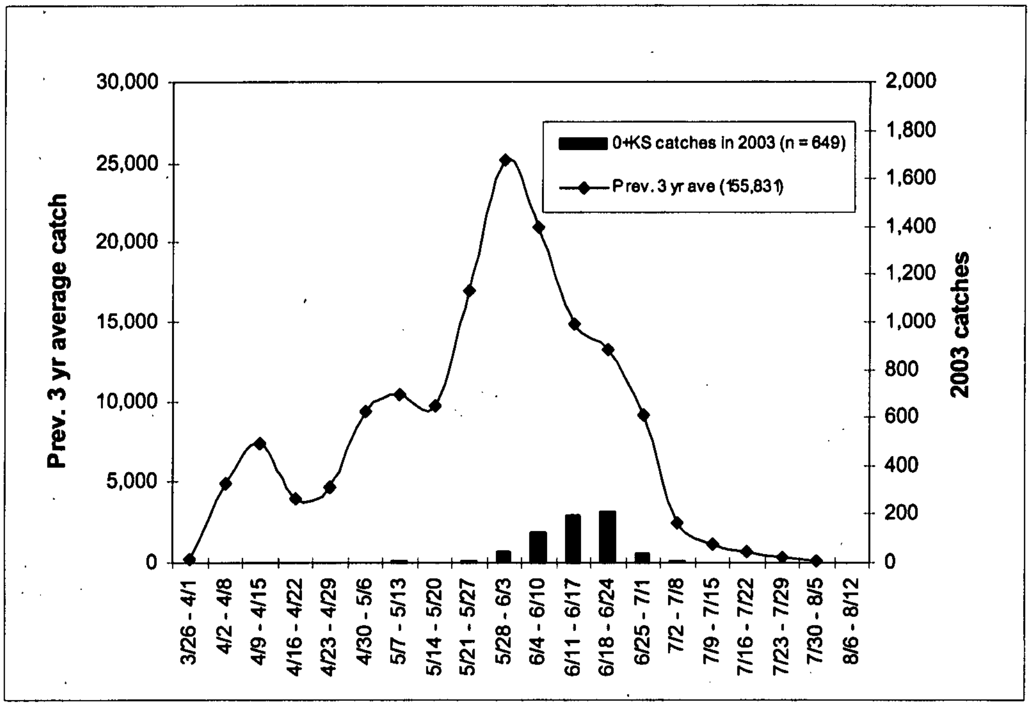


Figure 3. Comparison of 0+ Chinook salmon captures by week in 2003 with previous three yr average.

1+ Chinook Salmon

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 and older Chinook salmon juveniles.

One-year-old Chinook salmon (n = 29) were first caught in 2003 on 4/15, 23 d after trap placement. Catches in YR 2003 occurred from 4/15 – 6/1, with the majority captured 5/11 – 5/31 (n = 26 or 90%). 1+KS catches in YR 2002 occurred during 3/29 – 5/06, and in YR 2001, 1+KS were caught from 3/27 – 5/05. In YR 2002 and YR 2001, April accounted for the majority (73%) of 1+ Chinook salmon captures. When the YR 2003 data is combined, April (51%) and May (33%) accounted for the majority of captures. During the higher water year in 2003, the peak of 1+ Chinook salmon out-migration was delayed by one month.

0+ Steelhead Trout

A small number of 0+ steelhead (n = 8) were caught the first day following trap placement in YR 2003. In YR 2002 and YR 2000, 0+SH were first caught on the third day following trap placement; and in YR 2001, 0+SH were first caught 37 d after trap placement.

Peak 0+ steelhead trout catches by week in YR 2003 generally occurred 1 week after the peak in the average catch in the previous three study years (Figure 4). The majority of catches in YR 2003 occurred during June (n = 43,951 or 43%) and July (n = 48,833 or 47%), and those months accounted for 90% of the 0+SH catches. For the previous three year's data, May and June were the most important months for 0+SH out-migration, and accounted for 79% of the total catches. Using all year's data, May, June, and July accounted for 97% of the total catches.

0+ steelhead catches from 3/26 – 5/6 are very low because the fish have not yet emerged from redds, or moved downstream. Catches drop considerably from the end of July and the beginning of August, however, some 0+ steelhead out-migration still occurs.

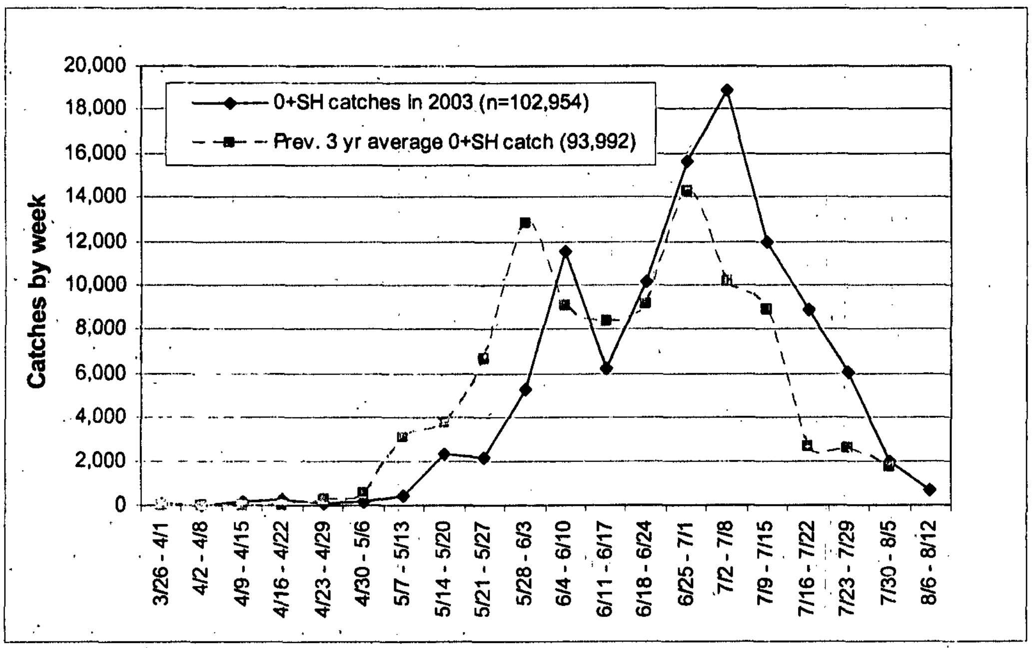


Figure 4. Comparison of 0+ steelhead catches by week in 2003 with previous 3 yr average.

1+ Steelhead Trout

The catch distribution of 1+ steelhead trout in YR 2003 approximated a normal bell shaped curve with a single weekly peak catch during 5/21 – 5/27 (Figure 5). The peak catch by week in YR 2003 was about 4 weeks later than the peak of the previous 3 yr average. There is a noticeable lack of catches in YR 2003 during late March, April and early May compared with the previous 3 yr average. 1+ steelhead trap efficiencies were relatively high (17%) during this time period, therefore, we did not miss the fish while trapping.

The months of April and May in YR 2003 accounted for 57% of the catches compared with the previous 3 yr average of 79% for those same months. In 2003, 1+SH catches in May and June accounted for 75% of the total 1+SH catch. During the higher water year in 2003, July accounted for more 1+SH catches (12%) than the average catch in July (2%) for the previous study years.

Catches by week in YR 2003 also show the trapping period covered the majority of downstream migration (e.g. the peak catch occurred eight weeks after trap placement) (Figure 5). 1+ steelhead catches by week also show that out-migration reached low levels in YR 2003 and the previous 3 year average by July 30th.

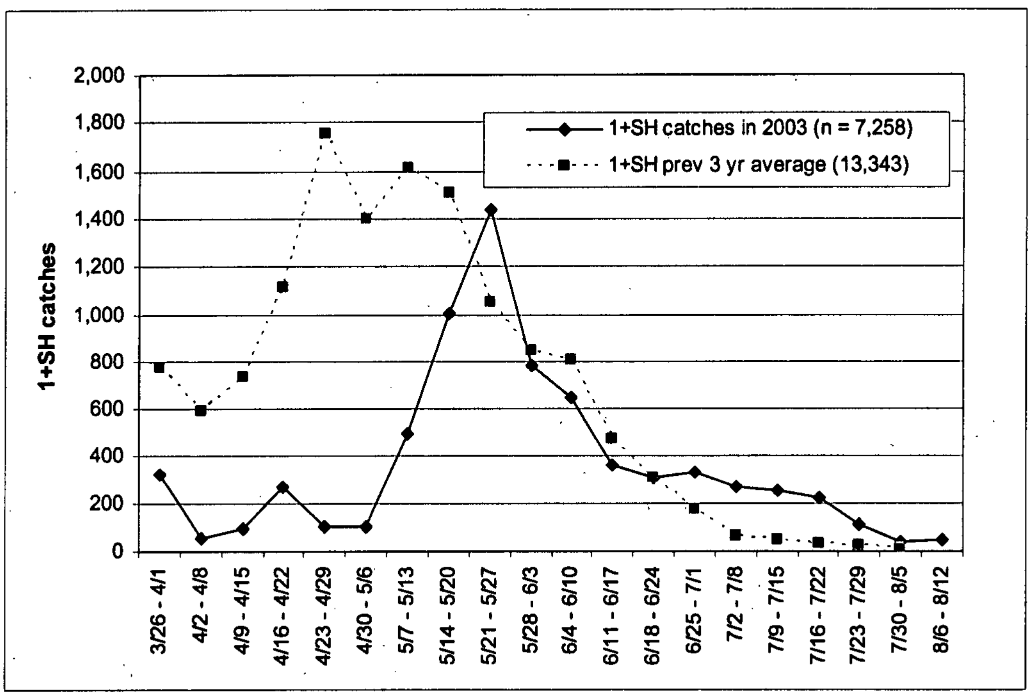


Figure 5. Comparison of 1+ SH catches in 2003 with previous 3 yr average.

2+ Steelhead Trout

The catch distribution of 2+SH in YR 2003 was bi-modal, and roughly approximated a bell shaped curve (Figure 6). Peak 2+ steelhead catches in YR 2003 occurred during April and May, however, some relatively high catches occurred in the first two weeks of July as well. The largest peak catch in YR 2003 was about two weeks later than the previous 3 yr average peak catch. Similar to 1+SH catches, there is a lack of catches in March – May in YR 2003 compared with the previous 3 yr average. 2+ steelhead trap efficiencies were relatively high (21%) during these months, therefore, we did not miss the fish while trapping.

The months of April and May in YR 2003 accounted for 61% of the catches compared with the previous 3 yr average of 74% for those same months. In YR 2003, 2+SH catches in June and July accounted for 36% of total 2+SH catch, compared with 22% for the same months in the previous 3 yr average.

2+ steelhead catches by week in 2003 show the trapping period probably encompassed the majority of out-migration (Figure 6). Catches by week for the previous 3 study years was climbing in the beginning weeks of trapping, and tapered off from July 23 onward. Catches by week in YR 2003 also tapered to low values from July 23 onward.

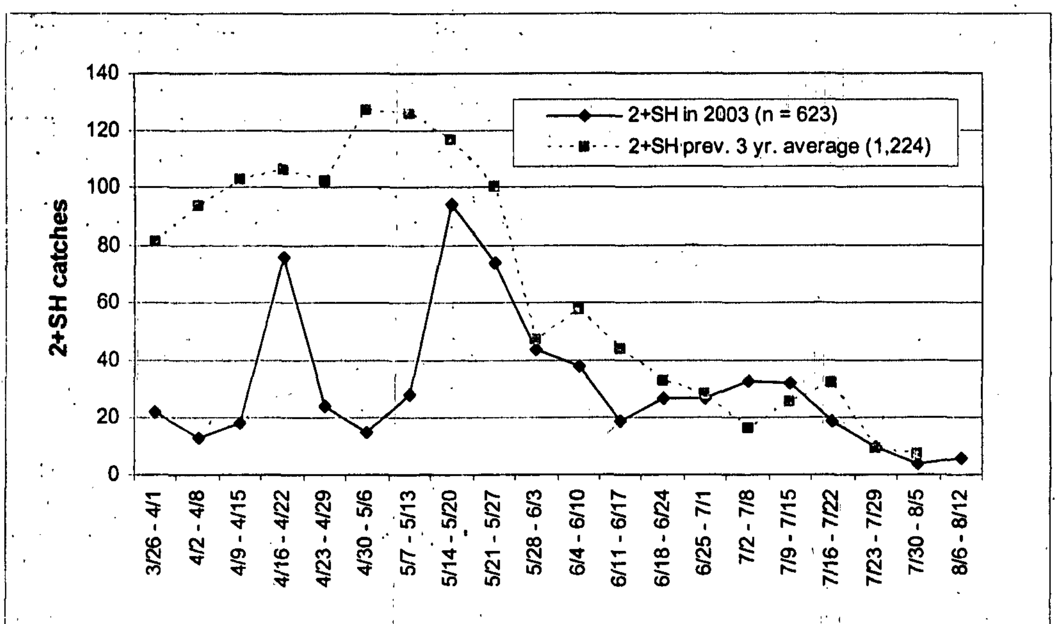


Figure 6. Comparison of 2+ steelhead catches in 2003 with previous 3 yr average.

Adult Pacific Lamprey

The first large peak in adult lamprey catches by week in 2003 was one week later than the peak in the previous 3 yr average (Figure 7). Higher catches occurred during 6/18 – 7/08 in 2003 compared with the previous 3 yr average which peaked 5/28 – 6/3. The majority of catches in YR 2003 occurred during May-June (83%), however, catches in July accounted for 12%. Similar to catches in YR 2003, catches in May-June for the previous 3 yr average accounted for 86% of total adult lamprey catches. For all study years combined, June accounted for most of the catches (55%), followed by May (30%).

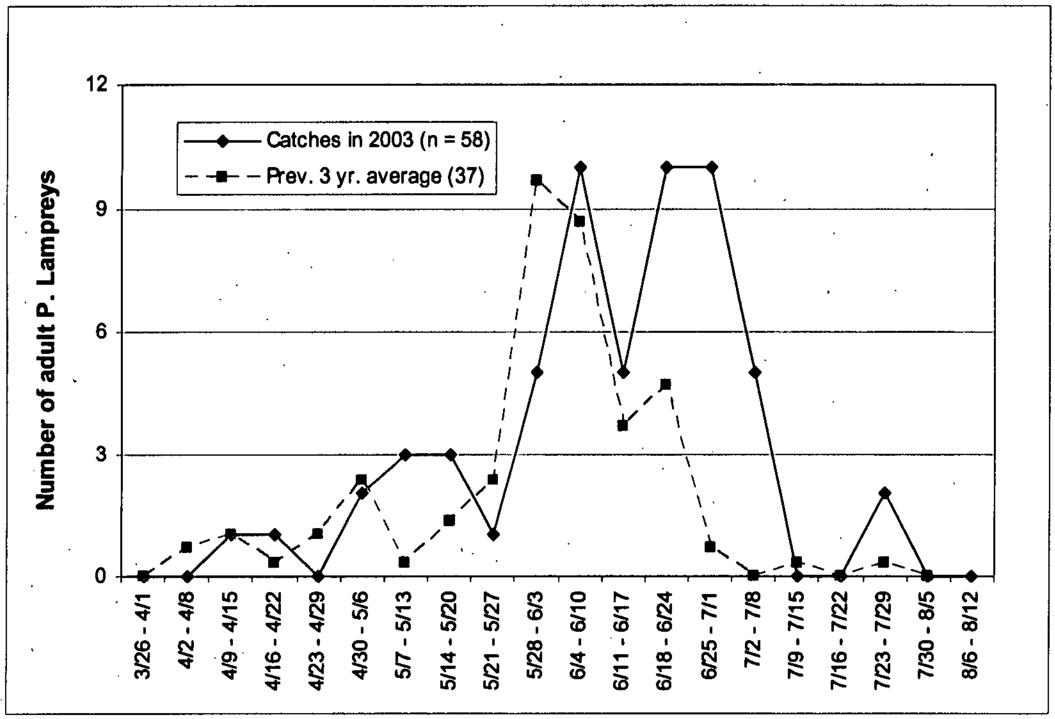


Figure 7. Comparison of adult Pacific Lamprey catches in 2003 with the previous 3 yr average.

Juvenile Lamprey (ammocoete)

A peak in juvenile lamprey catches in YR 2003 occurred in nearly every month of trap operation (Figure 8). In YR 2003, the greatest number of catches occurred during 5/28 – 6/3, two weeks later than the highest peak catch for the previous 3 yr average (Figure 8).

The majority of catches in YR 2003 occurred during May-June-July (86%). May and June catches in the previous 3 yr average accounted for 64% of total catches compared with 55% in YR 2003. Catches in April 2003 (n = 275) were much less than catches in April for the previous 3 yr average (n = 728).

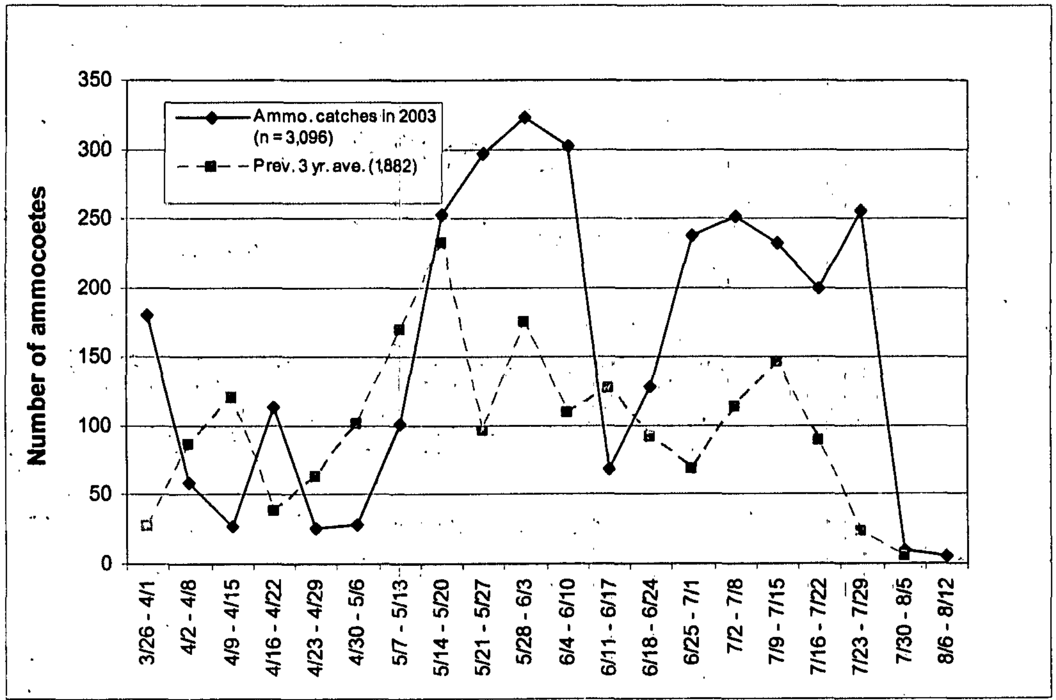


Figure 8. Comparison of juvenile lamprey (ammocoete) catches in 2003 with previous 3 yr average.

Flow Events

Stream discharge in upper Redwood Creek in WY 2003 (October 2002-September 2003) was considerably higher in December, April, and May than the historic and previous 3 yr average discharge for those months (Figure 9). The average flow in WY 2003 (Q_{av} = 260 cfs) was also higher than the historic (Q_{av} = 234 cfs) and previous 3 yr average (Q_{av} = 157 cfs) discharge (USGS 2003). The hydrograph shows discharges in June – October were nearly the same for WY 2003, historic values, and the previous 3 yr average.

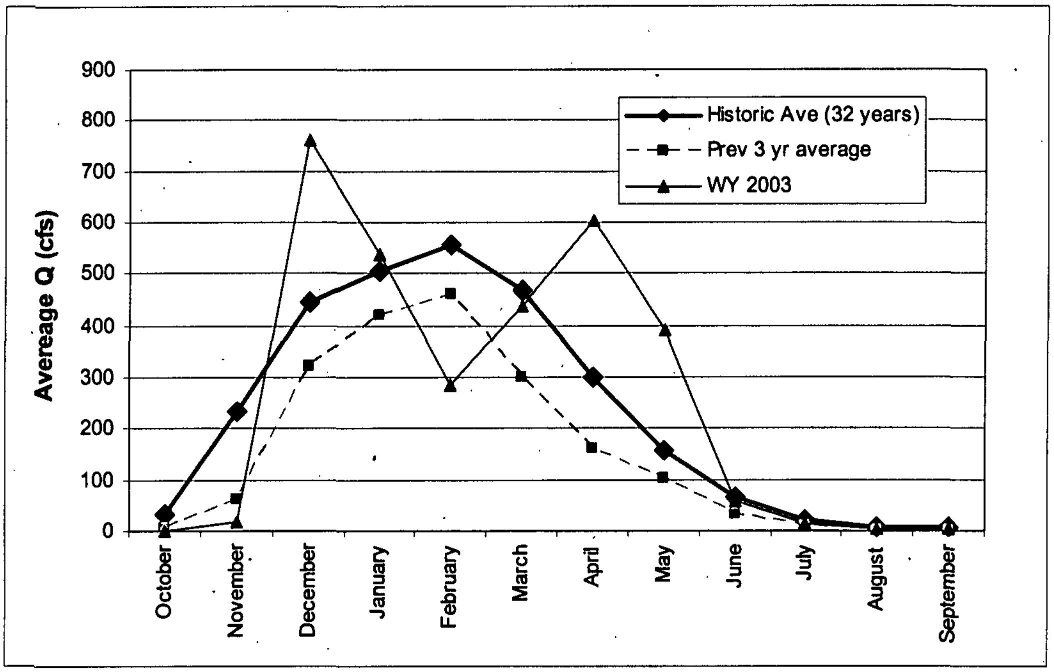


Figure 9. Average monthly discharge (cfs) in upper Redwood Creek, (USGS 2003).

Average flows during the 2003 trapping season were higher than the historic and previous three year average (Figure 10). Flows in April and May, 2003 were about 2 times the normal flow (historic) and considerably higher than the average flow in April and May for the previous 3 yrs of trapping (Figure 10). Unlike flows in previous trapping periods, the daily O'Kane gaging station hydrograph in 2003 was noticeably influenced by snow melt in April (the greatest snowfall within the trapping period occurred on April 2, 2003). Snow melt influence on stream discharge would typically increase streamflow from the latter part of the day (1500) until the peak at 2100 - 2400 hours; then streamflow would gradually decrease until solar radiation caused more snow melt, which would then once again raise the discharge in late afternoon/night (USGS O'Kane gaging station 2003).

Discharges in June-July decreased to similar low values for WY 2003, historic, and the previous 3 yr average (Figure 10). Our ability to effectively trap in above average flows strengthens the case for long term trapping in upper Redwood Cr.

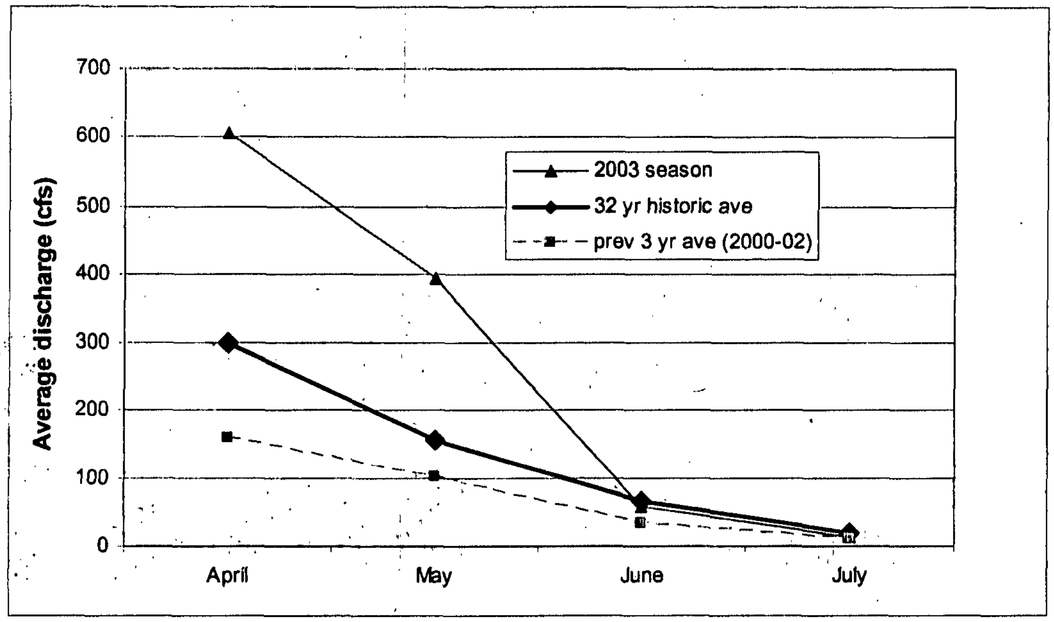


Figure 10. Average monthly discharge in upper Redwood Creek during out-migrant trapping period (USGS 2003).

Stream Gage Height (ft) and Stream Discharge (cfs)

The gage height at the trapping site closely reflected the stream discharge measured at the Blue Lake (O'Kane) (USGS 2003) gaging station (Figure 11). Data on discharge was taken at 1000 every day, and therefore does not show any higher or lower flows that could have occurred before or after 1000. Using this method, the largest increase in discharge in a 24 hr period occurred on 3/26 (+ 1,714 cfs) and 4/24 (+ 577 cfs).

Stream discharge and gage height at the trap site gradually decreased from May 7 through August 2 (Figure 11). The slight increase beginning August 3 was due to small amounts of precipitation within the watershed (upstream of the trap site).

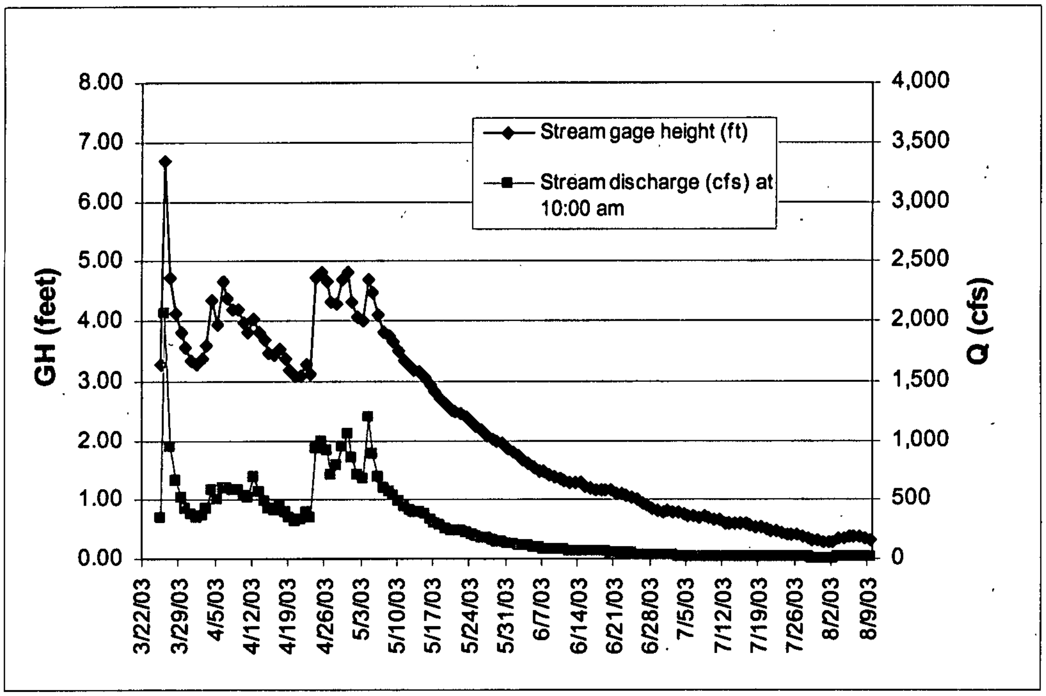


Figure 11. Gage height (feet) and stream discharge (USGS 2003) during smolt trapping in upper Redwood Creek, 2003.

Stream Gage Height

Flows during the early part of trapping in 2003 were variable, often extreme, and more difficult to trap than previous study years. Three groupings of high flows and five high flow peaks in the hydrograph were recognizable (Figure 12). The largest daily (24 hr) increases in gage height in YR 2003 were on 3/26 (3.42 ft), 4/4 (0.76 ft), 4/6 (0.70 ft), 4/24 (1.61 ft), 4/29 (0.41 ft), and 5/4 (0.70 ft). In YR 2002 peaks in gage height occurred on 4/17 (0.49 ft), 5/01 (0.36 ft), and 5/20 (0.14 ft). The largest daily increases in gage height in YR 2001 were 0.56, 0.34, and 0.72 ft, as compared to 1.14 and 0.60 ft in YR 2000.

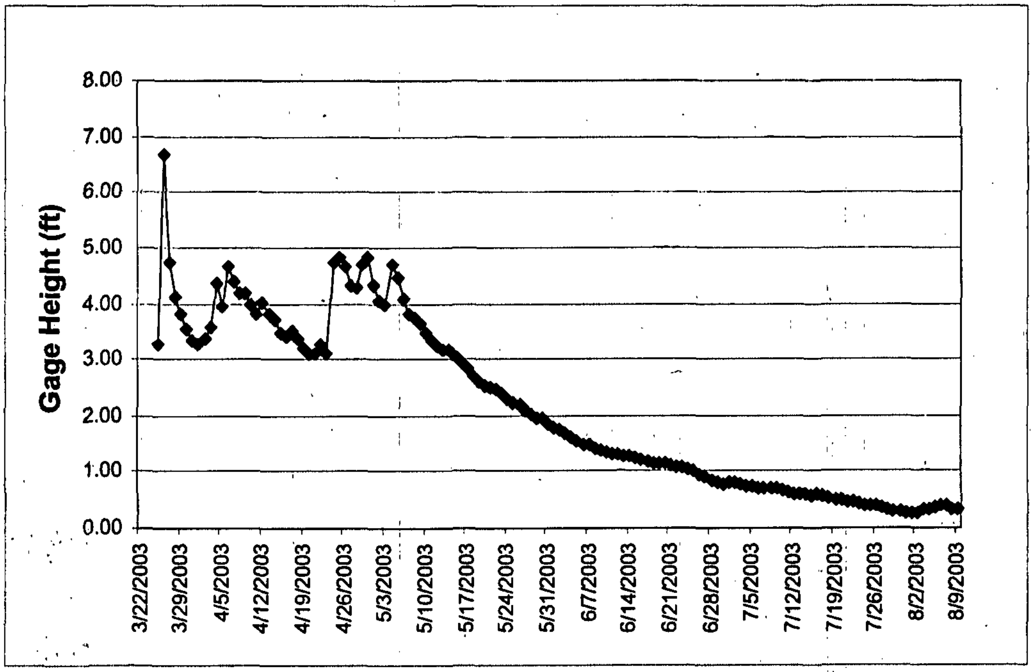


Figure 12. Staff gage at RST site, upper Redwood Creek, Humboldt County, Ca. 2003

Chezum Dam

Influences on Stream Gage Height

Chezum Dam, a summer dam typically located about 5.6 mi upstream of the trap site, was not built in YR 2003. Therefore, no comments can be made with respect to stream surface elevation changes, or possible effects of dam construction/operation on juvenile salmonid out-migration. During the four consecutive years of out-migrant trapping (2000-2003), Chezum Dam was built and operated in the summers of 2001 and 2002.

Influences on Stream Turbidity

We did observe a few (unexpected) increases in stream turbidity during lower flow periods (ie when storms had long passed). We are unsure why the stream became temporarily turbid.

Linear Relations of Catch with Stream Gage Height

Linear regression of daily gage height (ft) on daily catches of all salmonids combined in 2003 showed a significant, negative relationship ($p < 0.0001$; $R2 = 0.36$; power = 1.00). In 2001 a similar significant relationship was found (-), and in study years 2000 and 2002, no significant relationship was found ($p > 0.05$). Using average gage height by week and total salmonid catches by week, regression determined a significant negative relationship in 2003 as well ($p < 0.001$; $R2 = 0.49$; power = 0.98). This regression test was mainly influenced by 0+ steelhead catches because this species at age was more numerous than other species at age, and made up 92% of the total catches.

Regression of daily gage height (ft) on 0+ Chinook salmon daily catches (log (x+1) transformation) violated regression assumptions (NCSS 97), and results were not valid. 0+ KS catches in YR 2003 primarily occurred during June, when the hydrograph was gradually descending. In YR 2002, a weak positive relationship was found ($p < 0.01$; $R2 = 0.24$), and in YRS 2000 and 2001, no relationships were found ($p > 0.05$). The regression of average gage height (ft) by week on 0+ Chinook salmon catches by week (log x+1 transformation) in YR 2003 also showed no significant relationship ($p > 0.05$), similar to data in YR 2001 ($p > 0.05$). In YR 2002, a positive relationship occurred ($p < 0.05$; $R2 = 0.34$).

Regression for 0+ SH daily catches (with and without log (x+1) transformation) and daily stream gage height in YR 2003 violated regression assumptions (NCSS 97), and results were not valid. Similar to 0+KS catches in YR 2003, the majority of 0+SH catches in YR 2003 occurred during the descending limb of the hydrograph. In study years 2000, 2001, and 2002, a significant, yet weak negative relationship between 0+SH catches and daily gage height was found ($p < 0.05$; $R2 = 0.26$, 0.22, and 0.31). The regression of average gage height (ft) by week on 0+SH catches by week in YR 2003 showed a significant negative relationship ($p < 0.001$; $R2 = 0.49$; power = 0.98), similar to data in YR 2002 ("-"; $p < 0.05$; $R2 = 0.24$). In YR 2001, no significant relationship between average week gage height and 0+SH catches by week was detected ($p > 0.05$).

Regression of 1+ SH daily catches (log (x+1) transformation) and daily stream gage height in YR 2003 violated regression assumptions (NCSS 97), and results were not valid. In YR 2003, peak 1+SH catches did not correspond with any peaks in gage height. In study years 2002, 2001, and 2000 significant positive relationships were found ($p < 0.05$; $R2 = 0.35$, 0.59, and 0.34). The regression of average gage height (ft) by week on 1+ steelhead catches by week (log x+1 transformation) in YR 2003 violated regression assumptions (NCSS 97) and results were considered invalid and un-reliable. In YR 2002 (log (x+1) transformation) and YR 2001, positive relationships were found between average gage height and catches by week ($p < 0.05$; $R2 = 0.45$; 0.54).

Regression of 2+ SH daily catches and gage height (ft) in YR 2003 passed regression assumptions when catch data was transformed with log (x+1); a very weak positive relationship was found ($p < 0.01$; $R2 = 0.06$; power = 0.77). Only one peak 2+SH catch in 2003 occurred with a peak in gage height. In study years 2002 and 2001, regression assumptions were violated, rendering results unreliable. In YR 2000, 2+SH daily catches were positively related to gage height ($p < 0.05$; $R2 = 0.12$). In YR 2003, average gage height (ft) by week and weekly 2+SH catches (log (x+1) transformation) passed regression assumption tests, however, results were not significant ($p > 0.05$). In YR 2002 and YR 2001, there was a significant positive relationship ($p < 0.001$; $R2 = 0.36$ and 0.61).

Linear Relations of Catch with Lunar Phase

Linear regressions of daily fraction of moonlight on daily catches for all salmonids, and 0+KS and 0+SH violated assumptions of normality (even with log x+1 transformation), and results were not valid. Regressions with 1+SH and 2+SH catches (transformed with log x +1) passed assumption tests. Although statistical parametric relations were not warranted for 0+KS and 0+SH, some generalizations based upon graphical representations of the data can be made.

Similar to YR 2002 and YR 2001 data, 0+ Chinook salmon catches in YR 2003 generally decreased with a full moon (moon illumination fraction of 1.00). Although catches of 0+KS were drastically reduced in YR 2003, a small peak catch (n = 42) occurred at a moon illumination fraction of 0.67, and another (n = 56) occurred at 0.81. In YR 2002, the two largest daily peak catches occurred at moon illumination fractions of 0.87 and 0.75. A smaller peak in YR 2002 occurred at a fraction of 0.01. In YR 2001 peak catches occurred at illumination factors less than 0.51. In YR 2000, peak catches occurred during a moon illumination of 0.30 – 0.84.

0+ SH catches in YR 2003 generally decreased with a full moon and increased with new moons, similar to YR 2002 data. However, the two largest daily 0+ SH peak catches (n = 3000, 3133) in YR 2003 occurred at a moon illumination of 0.02 and 0.53. In YR 2002, the two largest peak catches occurred at fractions of 0.75 and 0.01. In YR 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 YR 2000, peak 0+ SH catches did not occur at moon illumination fractions greater than 0.17.

1+SH catches (log x+1 transformation) in YR 2003 showed a very weak positive relationship with moon illumination fractions ($p < 0.05$; R2 = 0.06; power = 0.83). Peak catches on 3/31 (n = 104), 4/21 (n = 77), 5/13 (n = 195), 5/22 (n = 278), and 6/29 (n = 78) corresponded to moon illumination fractions of 0.06, 0.83, 0.80, 0.67, and 0.00. 1+ SH catches in YR 2002 were also variable with respect to moon illumination. Two of the smaller peaks in YR 2002 were associated with a full moon; however, the largest peak catch occurred during a 0.01 moon illumination. In YR 2001, the majority of high catches were below a moon illumination fraction of 0.50 except for one peak catch which occurred at a moon illumination fraction of 0.99. Aside from the peak catch at 0.99 in YR 2001, results in YR 2001 and YR 2000 were similar (eg higher catches below 0.50 moon illumination).

2+SH catches (log x+1 transformation) in YR 2003 also showed a very weak positive relationship with moon illumination fractions ($p < 0.05$; R2 = 0.10; power = 0.95). Peak 2+SH catches on 4/20 (n = 17), 5/17 (n = 18), and 5/31 (n = 13) corresponded to moon illumination fractions of 0.83, 0.98, and 0.00. High catches in study years 2002, 2001, and 2000 occurred at full and new moon phases, with no clear pattern. For all four trapping seasons, 2+ steelhead were the most variable of all salmonids with respect to catches and moon illumination fractions.

Stream Temperatures

Stream temperatures in upper Redwood Creek increased over time (Figure 13). The average daily (24 hr period) stream temperature from 3/25/03 – 8/09/03 was 14.7 °C (or 58.5 °F) (95% CI 13.8 – 15.6 °C), and ranged from 7.05 – 23.78 °C (44.7 – 74.8 °F). In 2003, the average daily stream temperature exceeded 20 °C (68 °F) for 33 d out of 138 d (24%) of record. In 2002, exceedence was 34 d out of 129 d (26%), and in 2001, exceedence was 30 d out of 120 d (25%) of record. Temperature data in YR 2000 was not used in comparisons because the data was collected over slightly less than two months.

Relations of average stream temperature °C and gage height (ft) in YR 2003 were significantly negative ($p < 0.001$; $R2 = 0.91$; power = 1.0), very similar to the past three study years (negative relationship, $p < 0.001$). Gage height (ft) explained 91% of the variation in average stream temperatures (°C) in 2003, 89% in 2002, and 87% in 2001.

The maximum daily stream temperature in YR 2003 ranged from 7.9 – 28.4 °C (46.2 – 83.1 °F), and the minimum ranged from 6.1 - 20.7 °C (43.0 – 69.3 °F) (Figure 13). Maximum temperatures generally occurred in mid to late afternoon, well after the trapped fish were processed and released. However, during July and parts of August, we observed many juvenile steelhead using subsurface gravel water that entered the stream margins as thermal refugia prior to the afternoon.

The dip in stream temperatures from 7/30 – 8/6 was probably due to decreasing air temperatures and small amounts of rainfall (Figure 13).

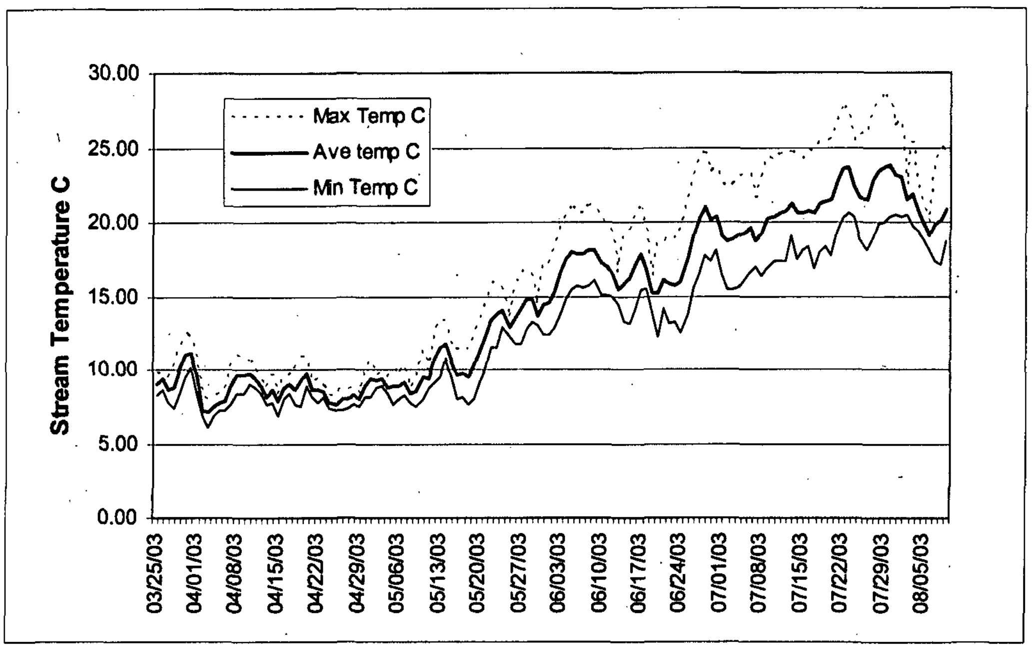


Figure 13. Upper Redwood Creek stream temperatures during the trapping period (°C), 2003.

The average stream temperature within the trapping period was 14.6 °C (58.3 °F) in YR 2003, 15.8 °C (60.4 °F) in YR 2002, 16.3 °C (61.3 °F) in YR 2001, and 15.9 °C (60.6 °F) in YR 2000.

The previous 3 yr average daily stream temperature during the trapping season was greater than average stream temperatures in YR 2003, particularly during April, May, and the latter part of June (Figure 14). Kruskall-Wallace One Way ANOVA on Ranks determined significant variation among treatment medians ($p < 0.05$). Median temperature of the previous 3 yr average (15.97 °C or 60.7 °F) was greater than the median stream temperature in YR 2003 (14.76 °C or 58.6 °F). Stream temperatures in YR 2003 were probably less than the previous three year average because of: 1) relatively higher amounts of precipitation, 2) more snow later in the season and snow melt in April, and 3) higher streamflow.

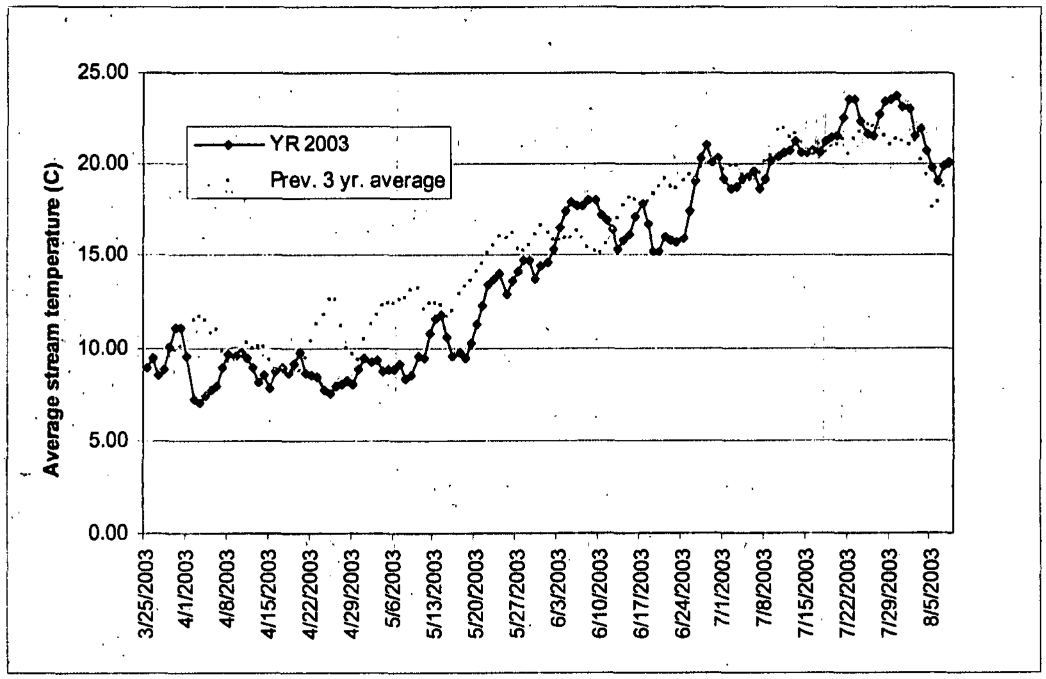


Figure 14. Average stream temperatures (°C) in 2003 and the previous 3 yr average.

Linear Relations of Catch with Average Stream Temperature

The linear regression of average daily stream temperatures °C on daily catches of all salmonids combined showed a positive relationship ($p < 0.001$; R2 = 0.34). Test results for 0+KS in YR 2003 were not valid because regression assumptions were not met (NCSS 97), similar to 0+KS data in YR 2002. 0+KS daily catches were not related to stream temperatures in YR 2001 ($p > 0.05$) and in YR 2000, a weak positive relationship was found ($p \leq 0.05$; R2 = 0.08).

Test results for 0+SH daily catches and average stream temperatures (°C) in YR 2003 were not valid because regression assumptions were not met (NCSS 97), similar to YR 2002 and YR 2001 data. In YR 2000, a significant positive relationship between 0+SH catches and average daily stream temperature was present ($p < 0.05$; R2 = 0.52).

Average daily stream temperature on 1+SH catches (log x+1 transformation) in YR 2003 was not significantly related ($p > 0.05$). In YR 2002, regression assumptions were violated and results were not reliable. In YR 2001 a significant positive relationship between 1+SH daily catches and average daily stream temperature was present ($p < 0.01$; R2 = 0.37); and in YR 2000, a negative relationship was present ($p < 0.05$; R2 = 0.20). Low R2 values indicate other variables besides stream temperature were influencing catches.

The regression of average daily stream temperature on 2+SH daily catches (log x+1 transformation) in YR 2003 showed a significant, but weak negative relationship ($p < 0.001$; R2 = 0.12). A significant negative relationship was also present in YR 2002 ($p < 0.001$; R2 = 0.58) and 2001 ($p < 0.0001$; R2 = 0.47). In YR 2000, no relationship was present ($p > 0.05$).

Regression of average stream temperature by week °C on catches of all salmonids by week was significant and positive ($p < 0.05$; R2 = 0.44) (Table 3). However, this test was strongly influenced by 0+SH catches. Although 2+SH catches by day were negatively related to stream temperature, 2+SH catches by week were not related to the average temperature by week (Table 3).

Table 3. Linear regression of average stream temperature (°C) by week on catches by week, 2003.

	Average weekly temperature °C			
Age/species	p	R2	power	relationship
All species	0.001	0.44	0.95	+
0+ KS*	> 0.05	NA	0.11	NA
0+ SH	0.001	0.46	0.96	+
1+ SH*	> 0.05	NA	0.05	NA
2+ SH	> 0.05	NA	0.22	NA

* Denotes log (x+1) transformation

A significant negative relationship between average week temperature (°C) and 0+KS week catches was present in YR 2002 ($p < 0.001$; R2 = 0.38) and YR 2000 ("-"; $p < 0.05$). In YR 2001, no significant relationship was present ($p > 0.05$).

0+ steelhead weekly catches were positively related to temperature (°C) by week in YR 2002 ($p < 0.05$; R2 = 0.26), and YR 2000 ($p < 0.05$). In YR 2001, no significant relationship was present ($p > 0.05$).

1+ steelhead weekly catches in YR 2002 and YR 2001 were negatively related to average week temperatures °C ($p < 0.05$; R2 = 0.60 and 0.51). Similar results were found in YR 2000 ("-"; $p < 0,05$).

2+ steelhead weekly catches in YR 2002 and YR 2001 were negatively related to average stream temperature °C ($p < 0.001$; R2 = 0.65 and 0.64). No relationship was found in YR 2000.

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 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, trap efficiency, and genetics, among other factors.

Fork Length and Weight

0+ Chinook Salmon

This year we measured (FL mm) 573 and weighed (g) 499 0+ Chinook salmon. Overall, fork lengths ranged from 34 – 87 mm, and averaged 67.3 mm; weights ranged from 0.3 – 7.3 g, and averaged 3.43 g (Table 4). 0+ Chinook salmon average fork length and weight in 2003 was considerably greater than previous study years (Table 4). However, in YR 2003 few 0+ Chinook salmon were captured March – May, and the sample size in YR 2003 was much lower than previous study years.

Table 4. 0+ Chinook salmon average fork length (mm) and weight (g) by study year, 2000-2003.

	0+ Chinook Salmon							
	Fork Length (mm)				Weight (g)			
Study Year	n	Range	AVE.	SEM	n	Range	AVE.	SEM
2003	573	34 - 87	67.3	0.3	499	0.3 - 7.3	3.43	0.05
2002	3517	34 - 85	52.4	0.2	1545	0.3 - 7.2	1.70	0.03
2001	2719	34 - 81	51.9	0.2	778	0.3 - 5.3	1.73	0.04
2000	3661	36 - 85	55.5	0.2	913	0.3 - 6.3	2.03	0.04

1+ Chinook Salmon

Twenty-nine fork length (mm) and weight (g) measurements were taken for 1+ Chinook salmon in YR 2003 (Table 5). Fork lengths in YR 2003 ranged from 105 – 146 mm, and averaged 123.4 mm (95% CI 120 – 127). 1+ Chinook salmon average fork length and weight in YR 2003 was greater than previous study years (Table 5); no 1+ Chinook salmon were captured in YR 2000. The greatest difference in average fork lengths and weights between study years (2003 vs. 2001) was 19.0 mm and 8.96 g.

Table 5. 1+ Chinook salmon average fork length (mm) and weight (g) by study year, 2000-2003.

	1+ Chinook Salmon							
	Fork Length (mm)				Weight (g)			
Study Year	n	Range	AVE.	SEM	n	Range	AVE.	SEM
2003	29	105 - 146	123.4	1.7	29	12.0 - 35.1	22.34	0.9
2002	17	70 - 148	108.5	3.9	17	4.3 - 41.5	16.70	2.0
2001	17	86 - 133	104.4	2.8	13	6.6 - 28.6	13.38	1.7
2000	-	-	-	-	-	-	-	-

0+ Steelhead Trout

A total of 3,338 fork length (mm) measurements were taken for 0+ steelhead trout in YR 2003. Overall, fork lengths ranged from 24 – 69 mm, and averaged 38.5 mm. 0+ steelhead trout average fork length in YR 2003 was slightly less than averages in YRS 2002, 2001 and 2000 (Table 6). The greatest difference in average 0+ steelhead fork lengths between any given study year was minimal (eg 2.4 mm).

Table 6. 0+ steelhead trout average fork length (mm) by study year, 2000-2003.

	0+ Steelhead Trout							
	Fork Length (mm)				Weight (g)			
Study Year	n	Range	AVE.	SEM	n	Range	AVE.	SEM
2003	3338	24 - 69	38.5	0.2	-	-	-	-
2002	3228	24 - 69	38.7	0.2	-	-	-	-
2001	1136	24 - 69	39.0	0.3	-	-	-	-
2000	2669	25 - 75	40.9	0.2	-	-	-	-

1+ Steelhead Trout

A total of 3,064 fork length (mm) and 1,633 weight (g) measurements were taken for 1+ steelhead trout in YR 2003. Fork lengths ranged from 57 – 119 mm and averaged 84.8 mm; weights ranged from 2.0 – 20.9 g and averaged 7.14 g (Table 7). For all four study years, the smallest fish were captured in the beginning of the trapping season. 1+ steelhead trout average fork length and weight in YR 2003 was less than averages in study years 2002, 2001, and 2000 (Table 7). The largest difference between average fork lengths (YR 2003 vs. YR 2000) and weights (YR 2003 vs. YR 2001) was 7.6 mm and 2.13 g, respectively.

Table 7. 1+ steelhead trout average fork length (mm) and weight (g) by study year, 2000-2003.

	1+ Steelhead Trout							
	Fork Length (mm)				Weight (g)			
Study Year	n	Range	AVE.	SEM	n	Range	AVE.	SEM
2003	3064	57 - 119	84.8	0.2	1633	2.0 - 20.9	7.14	0.09
2002	3049	51 - 119	86.7	0.3	1356	1.3 - 21.3	7.79	0.11
2001	2761	55 - 124	91.9	0.3	908	2.0 - 26.6	9.27	0.14
2000	2721	48 - 138	92.4	0.3	1455	1.3 - 30.7	8.29	0.13

2+ Steelhead Trout

This year we measured (FL mm) 625 and weighed (g) 583 2+ steelhead, or about 93% of the 2+ steelhead catch. In YR 2003, fork lengths ranged from 120 – 210 mm, and averaged 144.0 mm; weights ranged from 16.6 – 101.1 g and averaged 35.15 g (Table 8). 2+ steelhead trout average fork length and weight in YR 2003 was similar to YR 2002, and less than averages in YR 2001 and YR 2000 (Table 8). The largest difference between average fork lengths (YR 2003 vs. YR 2000) and weights (YR 2003 vs. YR 2000) was 20.4 mm and 13.97 g, respectively.

Table 8. 2+ steelhead trout average fork length (mm) and weight (g) by study year, 2000-2003.

	2+ Steelhead Trout							
	Fork Length (mm)				Weight (g)			
Study Year	n	Range	AVE.	SEM	n	Range	AVE.	SEM
2003	625	120 - 210	144.0	0.9	583	16.6 - 101.1	35.15	0.71
2002	1528	120 - 274	147.5	0.6	1463	12.8 - 229.6	37.87	0.51
2001	1316	125 - 218	151.2	0.5	1225	18.6 - 110.1	39.17	0.43
2000	710	136 - 220	164.4	0.6	480	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+ steelhead was 86.4 mm, and for 2+ steelhead was 143.9 mm.

Fork Length and Weight Over Time

Fork Lengths

Fork length and weight data in YR 2003 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 YR 2003 data and the average of the three previous study years. The lack of data in any given week 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 (Figure 15).

Correlation of week on average 0+ Chinook fork length (mm) in YR 2003 showed a highly significant positive relationship ($p < 0.001$; $r = 0.95$; power = 1.0), similar to the previous 3 yr average fork length (mm) over time ($p < 0.001$; $r = 0.97$; power = 1.0). 0+ Chinook salmon fork lengths steadily increased over time, and indicate growth was taking place. The difference in average fork length (mm) from the first week of captures (wk# 7) and the last week of captures in YR 2003 (wk# 15) was + 33.3 mm, compared with + 28.9 mm for the previous 3 yr average. 0+ Chinook salmon average fork length (mm) by week in YR 2003 (mean = 65.1 mm) was significantly greater than the average week fork length of the previous three study years (mean = 53.5 mm) ($p < 0.05$; power = 0.70). However, when truncating the previous three year average data to periods of data by week in YR 2003, no significant differences were found ($p > 0.05$; power = 0.35). The latter test is probably more appropriate because data in YR 2003 did not contain measurements from the smaller Chinook salmon fry normally encountered during March – April.

The correlation test for 0+ steelhead trout showed a highly significant positive relationship of fork length (mm) with time ($p < 0.001$, $r = 0.95$; power = 1.0), similar to the previous 3 yr average fork length (mm) over time ($p < 0.001$; $r = 0.97$; power = 1.0). 0+ steelhead trout fork lengths steadily increased over time, and indicate growth was taking place. The difference in average fork length (mm) from the first week of capture (wk# 1) and the last week of capture in YR 2003 (wk# 20) was + 22.7 mm, compared with + 19.6 mm for the previous 3 yr average. 0+ steelhead trout average week fork length (mm) in YR 2003 (mean = 37.1 mm) was not significantly different than the average week fork length of the previous three study years (mean = 37.4 mm) ($p > 0.05$; power = 0.05).

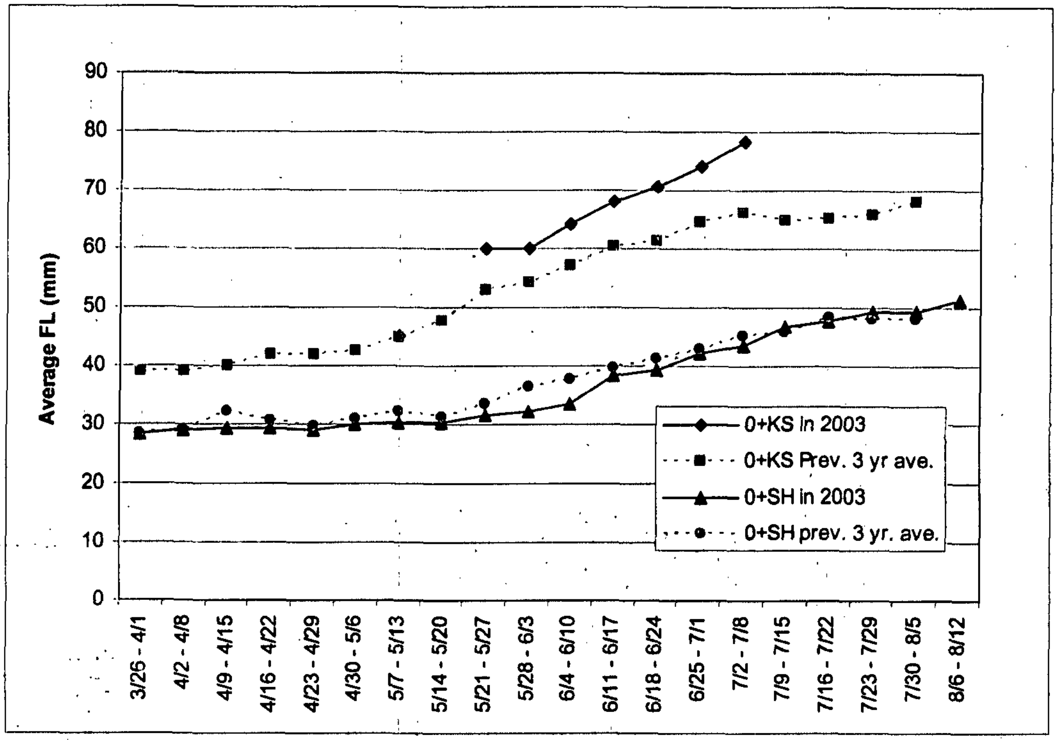


Figure 15. 0+ Chinook salmon and 0+ steelhead trout average fork lengths (mm) by week in 2003 and previous 3 year average.

The correlation test for 1+ steelhead trout showed a significant negative relationship of fork length (mm) with time ($p < 0.05$, $r = 0.52$; power = 0.7), unlike the significant positive relationship for the previous 3 year average ($p < 0.001$; $r = 0.79$; power = 1.0). (Figure 16). The difference in average fork length (mm) from the first week of capture (wk# 1) and the last week of capture in YR 2003 (wk# 20) was – 1.9 mm, compared with + 11.3 mm for the previous 3 yr average. 1+ steelhead trout average week fork length (mm) in YR 2003 (mean = 84.1 mm) was significantly less than the average week fork length of the previous three study years (mean = 90.9 mm) (ANOVA; $p < 0.001$; power = 0.97).

2+ steelhead trout average fork length (mm) by week in YR 2003 decreased over time (Correlation; $p < 0.05$; $r = 0.47$; power = 0.58). There was no significant variation in fork length (mm) by week for the previous 3 year average (Correlation; $p > 0.05$). The patterns of the average 2+ steelhead fork length in 2003 and the previous 3 year average are surprising similar in that fork lengths start out high, drop in May-June, and increase in July/early August (Figure 16). The difference in average fork length (mm) from the first week of capture (wk# 1) and the last week of capture in YR 2003 (wk# 20) was – 10.4 mm, compared with – 7.0 mm for the previous 3 yr average. 2+ steelhead trout average fork length (mm) by week in YR 2003 (mean = 145.1 mm) was significantly less than the average fork length by week of the previous three study years (mean = 153.1 mm) (ANOVA; $p < 0.05$; power = 0.62).

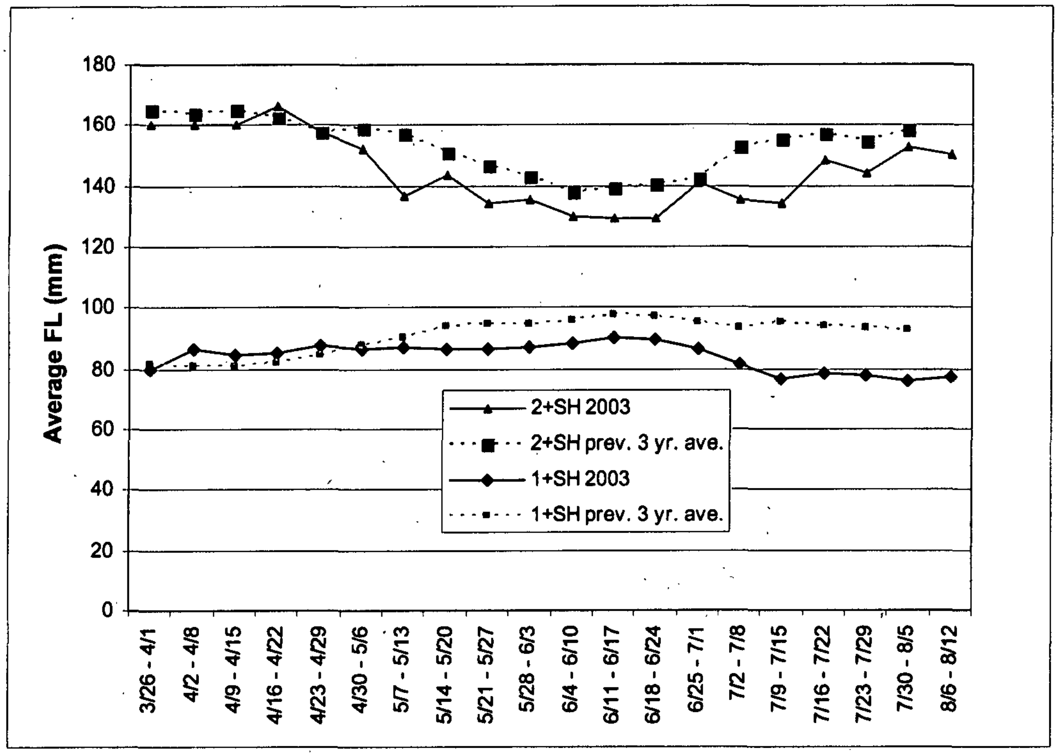


Figure 16. 1+ and 2+ steelhead trout average fork lengths (mm) by week in 2003 and the previous 3 year average.

Weight

The correlation of week number on average weight (g) for 0+ Chinook in YR 2003 showed a highly significant positive relationship ($p < 0.001$; $r = 0.98$; power = 1.0), similar to the previous 3 yr average weight (g) by week ("+", $p < 0.001$; $r = 0.99$; power = 1.0). Chinook salmon weights steadily increased over time, and indicate growth was taking place for the past 4 study years (Figure 17). The difference in average weight (g) from the first week of captures (wk# 7) and the last week of captures in YR 2003 (wk# 15) was + 4.18 g, compared with + 2.98 mm for the previous 3 yr average. Similar to the fork length data, 0+ Chinook salmon average weight (g) by week in YR 2003 (mean = 3.17 g) was significantly greater than the average week weight of the previous three study years (mean = 1.77 g) (ANOVA; $p < 0.01$; power = 0.81). When truncating the previous three year average data to periods of data collected in YR 2003, significant differences in weight were detected (ANOVA; $p < 0.05$; power = 0.70).

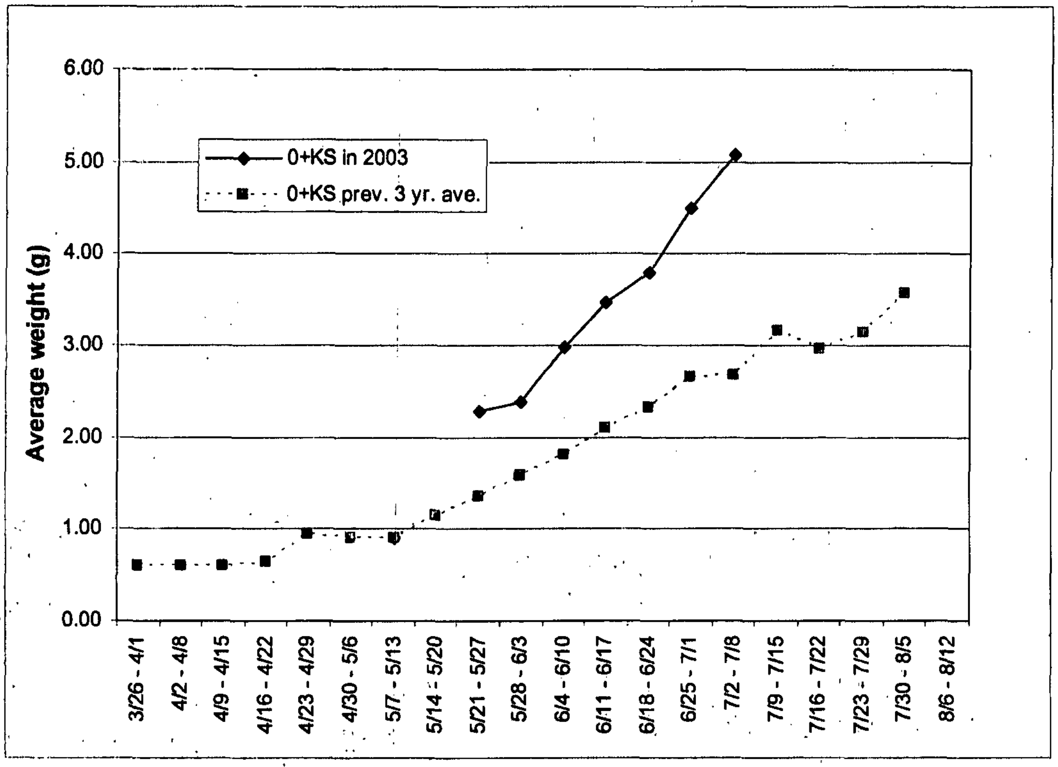


Figure 17. 0+ Chinook salmon average weight (g) by week in 2003 and the previous 3 study years.

The correlation of 1+ steelhead trout average weight (g) by week with time (week) showed a significant negative relationship was present ($p < 0.05$; $r = 0.55$), unlike the significant positive relationship for the previous 3 year average ($p < 0.001$; $r = 0.83$; power = 1.0). These test results were the same as for 1+ steelhead fork lengths. The difference in average weight (g) from the first week of capture (wk# 1) and the last week of capture in YR 2003 (wk# 20) was – 1.14 g, compared with + 4.24 g for the previous 3 yr average (Figure 18). 1+ steelhead trout median week weight (g) in YR 2003 (median = 7.35 g) was significantly less than the median week weight of the previous three study years (median = 9.39 g) (Kruskal-Wallis One-Way Anova on Ranks; $p < 0.001$).

The correlation of 2+ steelhead trout average weight (g) by week with time was not significant ($p > 0.05$). However, there was a significant negative relationship for the previous 3 year average weight (g) by week and time ($p < 0.05$; power = 0.62). The patterns of the average 2+ steelhead weight (g) in YR 2003 and the previous 3 year average are surprisingly similar in that average weight starts out high, drops in May-June, and increases in July/early August (Figure 18), similar to the pattern in fork length over time. The difference in average weight (g) from the first week of capture (wk# 1) and the last week of capture in YR 2003 (wk# 20) was – 9.91 g, compared with – 10.2 g for the previous 3 yr average. There was no significant variation among median week weights in YR 2003 (median = 36.8 g) and median week weights in the previous 3 year average (median = 40.70 g) (Kruskal-Wallis One-Way Anova on Ranks; $p < 0.05$; power = 0.36).

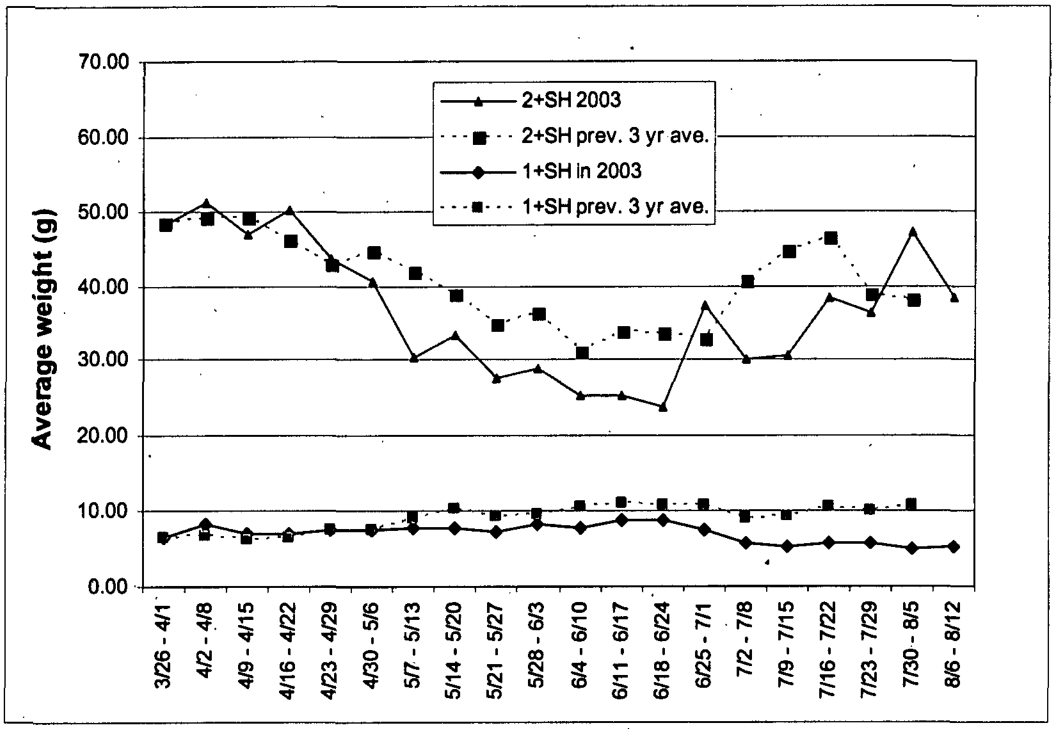


Figure 18. 1+ and 2+ steelhead trout average weight (g) by week in 2003 and the previous 3 year average.

Developmental Stages

All 1+ and 2+ steelhead trout captured were observed for developmental stages. For both 1+ and 2+ steelhead, the percentage of fish showing smolt characteristics increased considerably from previous study years (Table 9). Few 1+ steelhead (n = 27) and 2+ steelhead (n = 0) in YR 2003 were in a parr developmental stage (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. As in previous study years, observer variation was minimized by having the same individuals determine developmental stages. The most difficult stages to separate are pre-smolt and smolt. The combined percentage of pre-smolt and smolt in YR 2003 for 1+ steelhead and 2+ steelhead was 99.6 and 100%, respectively.

Table 9. Developmental stage for captured 1+ and 2+ steelhead, by study year 2000-2003.

	Developmental Stage (percentage)					
	1+ Steelhead Trout			2+ Steelhead Trout		
Year	Parr	Pre-smolt	Smolt	Parr	Pre-smolt	Smolt
2003	0.4	56.9	42.7	0.0	14.1	85.9
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

0+ Chinook salmon

We fin clipped and released 433 young-of-year Chinook salmon upstream of the trap site during 27 efficiency trials over the course of trapping. The average number of 0+ Chinook salmon used in our weekly trials (includes 3 - 6 efficiency trials) was 72, and ranged from 3 – 159 (per week). Efficiency trials were often run on consecutive days due to low catches and sample sizes, therefore, we could not determine the percentage of recaptures occurring one day after upstream release for many release groups. However, in YR 2002, the majority of recaptures (96%) occurred within one day following release.

Average weekly trapping efficiency in YR 2003 (mean = 68.4%, range = 46.3 – 100%) was higher than other study years (Table 10). Overall (seasonal) trap efficiency (number of recaptures/number marked) for 0+ Chinook salmon in YR 2003 was 65.1%, compared with 47.3% in 2002, 52.0% in 2001 and 33.9% in YR 2000 (Table 10).

Table 10. 0+ Chinook salmon trap efficiencies, 2000 - 2003.

	0+ Chinook salmon trap efficiency (percentage)		
	Weekly trapping efficiency		
Study Year	Range	Average	Seasonal
2003	46.3 – 100.0	68.4	65.1
2002	21.4 – 78.6	50.6	47.3
2001	3.2 – 96.3	55.3	52.0
2000	5.8 – 56.3	31.3	33.9

Weekly 0+KS trap efficiencies in YR 2003 were not related to gage height ($p = 0.07$). However, for the past three years, significant negative relationships were present ($p < 0.001$; $R2 = 0.58 – 0.78$). Although trap efficiencies in YR 2003 increased over time, correlation analysis did not determine a significant relationship ($p = 0.06$). In previous study years (ie 2000-2002), positive correlations between week number (time) and 0+KS trap efficiencies were present ($p < 0.001$; $R2 = 0.84 – 0.86$).

The majority of fin clipped 0+ Chinook salmon released upstream of the trap site were recovered in the 'correct' stratum. Out of 282 recaptured fin clipped Chinook, only one (0.35%) was caught in the following week's stratum; 99.6% were caught in the correct stratum. Expressed as a percentage of total marked Chinook salmon released, the straggler ($n = 1$) represented 0.23%. In YR 2002 and with a much larger sample size (2,329 marked recaptures), 99.61% were caught in the correct stratum. 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 1,890 one-plus year old steelhead upstream of the trap site during 54 efficiency trials. The average number of 1+ steelhead trout used in our weekly trials was 104, and ranged from 19 – 200 (per week). The majority of recaptures (98%) occurred within one day following release. In YR 2002, 95% of the recaptures occurred within one day following release.

Average weekly trapping efficiency in YR 2003 (mean = 20.8%, range = 12.7 – 35.3%) was considerably less than in YR 2002 (mean = 42.3%, range = 26.7 – 57.0%) (Table 11). Seasonal trap efficiency (number of recaptures/number marked) for 1+ steelhead trout in YR 2003 was 21.8%, as compared with 42.5% in YR 2002, 29.9% in YR 2001 and 20.0% in YR 2000 (Table 11).

Table 11. 1+ steelhead trout trap efficiencies, 2000 - 2003.

	1+ steelhead trout trap efficiency (percentage)		
	Weekly trapping efficiency		
Study Year	Range	Average	Seasonal
2003	12.7 – 35.3	20.8	21.8
2002	26.7 – 57.0	42.3	42.5
2001	0.0 – 46.3	24.0	29.9
2000	5.3 – 42.0	16.9	20.0

Weekly 1+SH trap efficiencies in YR 2003 were not related to average week gage height ($p > 0.05$) unlike study years YR 2002, YR 2001, and YR 2000 where positive relationships were found ($p < 0.001$; $R2 = 0.26 – 0.88$). Trap efficiencies did not significantly increase or decrease over time ($p > 0.05$), unlike during the previous three study years when trap efficiencies decreased over time ($p < 0.05$; $r = 0.48 – 0.68$).

The majority of fin clipped 1+ SH released upstream of the trap site were recovered in the correct stratum. Out of 411 recaptured fin clipped 1+SH, two (0.49%) were caught in the following week's stratum; 99.5% were captured in the correct stratum. In YR 2002, 98.9% of the 822 marked recaptures occurred in the correct stratum. The stragglers in YR 2003 (n = 2) represented 0.10% of the marked steelhead trout released upstream of the trap (n=1,936). 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 (eg 0+ Chinook salmon). We fin clipped and released 393 two-plus steelhead upstream of the trap during 56 efficiency trials. The average number of 2+ steelhead used in our weekly trials (includes 3-6 trials per week) was 23, and ranged from 8 – 56 (per week). The majority of recaptures (95%) occurred within one day following release, and was very close to the value in YR 2002 (96%).

Average weekly trapping efficiency in 2003 (mean = 17.9%, range = 0.0 – 30.4%) was less than in YR 2002 and considerably greater than YRS 2001 and 2000 (Table 12). Seasonal trap efficiency (number of recaptures/number marked) for 2+ steelhead trout in YR 2003 was 19.7%, as compared with 24.4% in YR 2002, 12.6% in YR 2001, and 15.9% in YR 2000.

Table 12. 2+ steelhead trout trap efficiencies, 2000 - 2003.

	2+ steelhead trout trap efficiency (percentage)		
	Weekly trapping efficiency		
Study Year	Range	Average	Seasonal
2003	0.0 – 30.4	17.9	19.7
2002	5.6 – 48.8	20.4	24.4
2001	0.0 – 20.7	10.9	12.6
2000	0.0 – 25.8	11.7	15.9

Weekly 2+ SH trap efficiencies in YR 2003 were not significantly related to the average gage height by week ($p > 0.05$), similar to data in YR 2000 ($p > 0.05$). However, in YR 2001, significant positive relations were found for gage height and 2+SH trap efficiencies ($p < 0.05$; R2 = 0.38). In YR 2002, weekly trap efficiencies were significantly related to gage height only when a dummy variable for night releases was included in the regression (0 = day release, 1 = night release; Zar 1999). Trap efficiencies for 2+ SH in YR 2003 were variable over time, and no significant correlation with week was detected ($p > 0.05$, $r = 0.08$, power = 0.19), similar to study years 2002, 2001 and 2000 ($p>0.05$).

The majority of fin clipped 2+ steelhead trout released upstream were recovered in the 'correct' stratum. Out of 77 recaptures, two (2.5%) were caught in the following week's stratum; conversely, 97.5% of the marked recaptures occurred in the correct stratum. Expressed as a percentage of total number of marked 2+ steelhead released upstream of the trap, the stragglers (n = 2) represented 0.51%. In study year YR 2002, 252 out of 253 marked recaptures (99.6%) were caught in the correct stratum. Clearly the assumption of passing the trap site soon after upstream release based upon time of recapture was met.

Population Estimates

0+ Chinook salmon

All population estimate models determined that very few 0+ Chinook salmon out-migrated from upper Redwood Creek in YR 2003. Comparisons of population model estimates for YR 2003 data show Carlson et al. (1998) and Darr (2000) gave similar results (Table 13). The Peterson estimate did not fall within the 95% CI of the Carlson et al. (1984) or Darr (2000) estimate, and was considered positively biased. Similar to previous study years, I chose to use the Carlson et al. (1998) estimate because it is usually more conservative, and has been field tested for accuracy with a counting fence.

Table 13. 0+ Chinook salmon population estimate model comparisons (percent error in parentheses), 2003.

Model	0+ Chinook Salmon
Carlson et al. 1998	987 (± 8.8 %)
Peterson (Ricker 1975)	1,408 (± 9.8 %)
Darr (2000)	1,043 (± 8.8 %)

We estimate that 987 (95% CI 900 – 1,074) 0+ Chinook salmon migrated past the trap site in YR 2003, compared with 518,189 (95% CI 494,834 – 541,543) in YR 2002, 378,063 (95% CI 335,290 – 420,835) in YR 2001, and 427,542 (95% CI 390,096 – 464,988) in YR 2000 (Figure 19). Population out-migration in YR 2003 was 0.19% of last year's estimate, and 0.22% of the previous three year average (average = 441,265). 0+ Chinook salmon population size in YR 2003 was severely reduced, and correlation analysis easily showed a negative slope to the regression line (Figure 19). Possible reasons for the decrease are given in Appendix 1.

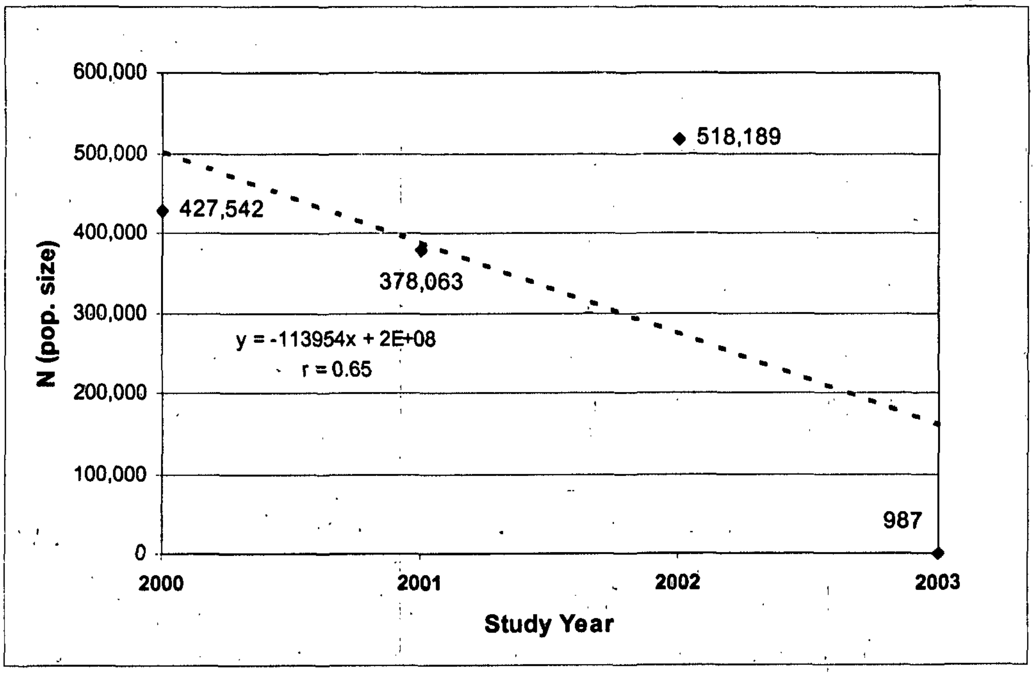


Figure 19. 0+ Chinook salmon out-migrant population estimates in four consecutive study years.

The total population estimate in YR 2003 divided by anadromous stream miles (37) and watershed area upstream of the trap site (65,000 acres) equaled 27 fish/mi and 0.01 fish/acre (Table 14). These values were substantially less than values for previous study years (Table 14).

Table 14. 0+ Chinook salmon population estimates divided by anadromous stream miles and watershed area above trap site, 2003-2000.

Study year	0+KS/mi	0+KS/acre
2003	27	0.01
2002	14,005	7.97
2001	10,218	5.82
2000	11,555	6.58

In 2003, the majority (94%) of the 0+ Chinook population out-migration occurred in June, with basically no out-migration occurring late March, April, May, and early August. Except for August, this pattern contrasted sharply with the previous three year average (Figure 20). The population estimate in YR 2003 is uni-modal, compared with a multi-modal distribution for the average of the three previous study years (Figure 20). The months of May-June accounted for the majority (72%) of 0+ Chinook salmon out-migration in the previous three study years; April was also an important month and accounted for 25% of the previous three year population estimates. Peak out-migration in 2003 occurred 6/15 – 6/21 (n = 360) compared to peaks in weekly out-migration that occurred 4/9 – 4/15 (n = 36,969), 5/7 – 5/13 (n = 45,053), 5/28 – 6/3 (n = 53,730), and 6/18 – 6/24 (n = 23,903) for the previous three year average (Figure 20). The greatest weekly peak in any given year (not graphically shown) was 79,848 (5/07/01 – 5/13/01). Similar to all study years, 0+ Chinook salmon population estimates by week tracked very well (same shape or pattern) as weekly catches. Both population out-migration lines show a bell shaped curve distribution, with migration tapering off to very low values 7/8 onward.

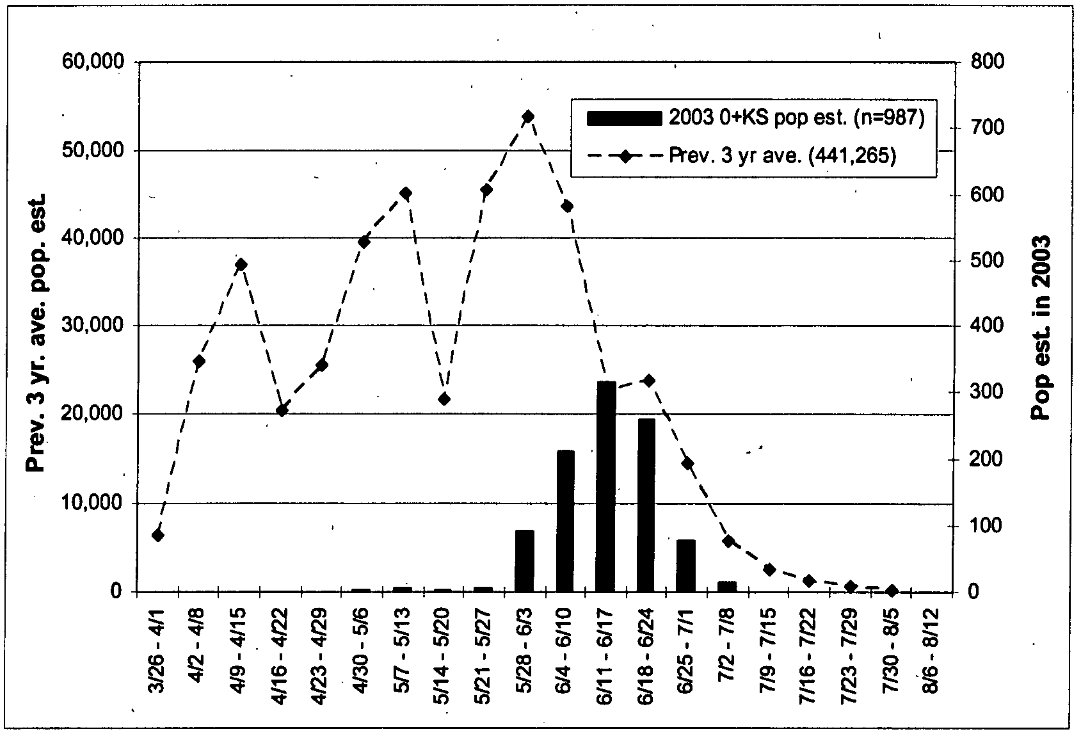


Figure 20. 0+ Chinook salmon population estimates by week in 2003 and the previous 3 year average.

<u>**1+ Steelhead trout**</u>

Comparisons of 1+ steelhead trout population estimates for 2003 data show Carlson et al. (1998), Peterson (Ricker 1975), and Darr (2000) gave similar results (Table 15). 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 15. 1+ steelhead trout population estimate model comparisons (percent error in parentheses), 2003.

Model	1+ Steelhead Trout
Carlson et al. 1998	30,670 (± 9.1 %)
Peterson (Ricker 1975)	32,036 (± 9.9 %)
Darr (2000)	31,982 (± 9.4 %)

We estimate 30,670 (95% CI 27,865 – 33,475) 1+ steelhead trout migrated past the trap site in YR 2003, compared with 28,501 (95% CI 26,701 – 30,300) in YR 2002, 50,174 (95% CI 45,159 – 55,189) in YR 2001, and 68,328 (95% CI 59,055 – 77,601) in YR 2000 (Figure 21). Population out-migration in YR 2003 was 1.1 times greater than in YR 2002, but 37% less than the previous three year average (average = 49,001). Over the four years of study, linear regression/correlation determined a negative relationship with time (year); 1+ steelhead population estimates decreased from study year 2000 to 2003. 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 recruitment to one year age due to poor or decreased over-winter survival of young of year fish, 3) changes in over-summer habitat space for rearing due to differences in stream discharge, 4) reduced habitat quality within study years, and 5) some combination of factors 1 - 4.

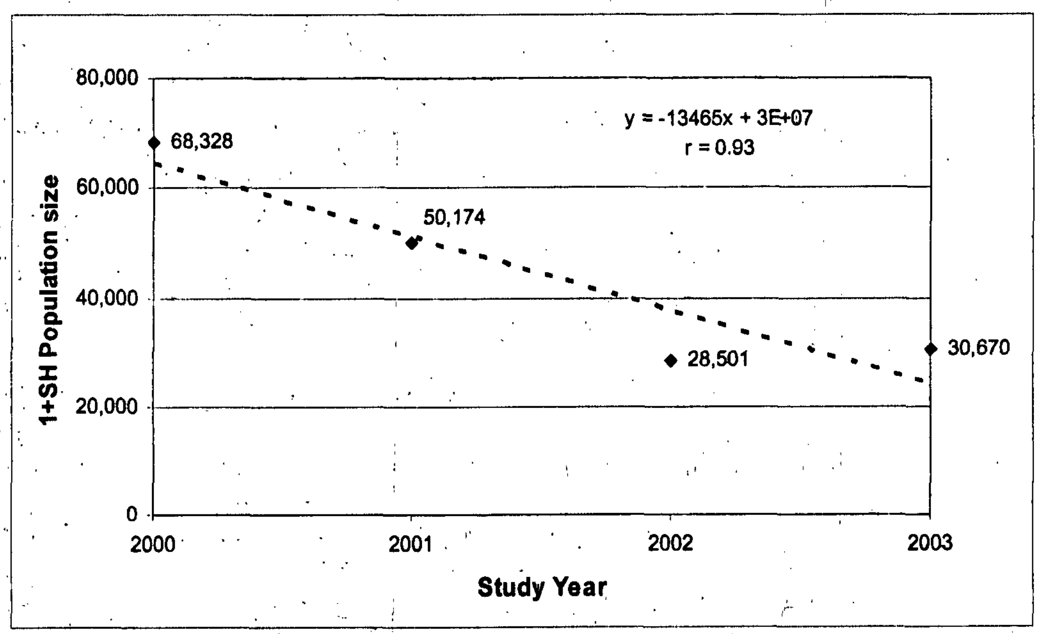


Figure 21. 1+ steelhead trout population estimates in study years 2000 - 2003.

The total population estimate in YR 2003 divided by anadromous stream miles (37) and watershed area upstream of the trap site (65,000 acres) equaled 829 fish/mi and 0.47 fish/acre (Table 16). Values in YR 2003 were slightly higher than in YR 2002, and much less than values for YRS 2001 and 2000.

Table 16. 1+ steelhead trout population estimates divided by anadromous stream miles and watershed area above trap site, 2000 - 2003.

Study year	1+SH/mi	1+SH/acre
2003	829	0.47
2002	770	0.44
2001	1,369	0.78
2000	1,847	1.05

In 2003, May (n = 12,503), and June (n = 9,634) were important months for 1+ SH population out-migration, and accounted for 72.2% of the total, which was similar to the average of May-June (73.0%) for the previous three years data. For YR 2003 data and the previous three years data, higher out-migration occurred in May than other months. 1+SH out-migration in YR 2003 during April (12.7%) was less than the average out-migration in April for the previous three years (22.4%). However, in the higher water year 2003, July accounted for more of the total out-migration (13.1%) than July of the previous study years (2.5%).

The pattern of population out-migration by week varied (Figure 22). Population out-migration greater than 4,000 individuals occurred one time in YR 2003, compared with six times for the previous three year average. The greatest weekly peak in any given year (not graphically shown) was 16,244 (5/07/00 – 5/13/00).

Both lines of 1+ steelhead population estimates show a bell shape curve distribution, with a single high peak occurring in May. The peak in YR 2003 was one week later than the peak for the average of the previous three years of data. Both population lines show population out-migration tapered by the end of July.

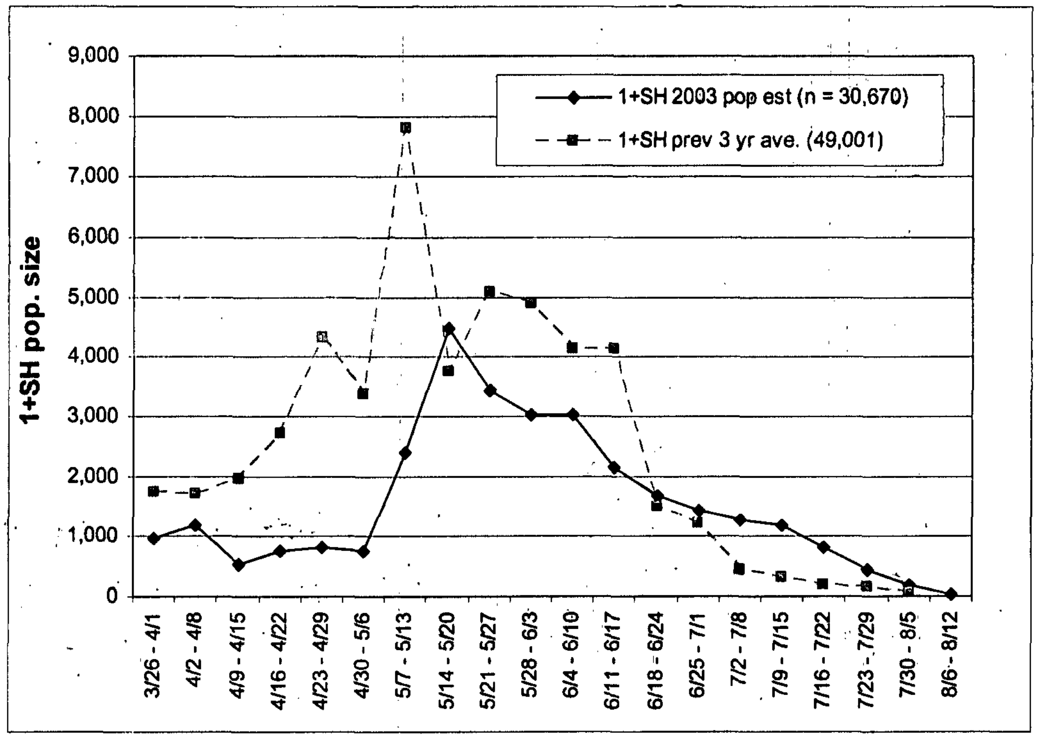


Figure 22. 1+ steelhead trout population estimates by week in 2003 and the previous three year average.

2+ Steelhead Trout

Although no weekly population estimates were pooled in YR 2003, three separate weeks had zero efficiency and the over-all trap efficiency was used to estimate the trap efficiency for those weeks. The resultant population estimate was about 11% less than if zero efficiencies were used for those strata.

Comparison of 2+ steelhead population model estimates in YR 2003 show Carlson et al. (1998) was slightly more conservative than the Peterson estimate (Ricker 1975), and considerably more conservative than the Darr estimate (2000) (Table 17). The Darr point estimate did not fall within the 95% CI of other estimates. The Darr population estimate was 1.4 times higher than Carlson et al. (1998) estimate, and considered positively biased. Darr's population estimate was 39% (or 1,124 2+SH) greater than the Carlson et al. (1998) estimate, and 28% (or 863 2+SH) greater than the Peterson (Ricker 1975) estimate. Although the Darr point estimate was considered biased, the 95% CI for Darr's point estimate (2,543 – 5,397) was wide enough to encompass the Carlson et al. (1998) and Peterson (Ricker 1975) population estimate.

I chose to use the Carlson et al. (1998) estimate because it is usually more conservative, makes better 'biological sense' and has been field tested with a counting fence, (albeit with young of year juvenile salmonids) (Sparkman 2002a).

Table 17. 2+ steelhead trout population estimate model comparisons (percent error in parentheses), 2003

Model	2+ Steelhead Trout
Carlson et al. (1998)	2,846 (± 19.5 %)
Peterson (Ricker 1975)	3,107 (± 19.1 %)
Darr (2000)	3,970 (± 35.9 %)

The total 2+ steelhead trout Carlson et al. (1998) population estimate over the course of the trapping period in YR 2003 equaled 2,846 (95% CI 2,291 – 3,401) compared with 7,370 (95% CI 6,286 – 8,455) in YR 2002, 12,668 (95% CI 9,786 – 15,550) in YR 2001, and 4,739 (95% CI 3,669 – 5,808) in YR 2000 (Figure 23). Population out-migration in 2003 was about 61% less than in YR 2002, and 66% less than the previous three year average (average = 8,259 individuals). Over the four years of study, linear regression/correlation determined a negative relationship with time (year); 2+ steelhead population out-migration decreased from study years 2000 to 2003.

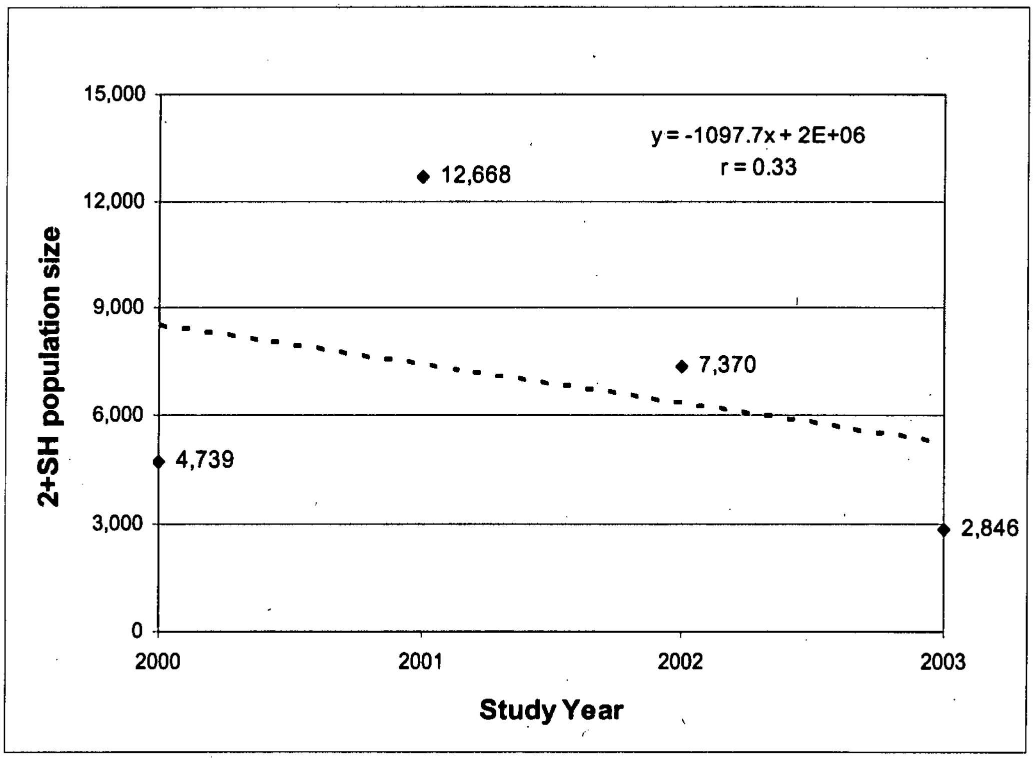


Figure 23. 2+ steelhead trout population estimates in 2000 - 2003.

The total population estimate in YR 2003 divided by anadromous stream miles (37) and watershed area upstream of the trap site (65,000 acres) equaled 77 fish/mi and 0.04 fish/acre (Table 18). Values in YR 2003 were much less than values for the previous 3 year's data.

Table 18. 2+ steelhead trout population estimate divided by anadromous stream miles and watershed area above trap site, 2000 - 2003.

Study year	2+SH/mi	2+SH/acre
2003	77	0.04
2002	199	0.11
2001	342	0.19
2000	128	0.07

In 2003, April (n = 612), May (n = 1,108), and June (n = 623) were the most important months for 2+SH out-migration and accounted for 83% of the total population estimate. For the previous three year average, April and May accounted for the majority of population out-migration (71%). Based upon the previous three year average, April was the peak month for 2+SH out-migration, however, in the wetter water year of YR 2003, May was the peak month. Additionally, June and July accounted for a greater percentage of out-migration in 2003 (37.2%) compared with the previous three year average (25.4%).

The pattern of 2+SH population out-migration by week in YR 2003 and for the previous three year average was variable (Figure 24). The previous three year average of 2+SH out-migration started out relatively high and climbed to the first and greatest peak three weeks after trap deployment (4/9 – 4/15). However, the average was strongly influenced by study year 2000 and 2001 because, unlike study years 2002 and 2003, 2+SH out-migration was relatively high in the beginning of the trapping season. 2+SH out-migration by week in YR 2003 was much less than the previous three year average (Figure 24), and reached the greatest peak (n = 363) during 5/14 – 5/20 (seven weeks after trap deployment or five weeks after the greatest peak for the three year average). Both patterns show out-migration tapered to low values by July 23rd.

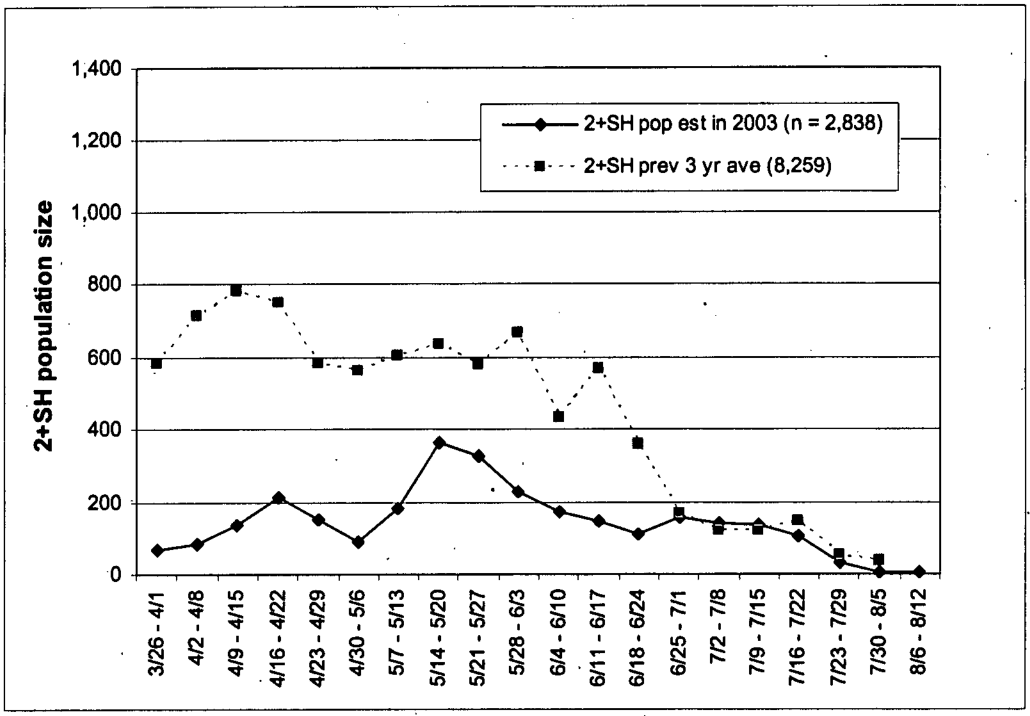


Figure 24. 2+ steelhead trout population estimates by week in 2003 and the previous three year average.

Additional Experiments

Numerous aquatic and terrestrial invertebrate species were found in the stomachs of 1+ and 2+ steelhead out-migrants in upper Redwood Creek (Table 19).

Table 19. Orders of invertebrate species found in the stomachs of 1+ and 2+ steelhead trout, 2003.

Aquatic or Terrestrial	Order
Aquatic	Ephemeroptera (Mayfly)
Aquatic	Plecoptera (Stonefly)
Aquatic	Trichoptera (Caddisfly)
Aquatic	Hemiptera (True Bug)
Aquatic	Megaloptera (Alder fly)
Aquatic	Coleoptera (Beetle)
Aquatic	Diptera (True fly)
Terrestrial	Arachnida (Spiders)
Terrestrial/aquatic	Oligochaeta (Earthworms)
Terrestrial	Hymenoptera (Ants)
Terrestrial/aquatic	Isopoda (Sow Bugs)

The large majority of juvenile salmonids held in the live car to test for delayed mortality survived (Table 17). Study results also show these fish were able to withstand stream temperatures as high as 22 °C for the 24 hr period. The 2+SH that died had gill lesions.

Table 17. Delayed mortality test results, 2003.

Date	Spp.	(n)	Average Temp (°C)	# Fin clipped Morts/total	# Fin clipped Percent Mortality	# Stomach pumped Morts/total	# Stomach pumped Percent Mortality
6/29 – 6/30	0+ KS	4	20.2	0/4	0.00	-	-
7/01 – 7/02	0+ KS	2	18.9	0/2	0.00	-	-
7/02 – 7/03	0+ KS	2	18.8	0/2	0.00	-	-
7/03 – 7/04	0+ KS	2	19.0	0/2	0.00	-	-
7/05 – 7/06	0+ KS	1	19.4	0/1	0.00	-	-
4/21 – 4/22	1+ SH	21	8.6	0/21	0.00	-	-
5/08 – 5/09	1+ SH	11	8.4	0/11	0.00	-	-
5/08 – 5/09	1+ SH	6	8.4	-	-	0/6	0.00
5/10 – 5/11	1+ SH	1	9.5	0/1	0.00	-	-
5/11 – 5/12	1+ SH	30	10.1	0/30	0.00	-	-
5/14 – 5/15	1+ SH	8	11.2	-	-	0/8	0.00
5/22 – 5/23	1+ SH	10	13.6	-	-	0/10	0.00
5/29 – 5/30	1+ SH	10	14.2	-	-	0/10	0.00
6/06 – 6/07	1+ SH	10	17.8	-	-	0/10	0.00
6/13 – 6/14	1+ SH	10	15.6	-	-	0/10	0.00
7/11 – 7/12	1+ SH	10	20.7	-	-	0/10	0.00
7/18 – 7/19	1+ SH	10	21.3	-	-	0/10	0.00
7/24 – 7/25	1+ SH	23	22.0	0/23	0.00	-	-
4/08 – 4/09	2+ SH	2	9.6	0/2	0.00	-	-
5/08 – 5/09	2+ SH	1	8.4	-	-	0/1	0.00
5/14 – 5/15	2+ SH	7	11.2	0/7	0.00	-	-
5/14 – 5/15	2+ SH	2	11.2	-	-	0/2	0.00
5/22 – 5/23	2+ SH	5	13.6	-	-	0/5	0.00
5/28 – 5/29	2+ SH	2	14.6	0/2	0.00	-	-
5/30 – 5/31	2+ SH	4	14.5	0/4	0.00	-	-
5/30 – 5/31	2+ SH	4	14.5	-	-	0/4	0.00
6/06 – 6/07	2+ SH	1	17.8	-	-	0/1	0.00
6/07 – 6/08	2+ SH	3	18.1	0/3	0.00	-	-
6/13 – 6/14	2+ SH	1	15.6	0/1	0.00	-	-
6/13 – 6/14	2+ SH	1	15.6	-	-	0/1	0.00
6/16 – 6/17	2+ SH	1	17.8	0/1	0.00	-	-
6/22 – 6/23	2+ SH	2	15.8	0/2	0.00	-	-
6/25 – 6/26	2+ SH	3	17.5	0/3	0.00	-	-
6/29 – 6/30	2+ SH	3	20.3	0/3	0.00	-	-
7/01 – 7/02	2+ SH	4	18.7	0/4	0.00	-	-
7/06 – 7/07	2+ SH	2	18.7	0/2	0.00	-	-
7/08 – 7/09	2+ SH	2	20.2	0/2	0.00	-	-
7/11 – 7/12	2+ SH	4	20.7	-	-	0/4	0.00
7/13 – 7/14	2+ SH	2	20.6	0/2	0.00	-	-
7/21 – 7/22	2+ SH	2	22.6	1/2	50.00	-	-

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 – 0.62%, and using all species was 0.32% of the total juvenile salmonid catch (Table 20). The larger, modified livebox and removing debris from the livebox at night helped reduce and minimize trap mortalities.

Table 20. Trapping mortality for juvenile salmonids in 2003.

Age/Species	Number captured	Number of mortalities	Percent mortality
0+ steelhead	102,954	355	0.34%
1+ steelhead	7,258	2	0.03%
2+ steelhead	623	1	0.16%
0+ Chinook	649	4	0.62%
1+ Chinook	29	0	0.00%
Cutthroat trout	1	0	0.00%
Total:	111,514	362	0.32%

Juvenile salmonid trap mortality in YR 2003 equaled 0.32%, and was less than previous study years (Table 21).

Table 21. Juvenile salmonid trap mortality in four study years.

Study Year	Number captured	Number of mortalities	Percent mortality
2003	111,514	362	0.32%
2002	361,426	1,480	0.41%
2001	239,262	1,631	0.68%
2000	191,760	934	0.49%
Total:	903,962	4,407	0.49%

DISCUSSION AND RECOMMENDATIONS

The fourth consecutive year of trapping in upper Redwood Creek can be characterized as a 'wet' year, with average precipitation and streamflow greater than historic and recent averages. Rainfall during the 2003 trapping season was nearly 2.6 times greater than the average rainfall in the previous three study years. Rainfall in April 2003 (14.6 in.) was four times higher than the average of the previous three study years, and 2.8 times higher than the 18 year average. High rainfall amounts caused the streamflow to rise to levels previously thought un-trappable. Although there were flows we could not safely trap in, we only missed 11 d or 8% of the normal trapping season that runs from the end of March to the beginning of August. Our ability to effectively trap in such variable weather and streamflow conditions as in 2003 re-enforces and strengthens the case for a long term juvenile salmonid out-migration study in upper Redwood Creek.

In the discussion of previous reports on trapping in upper Redwood Creek, I routinely mention the importance of conducting this monitoring study for multiple consecutive years in order to more fully address environmental (local and hemispherical) and biological variability. We are fortunate in Redwood Creek to have the USGS gaging station (about 8 miles upstream of the trap site) and a rainfall station (about five miles downstream of the trap site) to collect hydrologic data for each study year, in addition to fairly abundant data on physical characteristics of Redwood Creek (eg sediments, zones of aggregation or degradation, etc). We anticipate collecting large scale environmental data (eg El Nino, La Nina, Pacific Decadal Oscillations) from the literature when available. The current four study years we have collected juvenile salmonid data encompass some 'good' variability in stream discharge, which is ultimately related to rainfall and the hydrologic cycle, among other factors. Study years 2000 and 2002 were medium wet years, YR 2001 was a drought year, and YR 2003 was an above average wet year. The importance of streamflow on the abundance of juvenile salmonids may not be more evident than with our hypothesis concerning the loss of the Chinook salmon cohort in YR 2003 in upper Redwood Creek.

0+ Chinook Salmon

For the previous three years, young-of-year Chinook salmon (Ocean type) have dominated trap catches and population estimates. Upper Redwood Creek appeared to be doing 'pretty good' with a season high of 518,189 ($\pm$ 4.5%) migrating past the trap site in YR 2002; average population out-migration for the two years before YR 2002 was 402,802 individuals. The population estimate in YR 2003 of less than 1,000 individuals indicates a cohort or year class failure. One-thousand 0+ Chinook salmon equates to what would emerge from a single redd with mediocre to fair survival. I am confident that we did not miss 0+ Chinook salmon (that they somehow passed the trap without being caught) because: 1) trap efficiencies were relatively high (68%), and 2) the trap operated continually when 0+ Chinook salmon out-migration typically peak in upper Redwood Creek (May and June). Of course the next question we face "is why did the cohort failure happen?". I presented a multiple hypothesis with four plausible reasons for the decline because we really need another high water year with similar high peak flows to see if any

Chinook salmon juvenile out-migration occurs the following spring/summer (ie greater sample size). If no out-migration occurs after these flows (as in YR 2003), then we probably can define an upper threshold to discharges in upper Redwood Creek above which redd survival can be expected to be severely reduced. Don Chapman (pers. comm.) suggested early on that we critically look at differences in flows between study years with respect to streambed mobilization (and redd gravels jiggling). Comparisons of hydrologic data in 2003 with previous study years show that two flow events during December 2002 (4,800 cfs on 12/16/02; 6,300 cfs on 12/28/02) were higher than any measured flow event during the previous three winters. The greatest streamflow peak of about 6,300 cfs on December 28, 2002 was considered great enough to mobilize bedload and redd gravels based upon the experience of scientists (geologists, hydrologists) who have worked in Redwood Creek (Randy Klein, Greg Bundros, Vicki Ozaki, and Mary Ann Madej, pers. comm.). The recurrence interval (RI) for this flow event was calculated as 3.09 years (Randy Klein, pers. comm.). The duration of the 6,300 cfs flow was short (one hour), and by the next hour the high flow decreased to about 5,400 cfs. Stream flows greater than or the same as 5,000 cfs lasted for five hours near this time frame.

This year we were fortunate that the USFWS operated a trap in lower Redwood Creek; their results (catches) showed less than 500 young-of-year Chinook Salmon juveniles were captured (Bill Pinnix pers comm. 2003). If there were significant Chinook salmon juvenile production in Redwood Creek below our trap site, their trap would have caught many more juveniles than it did. The lower trap was instrumental in showing that the severe decrease in Chinook numbers was not limited to upper Redwood Creek, and probably included the entire Redwood Creek watershed upstream of where Prairie Creek (RM3) enters Redwood Creek.

Several investigators have indicated that the scour of redds due to high stream flows or floods can often cause severe decreases in production of juvenile salmonids (Gangmark and Bakkala 1960; McNeil 1966; Devries 1997; Holtby and Healey 1986; Tripp and Poulin 1986 *in* Schuett-Hames et al. 2000; Montgomery et al. 1996; Schuett-Hames et al. 2000; and Don Chapman pers. comm.). Estimates of mortality attributable to high flows and redd scour can reach 90% (Schuett-Hames et al. 2000), if not more. Schuett-Hames et al. (2000) also report that in the watershed where their research was conducted (Carnation Creek, Vancouver, BC), the recurrence interval for flow events does not have to be very large (RI 1.4 yr; 16.7 m^3/s or 590 cfs) to cause redd scour. Of course, any given RI for one stream that causes bedload mobility and redd scour may not cause the same effects in a different stream. Don Chapman (pers. comm.) suggested that even if the redd did not scour or become buried by excessive gravel deposition, high flows in late December could have shaken redd gravels surrounding egg pockets, and shocked sensitive, un-eyed Chinook salmon eggs. Un-eyed or 'green' eggs are in early stages of cell development, and are extremely susceptible to mortality from shock. This is a likely scenario because Chinook salmon spawning in Redwood Creek usually begins in late November to early December, dependent upon streamflow and other factors (eg disruption of sand bar formation at mouth of Redwood Creek to Pacific Ocean).

The idea of the negative relationship of high flows or an above average water year on juvenile Chinook salmon production in upper Redwood Creek has become our 'working' hypothesis. However, more data (streamflow and out-migrant population estimates) needs to be simultaneously collected because historic flow records show that yearly peak flows in upper Redwood Creek have reached or exceeded 6,000 cfs about one-half of the time (Mary Ann Madej pers. comm.). Studies designed to investigate bedload mobilization and redd scour (or excessive sediment deposition or intrusion in redds) on a yearly basis in upper Redwood Creek are recommended (eg. scour chains, streambed cross sectional profiles, etc) (Don Chapman pers. comm.; Mary Ann Madej pers. comm.), in addition to adult salmon spawning surveys.

With respect to the future of Chinook salmon in upper Redwood Creek, we can only hope that the variable age of returning adults (multiple adult age classes return each year), in addition to relatively high out-migration in the previous three years, will cover the recruitment failure in 2003. The 2003 cohort would have returned to Redwood Creek as adults in years 2005 (as two years old), 2006 (as 3 years old), 2007 (as 4 years old), and possibly 2008 (as 5 years old).

1+ Chinook Salmon

One-year-old Chinook salmon make up a small percentage of juvenile Chinook salmon catches (e.g. < 0.02%), exclusive of YR 2003 data. Slightly more 1+ Chinook salmon were captured in 2003 (n = 29) than previous study years (18, 21, 0). Prior to YR 2003 data, more 1+ Chinook salmon were captured in April (73%) than other months of trap operation. During the wet water year of 2003, both April (51%) and May (33%) were important months for out-migration. Using all year's data, 1+ Chinook salmon out-migration is over by June 1st. The timing of 1+ Chinook salmon from upper Redwood Creek is similar to the timing of out-migration for 1+ Chinook salmon in streams such as Brownlee-Oxbow section of Snake River (ID), Yakima River (WA), and Taku River (AK) (Healey 1991).

Fork lengths (mm) were originally used to separate 1+ Chinook (stream type) from 0+ Chinook (ocean type) juveniles because length differences were readily apparent. For example, the average size of 1+ Chinook salmon in YR 2003 was 123 mm (range 105 to 146 mm) compared with 67 mm (range 34 to 87 mm) for 0+ Chinook salmon. Fork lengths of 1+ Chinook salmon captured in upper Redwood Creek are comparable to 1+ Chinook salmon fork lengths in other streams (range in average = 68 to 134 mm)(Healey 1991).

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

1+ Chinook salmon from upper Redwood Creek are more likely to be progeny of late fall/winter-run Chinook salmon adults than from spring-run adults because few if any spring-run Chinook salmon are observed during the spring and summer (Dave Anderson, pers. comm.). For example, in 20 years of adult summer steelhead snorkel dives, adult spring Chinook salmon were observed in 1 year (Dave Anderson, pers. comm.). In addition, stream flows during late spring/summer months can become so low that adult upstream passage into upper Redwood Creek can become problematic. High stream temperatures (eg > °C) may also inhibit any adult spring-run Chinook salmon migration into upper Redwood Creek, or inhibit their ability to over-summer in pools. I recommend collecting genetic samples from both 1+ and 0+ Chinook salmon juveniles in the future to test for significant genetic differences between the two different life histories.

0+ Steelhead Trout

Considerable numbers of young-of-year steelhead trout are captured each season as they migrate out of upper Redwood Creek (four year average catch = 96,229 individuals). Large numbers of 0+ steelhead trout were observed each year in stream margins, and in the later part of the season, 0+ steelhead (and a few 1+ steelhead) were also frequently observed using thermal refugia where sub-gravel water entered the stream margin. The mainstem of Redwood Creek appears to be vital for 0+SH rearing, and the importance of the mainstem for 0+ steelhead rearing should not be underestimated. Boehne and House (1983; *in* Bjornn and Reiser 1991) support this finding by reporting results of their study in coastal and cascade streams that documented most of the steelhead spawning occurred in fourth and fifth order streams. In such cases, the offspring are at least beginning the rearing process in streams that are not small tributaries.

0+ steelhead trout downstream migration from upper Redwood Creek was on-going from time of trap deployment (end of March) through the end of the trapping season (early August). In YR 2003, peak out-migration occurred about one week later than the previous three year average, and may reflect rainfall and stream discharge differences among water year(s). Although May and June accounted for 79% of the catches in study years 2000-02, the months of June and July accounted for 90% of the 0+ steelhead catches in YR 2003. Using all four years of data, May-July accounted for 97% of the total catches. Downstream migration by week can be considerable, with peak catches reaching 18,872 individuals during July 2 – July 8, 2003. The greatest peak catch by week in any given study year was 21,167, and occurred 5/28 – 6/3 in YR 2002. Although catches dropped considerably from late July to early August in the four study years, some out-migration takes place after trap removal in early August (last day's catch on August 9 equaled 123 individuals).

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. A 'best' guess of population size for downstream migrating 0+ steelhead in 2003 would be over 200,000 individuals.

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) variable percentage of passive or active downstream migration or 5) some combination of factors 1, 2, 3, and 4. The potential of variable trap efficiencies among study years was considered small because most 0+SH catches occur in June when stream flows are typically the same. Additionally, the trap was 'fished' in the same manner throughout study years (use of weir panels, etc). Our study was not designed to specifically look at why more or less 0+ steelhead are out-migrating in one year compared with other study years. Catches of 0+ steelhead in a given year may influence catches of 1+ steelhead the following year. If the out-migrating 0+ steelhead do not re-migrate upstream of the trap site, then fewer 1+ steelhead will be produced the following year (assuming upstream 0+SH carrying capacity is not met).

The number of 0+ steelhead that can remain upstream of the trap site is some function of a fish's disposition to out-migrate (or to not out-migrate) and habitat carrying capacity. Meehan and Bjornn (1991) comment that steelhead have a variety of migration patterns that can vary with local conditions, and that the trigger for out-migration can be genetic or environmental. 0+ steelhead out-migration is probably not solely dependent upon habitat carrying capacity because 0+ steelhead are caught when upstream habitat space appears fairly high. It appears (at least in upper Redwood Creek) that some 0+ steelhead will always be out-migrating regardless of the current carrying capacity of upstream habitat. For example, we routinely catch 0+ steelhead in April and May which is a time when streamflow and habitat space are relatively high. Some authors (e.g. Graves and Burns 1970) attribute early out-migration to changes in habitat carrying capacity, which can change from year to year. Habitat carrying capacity is related to environmental (eg hydrology, cover, stream depth and discharge, stream temperatures, sedimentation, etc.) and biological variables (eg food availability, predation, and salmonid behavior), and any interactions between the two (Murphy and Meehan 1991). Trap catches of 0+ steelhead leaving upper Redwood Creek regressed positively with average stream temperature ($p = 0.001$; $R2 = 0.46$). This may indicate that as streamflow decreased (evidenced by stream gage height), stream temperatures increased (evidenced by temperature monitoring), and more 0+ steelhead trout moved downstream to be captured. It is probable that prior to out-migration, hundreds or even thousands of young-of-year steelhead trout resided in places where less than 50 reside during the critical low-flow period (and electro-fishing months) of August, September, and October.

Thus, the large numbers of 0+ steelhead trout re-distributing in a downstream manner May through July suggest late summer electro-fishing/snorkel counts in August, September, and October is an improper tool to monitor how many fish were produced in a given tributary, stream reach, or specific habitat location. The electro-fishing/snorkel population estimate will only include some smaller percentage of fish which failed to out-migrate. For example, electro-fishing efforts undertaken in August – October in upper Redwood Creek would not be able to include the $90,000^{+}$ steelhead that out-migrated prior to sampling, particularly if the juveniles stayed in mainstem habitats where electro-fishing normally cannot efficiently occur. Large numbers of 0+ steelhead probably out-migrate in other streams besides Redwood Creek as well, and this appears to be a normal life history strategy in Northern California. The US Forest Service trapping efforts in Horse Linto Creek (tributary to Trinity R, CA.) in YR 2003 showed that 14,184 young-of-year steelhead trout (or 97% of the total steelhead catch) were caught from April 22 – July 20 as they emigrated downstream; an additional USFS trap in Willow Creek (tributary to Trinity R) also caught a much larger number of young-of-year steelhead trout than older age classes (Cindy Walker pers. comm. 2003; Rowe 2003).

I am doubtful that a large majority of the 0+ steelhead population that out-migrates prior to August or September can be viewed as 'surplus' or 'lost' production, which will never augment future adult steelhead populations. Meehan and Bjornn (1991) state that some steelhead populations normally out-migrate soon after emergence from redds to occupy other rearing areas. In streams that are temperature impaired (many in Humboldt county are; see CWA 2002), out-migration prior to times when streams reach high or maximum temperatures (late July/August) can be viewed as an advantageous life history strategy. Graves and Burns (1970) found that the percentage of the total juvenile steelhead catch consisting of fry ranged from a low of 5% to a high of 81%, the increase of which they attribute to negative changes in habitat and carrying capacity. I speculate that the more numerous 0+ steelhead out-migrating to better rearing areas are the ones that will have a greater survival and influence on steelhead population dynamics than the few that stay behind in often less favorable habitat. However, I do not know of any studies which have specifically looked into this.

I question the usefulness of sampling designs which determine population estimates of 0+ and 1+ steelhead trout in August-October to track steelhead population (and sub-population) status and trends over years. As previously mentioned, these efforts would not include the tens of thousands, if not more, juvenile steelhead that emigrated prior to the sampling period. Additionally, 0+ steelhead trout populations can be subjected to severe losses due to mortality, often exceeding 80% before reaching age one (Meehan and Bjornn 1991). Such high mortality would severely limit any inference about future population projection based upon young of year steelhead numbers. Natural mortality will also occur to the 0+ cohort as they age from one to two years old, and from two years old to returning adult. Utilizing seven years of data, Ward and Slaney (1993) found that the number of steelhead smolts eventually produced (about 6,500) from steelhead fry was the same regardless of whether there were 80,000 – 240,000 fry produced from spawning activity. In such a scenario, increasing numbers of 0+ steelhead encountered over years would give a false signal of population projection and status/trends. For example, if in year one I determined 80,000 fry were present, in year two I determined 160,000 fry were present, and in year three I determined 240,000 fry were present, I would logically expect more smolts to be present in the future, which would then equate to more adults in the future (holding other factors constant). However, 80,000 to 240,000 fry lead to the same number of smolts; the number of fry encountered would not be very meaningful. To project back from 0+ SH to adults that produced them would also not be very meaningful if most of the 0+SH out-migrated prior to the 0+SH sampling period in late summer/early fall; or if the number of 0+SH remaining in August-October each year was merely an artifact of varying percentages of out-migration.

1+ Steelhead Trout

One plus-year-old steelhead trout catches in the four study years ranged from 7,258 – 14,775 and have declined from study year 2000 to 2003. The low catches in YR 2003 (n = 7,258) are responsible for the negative trend (albeit short term) over years because previous catches (by study year) were similar to each other (12,217 – 14,775). Although the number of days not trapped (n = 11 or 8% of trapping period) in 2003 was greater than other study years (average = 2 days missed trapping), it is unlikely that these missed days would account for a large percentage of out-migration. During higher flow periods in April and May 2003, trap efficiencies for 1+SH were high enough (eg 18%) to show that the trap was properly functioning. Based upon good trap efficiencies and low catches of un-marked fish, it appeared that 1+ steelhead out-migration decreased during those high and muddy flow events; the fish probably resided near cover (refugia) until flows decreased to where normal out-migration would once again occur. During the higher water year in 2003, 1+SH out-migration (using catches) was delayed compared with the average of the three previous study years. For example, catches in May and June accounted for 75% of the total catch, compared with the previous three year average where 79% were caught in April and May. Additionally, more 1+SH out-migrated in July (12%) in 2003 than for the average in July for the previous three study years (average = 2%, range = 1.6 – 3.3%). Regardless of study year, May was the most important month for 1+SH out-migration. The peak catch by week in YR 2003 occurred four weeks after the peak of the average of the previous three study years. The 1+ steelhead catch distribution in YR 2003 approximated a bell shaped curve, and suggest the trapping period covered significant out-migration. In addition, the peak catch by week in YR 2003 occurred about eight weeks after trap placement. 1+ steelhead catches dropped considerably from the end of July in YR 2003; and in the previous three study years, 1+ steelhead catches decreased considerably from the first week of July to the end of the trapping period.

1+ steelhead average fork length (mm) steadily decreased over study years, from a high of 92.4 mm in YR 2000 to a low of 84.8 (mm) in YR 2003. 1+ steelhead average week fork length in YR 2003 was significantly less than the average of the three previous study years. 1+ steelhead weight showed the same relationships as fork length.

1+ Steelhead Trout Population Size

Trap efficiencies for 1+ steelhead in YR 2003 were less than in YR 2002, but about the same as in study years 2000 and 2001. Unlike previous study years, trap efficiencies in YR 2003 were not related to gage height or time (week). Similar to previous study years, the majority of marked fish recaptures fell within the correct stratum (eg 99.5%) and provided more evidence that the assumption of marked fish passing the trap site within the correct stratum was met.

The preliminary trend of 1+ steelhead trout population out-migration over the four study years was negative. However, additional study years are required to more fully describe patterns in 1+ steelhead out-migration from upper Redwood Creek. The 1+ steelhead population in YR 2003 was slightly higher (1.1 times greater) than in YR 2002, 39% less than in YR 2001, and 55% less than the estimate in YR 2000. The 1+ steelhead estimate in YR 2003 was 37% less than the previous three year average (ave. = 49,001). 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 of 0+ steelhead, 5) over winter survival of 0+ steelhead, and 6) some combination of factors 1-5. Although more data is required to answer why the 1+SH population appears to be decreasing, it could be due to large numbers of 0+ steelhead leaving upper Redwood Creek in the previous study year(s) (which assumes 0+ SH carrying capacity upstream of the trap site is not met).

Similar to catch data, population data in study year YR 2003 showed a temporal delay in out-migration compared with the previous three year average. For example, less out-migration occurred in April (13%) and May (41%) 2003, than for April (22%) and May (49%) in the previous three year average. However, in both data sets, May was the most important month for 1+ steelhead population out-migration. In the wet water year of 2003, June and July accounted for far more out-migration (44%) than June and July during the previous three year average (26%). The peak population out-migration by week in 2003 showed a slight temporal delay from the previous three year average by one week. 1+ steelhead out-migration by week can be considerable, with the peak of the previous three year average equaling 7,824 individuals. In YR 2003 the greatest peak by week for 1+ steelhead was 4,483. Using all four years of data, the greatest peak in weekly out-migration was 16,244 in YR 2000, 6,963 in YR 2001, 4,180 in YR 2002, and 4,483 in YR 2003.

The 1+ steelhead weekly population out-migration in YR 2003 (and for the previous three year average) approximated a bell shaped curve, and suggest the trapping period covered significant out-migration. In addition, the peak catch by week in YR 2003 occurred about seven weeks after trap placement. 1+ steelhead out-migration in YR 2003 dropped to very low values at the end of July; in the previous three study years, 1+ steelhead out-migration decreased considerably by the first week of July.

The large numbers of 1+ steelhead emigrating in April, May, June, and sometimes July would not be included in electro-fishing/snorkel surveys conducted in August, September, or October Thus, the number of 1+ steelhead encountered during those months may not reflect the true numbers originally present in that habitat, reach, or stream.

The USFWS marked about 581 1+ steelhead at the upper Redwood Creek trap site to investigate travel time from this trap (RM 32) to their trap located at RM 4. Unfortunately, they did not catch any of the specially marked fish (photonic), but they later snorkeled the Redwood Creek estuary and observed some of the 1+ fish that were given photonic marks. The USFWS did catch some of the fin clipped 1+ steelhead that we used in efficiency trials. In addition, Dave Anderson and I observed upper Redwood Creek fin clipped 1+ steelhead in the estuary during June 2003.

Currently we are unsure what percentage of the 1+ steelhead trout are actually entering the estuary and ocean. We do know that some 1+ steelhead emigrating from upper Redwood Creek are in the estuary because we observed fin clipped fish while assisting Dave Anderson's estuary sampling during the summer of 2003 and 2002. Adult steelhead scale collection and analyses are recommended to determine the freshwater age of returning adult steelhead in upper Redwood Creek. In YR 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, Maher and Larkin (1955) found that in a British Columbia river, 1.9% of the returning adult steelhead examined for life history showed an ocean entry at one-years-old. They further documented returning adults that spent one year in freshwater reached adult lengths similar to the adult length of juvenile steelhead that spent 2 or 3 years in the freshwater before ocean entry (Maher and Larkin 1955). Shapovalov and Taft (1954) reported eight percent of the returning steelhead adults in a given sample (n = 116) had spent one year in freshwater as juveniles. Pautzke and Meigs (1941) found a much higher percentage of the one year freshwater residency life history (eg 16%) in adult steelhead collected from the Green River in Puget Sound. In the Keogh River in British Columbia, McCubbing (2002) reported that eight percent of the returning adult steelhead had spent one year in freshwater before entering the ocean. To briefly summarize, we know that some of the 1+ steelhead trout emigrating from upper Redwood Creek are entering the estuary and presumably the ocean, but we do not know what percentage of the returning adult steelhead in upper Redwood Creek have this life history. We also know that of the 374 1+ steelhead marked with an elastomer fin injection in 2001, none were re-captured by the upper trap in subsequent study years, thus providing some evidence that these fish were not re-migrating back upstream of the trap site after out-migrating from upper Redwood Creek. Had the fish migrated back upstream of the trap site and then resumed downstream migration the following spring/summer, we would have caught at least a few individuals (assuming mark retention).

2+ Steelhead Trout

In several studies investigating steelhead life histories, the majority of the returning adult steelhead spent two or more years as juveniles in freshwater prior to ocean entry (Pautzke and Meigs 1941; Maher and Larkin 1955; Smith and Ward 2000; McCubbing 2002). For example, Pautzke and Meigs (1941) reported that 84% of returning adult steelhead in the Green River had spent two or more years as juveniles in freshwater. Maher and Larkin (1955) found that 98% of the adult steelhead they examined had spent two or more years in freshwater prior to entering the ocean, and McCubbing (2002) reported 92% of steelhead adults in a British Columbia stream had spent two or more years as juveniles in freshwater. Thus, it appears that 2+ steelhead trout juveniles are the most important (and most direct) group of juvenile steelhead that contribute to future adult steelhead populations.

Two plus year old steelhead trout catches in the four study years ranged from 623 – 1,589, and have declined from study year 2000 to 2003. However, prior to YR 2003 data, the three year pattern in catches was positive. The 11 days that we did not trap in

2003 were considered to have only small effects on total catches; each catch day expressed as a percentage of total catch ranged from 0.0 – 2.9%. The maximum daily catch in 2003 (n = 18; on 5/17, 5/20, and 5/21) equated to 2.9%. During higher flow periods in April and May 2003, 2+ SH trap efficiencies were high enough (21%) to show that the trap was properly functioning. Based upon good trap efficiencies and low catches of un-marked fish, it appeared that 2+ steelhead out-migration decreased during high and muddy flow events during late March and April. I speculate that these fish resided near cover (for refugia) until flows decreased to where normal out-migration would once again occur. During the higher water year in 2003, 2+ steelhead out-migration in April 2003 (22% of total) was much less than previous study years for April (average = 37%). Catches in May were nearly the same percentage for YR 2003 data (38%) and the average of the previous three study years (37%). More noticeable differences in the percentage of total catch occurred in June (20%) and July (16%) 2003, compared with the average of the same months for the previous three study years (14% for June, 8% for July). May accounted for more 2+ steelhead catches in YR 2003 and for the average of the previous three study years than any other month of trap operation; and using all year's catch data, May was the most important month for 2+ steelhead catches. The first peak catch by week in 2003 (4/16 – 4/22) occurred two weeks before the average of the previous three study years, and the second peak catch in 2003 (5/14 – 5/20) occurred two weeks after the peak of the average of the previous three study years (4/30 – 5/6).

2+ steelhead average fork length (mm) decreased over study years, from a high of 164 mm in YR 2000 to a low of 144 mm in YR 2003. 2+ steelhead average week fork length in YR 2003 was significantly less than the average of previous study years. Weight showed similar relationships except there was no significant difference between the median weight in YR 2003 and the previous three year median. The general decrease in fork length over study years could negatively affect survival to adulthood, based upon Ward and Slaney (1988) who found that steelhead smolt to adult survival was positively correlated with smolt length and weight. However, whether this will be similar for 2+ steelhead smolts leaving upper Redwood Creek is unknown. Additional growth should occur in the Redwood Cr estuary.

<u>2+ Steelhead Trout Population Size</u>

Trap efficiencies in YR 2003 (18%) were less than in YR 2002, and higher than in study years 2000 and 2001. 2+ steelhead trap efficiencies in YR 2003 were not linearly related to gage height (stream surface elevation), nor were efficiencies related to time (week). Similar to previous study years, the majority of marked fish recaptures fell within the correct stratum (eg 97.5%) and provided more evidence that the assumption of marked fish passing the trap site within the correct stratum was met.

The overall (seasonal) trap efficiency was used for three separate weeks because for those strata we had no marked recaptures; the resulting population estimate was about 11% less than if zero efficiencies were used during those strata. I believe that inserting the overall trap efficiency for 2+ steelhead into strata without marked recaptures is appropriate because it is theoretically impossible to catch out-migrating juvenile salmonids with a zero percent trap efficiency (when recapture #'s = 0). The mark/recapture models used for determining population estimates frequently overcome this by adding a "1" to either the number of marked fish released or to the number of captured fish, and to the number of recaptured fish. Otherwise, in cases of no recaptures in a given stratum, there would be a zero population estimate because of a "0" in the recapture component to the model, which is usually a denominator in the model equation. For illustration, the basic population estimate model equation is $N = MC/R$, and if the $R = 0$, then $N = 0$; however, if the trap caught fish (which it did for those strata), then N could not equal zero. It seems un-likely that a weekly population estimate derived from a zero recapture would be accurate.

To overcome this, ODFW protocol recommends inserting the seasonal trap efficiency. ODFW cautions that the method of inserting an overall or season trap efficiency for a stratum (week) may be less accurate under a condition when the majority of recaptures occurred under different flows than when the marked fish were released. This is a reasonable assertion. However, with the Redwood Creek trap data, we have multiple marked releases and subsequent recaptures occurring throughout the course of trapping, which minimizes this potential problem. Additionally, the seasonal trap efficiency that I inserted was numerically close to trap efficiencies for weeks before and after the troubled stratum. Nevertheless, I believe ODFW's method would produce a more reliable estimate than if the investigator 'let' the model calculate a weekly population estimate based upon zero recaptures.

The models I used for determining the 2+ steelhead population estimate in YR 2003 gave varied estimates. The 2+ steelhead population estimate in YR 2003 using Carlson et al. (1998) was slightly more conservative than the Peterson estimate (Ricker 1975) by about 261 fish, and considerably more conservative than the DARR (2000) estimate by 1,124 2+SH. The Darr (2000) estimate was noticeably higher (by a factor of 1.3 – 1.4) than either the Carlson et al. (1998) or Peterson (Ricker 1975) estimate. In 2003, DARR produced a very unlikely (and unreliable) population estimate of about 750 fish for weeks 17 and 18 (7/13 -7/26), as compared with the Carlson et al. (1998) estimate of 194 individuals for the same time period. This time period is when the stream is in a low flow condition, and based upon the previous three years, corresponds to relatively low numbers of 2+SH out-migrants. Additionally, the majority of the stream is passing through the cone area of the trap such that it appears very unlikely that 750 fish could pass the trap with only 35 being captured. On the other hand, it is likely that 194 individuals could pass the trap site with 35 2+ SH captured. The Darr population model (2000) consistently (4 years in a row) produced a much higher estimate (and with wider confidence intervals) for 2+ steelhead than other models, and appears to be unreliable with respect to estimating 2+ steelhead population point estimates (Sparkman 2002a). Phil Law (pers. comm.) gave compelling reasons (statistical and biological) for favoring the Carlson et al. (1998) model over DARR (Appendix 6).

The preliminary trend in 2+ steelhead population out-migration from upper Redwood Creek over the four years of study was negative. I must urge caution in interpreting these preliminary results because it could take a minimum of 10 years to detect the 'true' longer-term trend in population out-migration. Additionally, prior to the 2003 study year, the pattern of population out-migration over the previous three years of study was positive. The 2+ steelhead population estimate in YR 2003 was 61% less than in YR 2002, 77% less than the YR 2001 estimate, and 40% less than the 2+ steelhead population estimate in YR 2000. The 2+ steelhead population estimate in YR 2003 was about 65% less than the previous three year average (ave. = 8,259). Differences in out-migrant population size among years could be due to numerous factors, and may relate to the number of 0+ or 1+ steelhead that emigrated the year before (assuming upstream carrying capacity was not met). If carrying capacity was met, I speculate that the number of 0+ and 1+ steelhead that out-migrated will not affect next year's out-migrant populations. As we collect more trapping data over years (and data points), we will be able to investigate such relationships with more certainty using linear regression techniques.

Similar to catch data, 2+ steelhead population out-migration in 2003 appeared to show a temporal delay compared with the previous three year's data and the average of the previous three years. For the past three years, 2+ steelhead out-migration was typically highest in April (except for 2001 where May was the highest), which accounted for 30 – 40% of the 2+SH population estimate. In 2003, April accounted for 22% of the total population estimate. April accounted for more out-migration than other months using the average of the previous three years (eg 39%). In YR 2001 and YR 2003, May accounted for the highest percentage of 2+SH out-migration (33 – 39%). In the wet water year of 2003, July accounted for more 2+SH out-migration (15%) than July for the previous three years data (range = 5 – 10%; ave. = 6.5%). Using all years data, April and May accounted for the majority of 2+SH out-migration (69%).

Similar to 1+ steelhead population out-migration, the weekly peak in 2+ steelhead population out-migration showed a slight temporal delay from the previous three year average by one week. 2+ steelhead out-migration by week can be considerable, with the peak of the previous three year average equaling 783 individuals. In YR 2003 the greatest peak by week for 2+ steelhead was 363. Using all four years of data, the greatest peak in weekly out-migration was 1,094 in YR 2000, 1,463 in YR 2001, 847 in YR 2002, and 363 in YR 2003. The 2+ steelhead weekly population out-migration in YR 2003 approximated a normal bell shaped curve, and suggests the trapping period covered the majority of significant out-migration. This contrasts the average of the previous three years in which the distribution appears skewed to the left (beginning to middle of trapping period). However, the skewness is primarily due to study year 2000 when the peak in weekly out-migration occurred the second week of trap operation. For the remaining study years (2002 and 2002), the peak in out-migration occurred 9 and 3 weeks after trap placement. 2+ steelhead out-migration reached low levels near the end of July for the average of the previous three years and 2003 data (< 54 individuals per week).

The USFWS marked about 18 2+ steelhead trout at the upper Redwood Creek trap site to investigate travel time to the trap at RM 4. The lower trap did not catch any of the marked 2+ steelhead trout, however, some were observed in the estuary while snorkeling.

As with 1+ steelhead, I recommend that we should have a person assist Dave Anderson in his estuary sampling to specifically look for either photonic (mark used by USFWS) or efficiency fin clipped 2+ steelhead.

Although there seems to be few studies that specifically look at steelhead smolt to adult survival, steelhead life history studies in a British Columbia stream (Keogh River) show there is a positive linear relationship between out-migrating 2+ smolts and returning adult steelhead (Ward 2000). Ward (2000) cites other authors who report of similar positive linear relationships between smolts and adults along the British Columbia coast (eg Smith and Ward 2000; Welch et al. 2000). Additionally, Ward (2000) showed that by separating data into two time series (1976-1986 and 1987-1994), a Beverton-Holt curve explained 97% and 79% of the variability in the number of 2+ steelhead smolts produced by returning spawners for those two time periods. Survival from smolt to adult can be variable, and may range from an average of 15% (during 1976-1989) to an average 3.5% (during 1990-1995) (Ward 2000). Ward and Slaney (1988), reporting on data from the Keogh River for 1978 – 1982 cohorts, determined survival from smolt to adult ranged from 7% to 26%, and averaged 16%. Meehan and Bjornn (1991) reported steelhead smolt to returning adult survival can be a relative high ranging from 10 – 20% in streams that are coastal to a low survival of 2% in streams where steelhead must overcome dams and travel long distances to reach spawning grounds.

With respect to younger juvenile stages (0+ and 1+), the 2+ steelhead smolt is the best candidate for assessing steelhead status, trends, and abundance when information on adult steelhead is unavailable or un-attainable. 2+ steelhead have overcome the numerous components of stream survival that younger steelhead (0+ and 1+) have not yet completely faced (over-summer, over-winter, etc). For example, any given estimate for 0+ and 1+ steelhead taken during the late summer will be particularly tenuous for use as a trend or status if high mortality occurs over the winter. However, the spring/summer emigrating 2+ steelhead smolt survived the over-wintering period (and all previous potential bottle necks in the stream, excluding the estuary). Along these same lines, Ward et al. (2003) reported that the 2+ smolt was a more reliable response variable than juvenile densities because of being less variable.

Coho Salmon

For the past consecutive four years we have not seen any juvenile coho salmon. We look at every individual fish we catch, and it seems highly probable that the trapping effort would catch some juveniles if they were present above the trap site. Therefore I don't believe that coho salmon are successfully returning to spawn upstream of 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, pers. comm. 2001) observed schools of adult coho salmon in areas upstream of the current trap site while growing up in Redwood Valley. He particularly mentioned seeing coho in the 1940's and early 1950's. Every year he watched the fish swim past him 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. Minor Creek, a tributary to Redwood Creek upstream of the trap site, supposedly supported runs of coho salmon. Lacks Creek, a tributary to Redwood Creek downstream of the trap site by about 9 miles, supports coho salmon (Bill Jong, pers. comm.; CDFG 1953). Prairie Creek (tributary to Redwood Creek at about RM 3) supports a fairly stable population of coho salmon.

Cutthroat Trout

A low number of cutthroat trout were captured in all four study years (< 9 individuals each year, total = 18). 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. For example, juvenile salmonid trapping efforts in Prairie Creek consistently capture cutthroat trout during spring/early summer as they migrate downstream (Walt Duffy, pers. comm.). We did not consider any of the young-of-year steelhead to be progeny of cutthroat trout because few aged 1 and older cutthroat trout were captured in any given year (< 9 per year; average 4 per year). It seems very unlikely that low numbers of cutthroat trout could produce a significant portion of the juvenile trout captures. We considered the percentage of 0+ cutthroat included in the 0+ steelhead catch was low and negligible.

Electro-fishing and snorkel surveying tributaries and mainstem reaches of Redwood Creek are recommended to determine the current spatial structure of cutthroat trout in the Redwood Creek watershed.

ACKNOWLEDGEMENTS

I would like to thank Bob Barnum for access to his property, and his continued interest in salmon and steelhead in upper Redwood Creek. I thank Redwood Creek Landowners Association for continued assistance in trap operations and funding over the course of the study, and the CDFG Steelhead Report Card Program for providing funding in June, July, and August. I thank Don Chapman for his interest in the study, and for offering valuable suggestions and comments. I thank Phil Law for critically reviewing population estimate methods, mark-recapture data, and model choice. I would also like to thank Catherine Stone for reviewing the manuscript, and I thank Doug Parkinson for his contribution to the study. A big thanks goes to the crew that counted and looked at every fish we captured and marked, for removing debris in the evenings/night, and for their positive attitudes. The crew included: Pat Moorhouse, Damon Zeller, Margo Williams, Todd Newhouse, Mike Gillmore, and Forest Cottrell, with occasional help from Cindy Walker and Heidi Peura. I would also like to thank Colinda Gutierrez, Cambell Thompson, and Scott Silloway for building the water circulatory system; and Mark Zuspan for constructing the live cages used for releasing efficiency fish at night.

LITERATURE CITED

Bjornn TC, and DW Reiser. 1991. Habitat requirements of salmonids in streams. Pages 83-138 *in* W.R. Meehan (ed.). Influences of forest and rangeland management on salmonid fishes and their habitats. Special Publication 19, American Fisheries Society. Bethesda, Maryland.

Brown R. 1988. Physical rearing habitat for anadromous salmonids in the Redwood Creek basin, Humboldt County, California. MS thesis, Humboldt State University, Arcata, California. 132 p.

[CDFG] California Department of Fish & Game. 1953. Lacks Creek stream survey. Call number 3496.

Carlson SR, LG Coggins Jr., and CO Swanton. 1998. A simple stratified design for mark-recapture estimation of salmon smolt abundance. Alaska Fishery Research Bulletin 5(2): 88-102.

Cashman SM, HM Kelsey, and DR Harden. 1995. Geology of the Redwood Creek Basin, Humboldt County, California. Pages B1 – B13 *in* Nolan KM, Kelsey HM, and Marron DC, editors. Geomorphic Processes and Aquatic Habitat in the Redwood Creek Basin, Northwestern California. US Geologic Survey Professional Paper 1454.

[CDWR] California Department of Water Resources. 2003. CDEC bulk data: O'Kane (Blue Lake) (Redwood Creek). Web page http://cdec.water.ca.gov/cgi-progs/selectQuery?

[CWA] California Water Act. 2002. CWA section 303(d) list of water quality limited segment; approved by the State Water Resources Control Board, February 4, 2003.

Darroch Analysis with Ranked Reduction (DARR). 2000. Version 1.0.1.

Devries, P. 1977 Riverine salmonid egg burial depths: review of published data and implications for scour studies. Canadian Journal of Fisheries and Aquatic Sciences 54:1685-1698.

Gangmark HA, and RG Bakkala. 1960. A comparative study of unstable and stable (artificial channel) spawning streams for incubating king salmon at Mill Creek. California Fish and Game. 46:151-164.

Graves DS, and JW Burns. 1970. Comparison of yields of downstream migrant salmonids before and after logging road construction on the South Fork Caspar Creek, Mendocino County. California Department of Fish and Game, Inland Fisheries Administration Report No. 70-3: 1-12.

Healey MC. 1991. Life history of Chinook Salmon (*Oncorhynchus tshawytscha*). Pages 313 – 393 *in* C. Groot and L. Margolis (eds.). Pacific Salmon life histories. UBC Press, University of British Columbia, Vancouver BC.

Hintze J. 1998. Number Crunchers Statistical System. NCSS 97, Version 6.0.

Maher FP and PA Larkin. 1955. Life history of the steelhead trout of the Chilliwack River, British Columbia. Transactions of the American Fisheries Society 84:27-38.

McCubbing D. 2002. Adult steelhead trout and salmonid smolt migration at the Keogh River, B.C. during Spring 2002. Habitat Conservation Trust Fund. Contract Number: CBIO3006. Province of British Columbia, Ministry of Water, Land, and Air Protection, Biodiversity Branch, Fisheries Research and Development, University of British Columbia, Vancouver, BC. 34 p.

McNeil WH. 1966. Effect of the spawning bed environment on reproduction of pink and chum salmon. Fishery Bulletin Volume 65, Number 2. Contribution Number 198. College of Fisheries. University of Washington, Seattle.

Meehan WR, and TC Bjornn. 1991. Salmonid distributions and life histories. Pages 47-82 *in* W.R. Meehan (ed.). Influences of forest and rangeland management on salmonid fishes and their habitats. Special Publication 19, American Fisheries Society. Bethesda, MD.

Merritt RW, and KW Cummins, eds. 1996. An introduction to the aquatic insects of North America. Dendall/Hunt Publishing Company, Dubuque, Iowa.

Montgomery DR, JM Buffington, NP Peterson, D Schuett-Hames, and TP Quinn. 1996. Streambed scour, egg burial depths, and the influence of salmonid spawning on bed surface mobility and embryo survival. Canadian Journal of Fisheries and Aquatic Sciences 53:1061-1070.

Murphy ML, and WR Meehan. 1991. Stream Ecosystems. Pages 17 – 46 *in* W.R. Meehan (ed.). Influences of forest and rangeland management on salmonid fishes and their habitats. Special Publication 19, American Fisheries Society. Bethesda, MD.

[NMFS]. National Marine Fisheries Service. 1997. Final Rule: Endangered and Threatened Species: Threatened status for Southern Oregon/Northern California Coast Evolutionarily Significant Unit (ESU) of coho salmon. Federal Register, Vol. 62, No. 87, May 6, 1997. 24,588 p.

[NOAA] National Oceanic and Atmospheric Administration. 2000. Endangered and Threatened Species: Threatened Status for one steelhead Evolutionarily Significant Unit (ESU) in California: Final Rule. 50 CFR Part 223 [Docket No. 000202022-0156-02] ID 012100F, RIN 0648-AN58, pps. 36,074-36,094.

[NOAA] National Oceanic and Atmospheric Administration. 1999. Endangered and Threatened Status for Southwestern Washington/Columbia River Coastal cutthroat trout in Washington and Oregon, and delisting of Umpqua River cutthroat trout in Oregon: Proposed Rule; 50 CFR Parts 223, 224, and 226, Docket No. 960723205-9057-02, ID 121198A, RIN 1018-AF45; pps 16397-16413.

[NOAA] National Oceanic and Atmospheric Administration. 1999. Endangered and Threatened Species; Threatened Status for two Chinook salmon Evolutionarily Significant Units (ESUs) in California: Final Rule. 50 CFR Part 223 [Docket No. 990303060-9231-03],ID 022398C, RIN 0648-AM54, pps. 50,394-50,415.

[NOAA] National Oceanic and Atmospheric Administration. 1999. Fact Sheet: West Coast Coho Salmon (*Oncorhynchus kisutch*). 2 p.

[ODFW] Oregon Department of Fish and Wildlife. 2002. Sampling protocols for downstream migrant fish traps. Salmonid life-cycle monitoring project. Http://www.orst.edu/Dept/ODFW/life-cycle/TRPMETH3.HTM

Pautzke CF, and RC Meigs. 1941. Studies on the life history of the Puget Sound steelhead trout (*Salmo Gairdnerii*). Transactions of the American Fisheries Society, 70:209-220.

Ricker WE. 1975. Computation and Interpretation of Biological Statistics of Fish Populations. Bulletin of the Fisheries Research Board of Canada. 382 p.

Rowe TA. 2003. Downstream Migrant Trapping Report: Horse Linto Creek and Willow Creek. U.S.D.A. Forest Service, Lower Trinity Ranger Station, Willow Creek, California, USA.

Schuett-Hames DE, NP Peterson, R Conrad, and TP Quinn. 2000. Patterns of gravel scour and fill after spawning by chum salmon in a Western Washington stream. North American Journal of Fisheries Management 20:610-617.

Shapovalov L, and AC Taft. 1954. The life histories of the steelhead rainbow trout (*Salmo gairdneri gairdneri*) and silver salmon (*Oncorhynchus kisutch*) with special reference to Waddell Creek, California, and recommendations regarding their management. Fish Bulletin Number 98. California Department of Fish and Game, Sacramento. 375 p.

Shaw T, and CL Jackson. 1994. Little River Juvenile Salmonid Out-Migration Monitoring. United States Fish and Wildlife Service, Coastal California Fish and Wildlife Office, Arcata, Ca. 44 p.

Smith BD, and BR Ward. 2000. Trends in wild adult steelhead (*Oncorhynchus mykiss*) abundance for coastal regions of British Columbia support the variable marine survival hypothesis. Canadian Journal of Fisheries and Aquatic Sciences 57:271-284.

Solazzi MF, SL Johnson, B Miller, and T Dalton. 1998. Salmonid life-cycle monitoring project. Oregon Department of Fish and Wildlife, 31 p.

Sparkman MD. 2002a. Upper Redwood Creek juvenile salmonid downstream migration study, 2000-2002. California Department of Fish and Game Steelhead Research and Monitoring Program Annual Report 2a5:62 p.

____________ 2002b. Mad River juvenile steelhead downstream migration study. California Department of Fish and Game Steelhead Research and Monitoring Program Annual Report 2a3:32 p.

____________ 2000. Redwood Creek rotary screw trap downstream migration study, Redwood Valley, Humboldt County, California, April 4-August 5, 2000. 38 p.

Tripp D, and VA Poulin. 1986. The effects of logging and mass wasting on salmonid spawning habitat in streams on the Queen Charlotte Islands. British Columbia Ministry of Forests and Lands, Land Management Report 50, Vancouver.

[USGS] United States Geological Service. 2003. Surface water data for California: monthly stream flow statistics. Web page *http://water.usgs.gov/ca/nwis/monthly?*

Ward BR. 2000. Declivity in steelhead (*Oncorhynchus mykiss*) recruitment at the Keogh River over the past decade. Canadian Journal of Fisheries and Aquatic Sciences 57:298-306.

____________2003. In press. Stream restoration for anadromous salmonids by the addition of habitat and nutrients. Symposium abstract http://www.asf.ca/symposium2002/abstracts/4-5addedhabitat.html

Ward BR and PA Slaney. 1988. Life history and smolt-to-adult survival of Keogh River steelhead trout (*Salmo gairdneri*) and the relationship of smolt size. Canadian Journal of Fisheries and Aquatic Sciences 45:1110-1122.

____________ 1993. Egg-to-smolt survival and fry-to-smolt density dependence of Keogh River steelhead trout. Pages 209-217 *in* RJ Bigson and RE Cutting [eds.]. Production of juvenile Atlantic salmon, *Salmon salar*, in natural waters. Canadian Special Publication of Fisheries and Aquatic Sciences. 118.

Zar JH. 1999. Biostatistical Analysis. Prentice Hall, Upper Saddle River, New Jersey. 663 pps.

PERSONAL COMMUNICATIONS

Anderson, David. 2003. Redwood National and State Parks, Fisheries Biologist, Orick, California.

Bundros, Greg. 2003. Redwood National and State Parks, Geologist, Arcata, Ca.

Chapman, Don W. 2003. McCall, Idaho.

Chezum, Bill. 2001. Upper Redwood Creek resident and property owner. Redwood Valley, Humboldt County, California.

Chezum, Mike. 2002. Upper Redwood Creek resident and property owner. Redwood Valley, Humboldt County, California.

Duffy, Walter G. 2003. California Cooperative Fishery Research Unit Project Leader, U.S. Geological Survey, Humboldt State University, Arcata, Ca.

Klein, Randy. 2003. Redwood National Park Service, Hydrologist. Arcata, Ca.

Jong, Bill. 2003. California Department of Fish & Game, Fisheries Biologist, Arcata, Ca.

Law, Phil. 2003. California Department of Fish and Game, Biometrician, Belmont, Ca.

Madej, Mary Ann. 2002. Redwood National Park Service, Research Geologist, Arcata, Ca.

Ozaki, Vicki. Redwood National Park Service, Geologist. Arcata, Ca.

Peters, Charlotte. 2001. Redwood Creek Watershed Map. Information Services, California Department of Fish and Game, Eureka, Ca.

Pinnix, William. 2003. United States Fish and Wildlife Service Fishery Biologist, Arcata, Ca.

Shiffer, Patricia. 2003. U.S. Geologic Survey, Sacramento, CA 95819-6129.

Stover, Marlin. 2000. Upper Redwood Creek long time resident and property owner. Redwood Valley, Humboldt County, California.

Walker, Cindy. 2003. US Forest Service Fisheries Technician. Six Rivers National Forest.

APPENDICES

Appendix 1. Q and A to explain severe decrease in 0+ Chinook salmon catches and population estimate in 2003.

Q1: Are the low numbers of Chinook salmon captured in the 2003 season due to high flows in the early part of the trapping season (March-April)?

A1: No, the low number of Chinook salmon caught in 2003 was not due to higher than average flows in late March and most of April. Using the previous three years of population data, peak out-migration from upper Redwood Creek occurs in May and June, which collectively accounted for 72% of total population out-migration. Although we did miss 11 days of trapping due to high flows in 2003, these days occurred in March and April, when out-migration is low. Additionally, trap efficiencies for 1+ and 2+ steelhead in April 2003 were 18 and 21%, respectively. Young-of-year Chinook salmon trap efficiencies, based upon the previous three years of study, are usually 2 - 3 times greater than steelhead efficiencies. Therefore, the trap was operating efficiently enough to capture downstream migrating young of year Chinook salmon if present in late March and April. Trapping efficiency for 0+ Chinook salmon in 2003 was 65%.

Q2: Did you operate the trap at various places in the stream to catch young of year Chinook out-migrating near stream edges?

A2: Yes, during March and April the trap was fished near the edges of the stream during the highest trappable flows, and also in the middle of the stream in the now widened thalweg. We generally found that as the trap was moved more into the middle of the stream, catches increased, particularly for the older and larger steelhead trout. No matter where the trap was located in the stream during late March and all of April, we only caught four young of year Chinook salmon. For the remainder of the season (May-early August) the trap was placed in the thalweg.

Q3: Why were there relatively high catches of young-of-year steelhead compared to low catches of young of year Chinook salmon?

A3: The answer to this question will require more study years, particularly to determine why there were relatively no Chinook salmon in 2003. Although there may be some run timing overlap between Chinook salmon and steelhead trout in upper Redwood Creek, adult spawning generally takes place at different times for the two species. Chinook salmon are considered to be primarily mid to late November, December, and January spawners, whereas steelhead (winter run) probably spawn from January through April. Each year we observe winter-run steelhead spawning upstream of the trap site in April. With respect to stream flow conditions, the Chinook salmon in the 2002/03 season faced much higher flows than did steelhead trout in 2003. For example, Chinook salmon redds constructed prior to December 28, 2002 faced a 6,300 cfs streamflow on December 28, as compared with a maximum streamflow of 3,500 cfs on March 26, 2003 that steelhead redds experienced. Evidently, steelhead redds that were constructed prior to March 26, 2003 did not suffer from redd scour because of our relatively high catches in YR 2003.

Q4: Why do you think there were few young of year Chinook salmon in YR 2003?

A4: There is no doubt that there were far less Chinook salmon out-migrating from upper Redwood Creek in the 2003 season compared to the previous study years. The very small numbers at the population level in 2003 (n = 987 individuals) indicate a year class and cohort failure for 2003. This failure is probably not restricted to upper Redwood Creek because the lower Redwood Creek fish trap (operated by USFWS) did not catch many Chinook salmon either. The four most likely reasons for the cohort failure in 2003 are:

1. The adult Chinook salmon 2002/03 run size was drastically low.

2. High flows in December jostled redd gravels surrounding egg pockets and shocked (and killed) sensitive eggs during early cell development (leading hypothesis #1).

3. High flows in the winter scoured (or conversely, buried) and destroyed Chinook salmon redds (flows were higher in 2002/03 winter than during previous three study years) (leading hypothesis #2).

4. Some combination of factors 1, 2, and 3.

Examination of peak flows, average flow by water year, and 0+ Chinook population estimates may offer insights into 0+ Chinook salmon population dynamics over the four study years (see table 22 below, page 77). It appears that 0+ Chinook salmon did well in a drought year (2000/01) and intermediate flow years (1999/00, 2001/02); and crashed in the higher water year (2002/03). The 32 year historic average flow was 234 cfs compared with an average flow of 260 cfs in WY 2003 (USGS 2003). Peak flows in 2002/03 were considered large enough to mobilize bedload and redd gravels (Randy Klein, personnel communication).

Table 22. Relationship of peak flows and average discharge by water year (WY), and 0+ Chinook salmon population estimates in four years of study, upper Redwood Creek, Humboldt County, Ca.

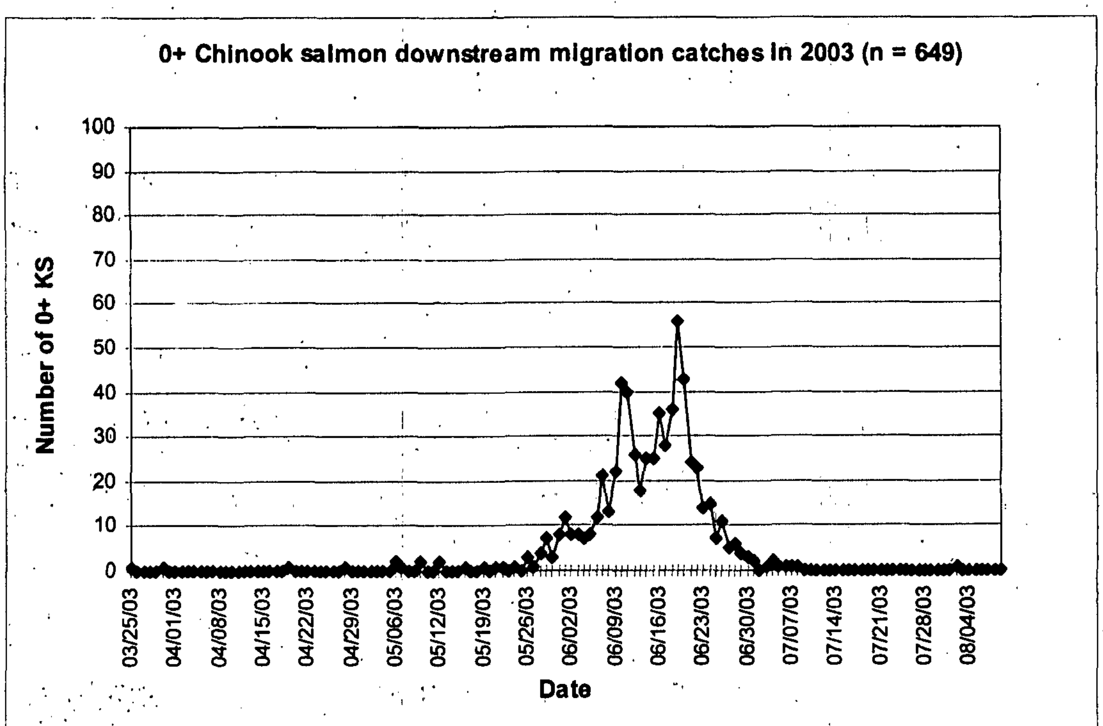
Season	Date of high flow*	Peak high flow (cfs)*	Average WY discharge (cfs)*	0+ Chinook population size
1999/00	1/11/2000	3,870	189	427,542
1999/00	1/14/2000	3,500		
1999/00	2/14/2000	4,293		
2000/01	12/14/2000	525	77	378,063
2000/01	12/15/2000	450		
2000/01	1/10/2001	378		
2001/02	12/05/2001	3,949	205	518,189
2001/02	12/14/2001	3,050		
2001/02	12/17/2001	2,200		
2001/02	1/06/2002	2,400		
2001/02	2/20/2002	2,907		
2002/03	12/14/2002	2,700	260	987
2002/03	12/16/2002	4,800		
2002/03	12/28/2002	6,300		
2002/03	12/31/2002	3,600		

*** Data from USGS (2003) O'Kane Blue Lake Gaging Station and P Shiffer, pers comm. ,USGS.**

Appendix 2. Daily catch distribution for 0+ Chinook salmon, 2003.

The daily catch distribution for 0+ Chinook salmon showed one distinct grouping in YR 2003 (see figure below). Peak daily 0+ Chinook salmon catches in YR 2003 occurred on June 10 (n = 42) and June 19 (n = 56), compared with peak catches in YR 2002 that occurred on April 9 (n = 3,370), April 30 (n = 6,516), May 31 (n = 9,375), and June 3 (n = 6,635). Peak catches in YR 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); and in YR 2000, peak catches occurred on May 27 (n = 4,232), June 7 (n = 3,832), and June 21 (n = 5,457).

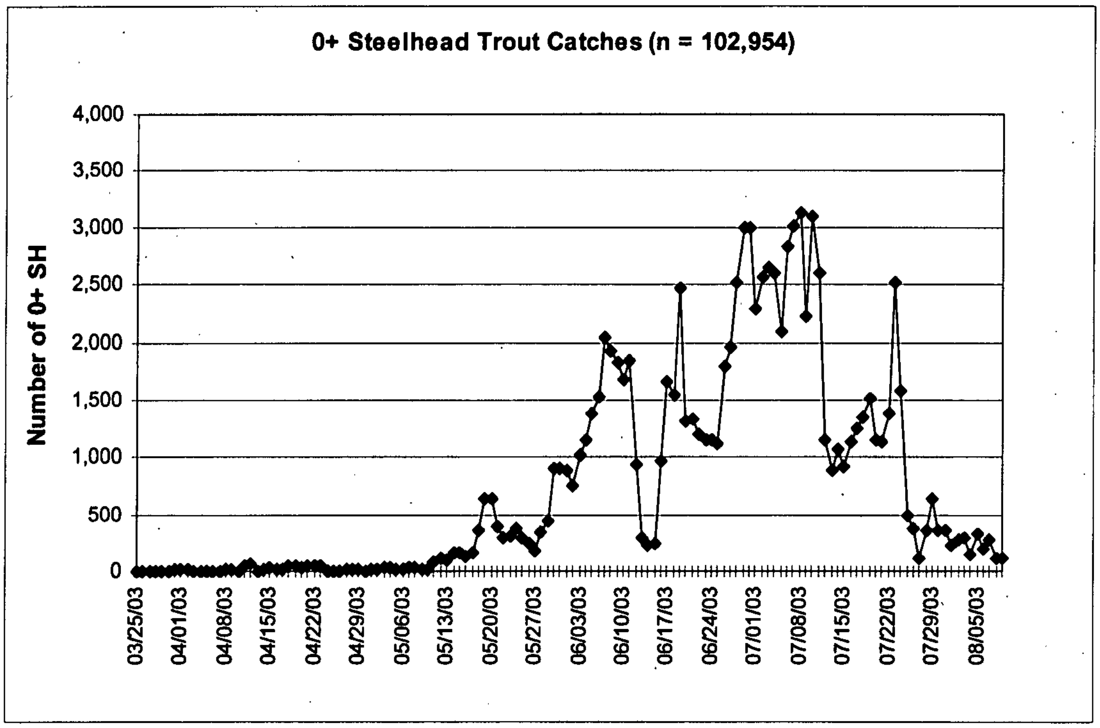
The pattern of catches (bell shaped curve) in YR 2003 show the trapping period encompassed downstream migration (see figure below). Eleven days not trapped during late March and April were not considered to impact the total catch to any large degree (see appendix 1). The right tail of the catch distribution shows that daily out-migration tapered off to values approaching zero around July 7, 2002.



Appendix 3. Daily catch distribution for 0+ steelhead trout, 2003.

Considerable numbers of 0+ steelhead emigrate from upper Redwood Creek. Peak daily catches occurred on 5 days in YR 2003: June 7 (n = 2,040), June 19 (n = 2,470), June 29 (n = 3,000), July 8 (n = 3,133), and July 23 (n = 2,525) (see figure below). Daily 0+ steelhead peak captures in YR 2002 occurred on May 31 (n = 5,684), and July 11 (n = 6,088), whereas the two highest peak catches in 2001 occurred on May 27 (n = 4,457), and June 27 (n = 6,993). In YR 2000, the highest peak catches occurred on June 28 (n = 2,439), and July 2 (n = 2,282).

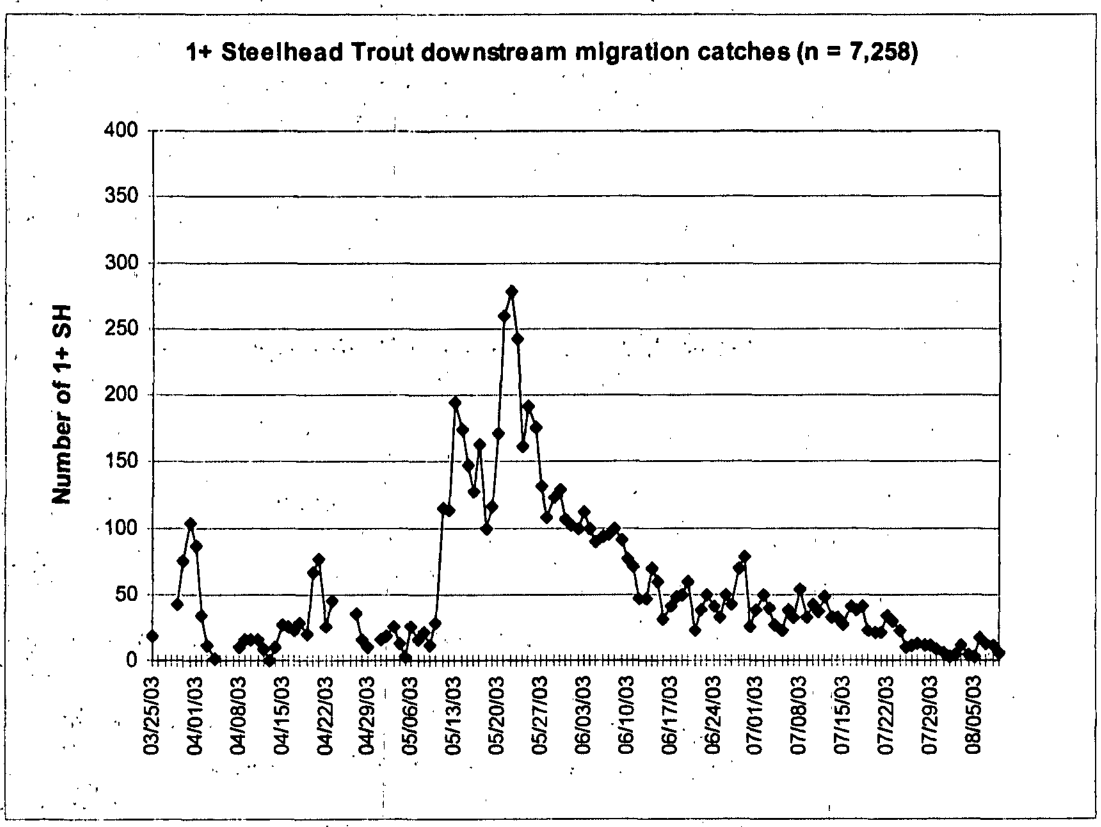
The pattern of daily catches in YR 2003 show the trapping period encompassed downstream migration or stream re-distribution (see figure below). Zero catch days to the left on the catch distribution correspond to times when fry have not emerged from redds, or moved downstream. 0+ steelhead downstream migration in YR 2003 generally started in May. Low catches on the right tail of the distribution (early August) show out-migration substantially decreased to values near zero. The daily captures in YR 2003 expressed as a percentage of the total catch ranged from 0 – 3.0%. Nights missed trapping in late March/April did not impact the total catch to any large degree because 0+ steelhead out-migration is typically low during that time period.



Appendix 4. Daily catch distribution for 1+ steelhead trout, 2003.

The catch distribution of 1+ steelhead trout in YR 2003 showed peak catches on 5 days: March 31 (n = 104), April 21 (n = 77), May 13 (n = 195), May 22 (n = 278), and June 29 (n = 78) (see figure below). The highest daily peak catch in YR 2003 (n = 278) was much less than the highest peak in YR 2002 (n = 442) and previous years (YR 2001 n = 710, YR 2000 n = 544). The peak catch in YR 2002 occurred on 5/13/02. In YR 2001 and YR 2000, the highest daily peak catch occurred on 5/16/01 (n = 710) and 5/10/00 (n = 544), respectively. Peak catches for 1+ steelhead typically occur near the middle of May.

The pattern of catches in YR 2003 show the trapping period encompassed the majority of downstream migration (see figure below). Low catches in April and the first half of May were not due to inefficiently trapping higher flow events because 1+ steelhead trap efficiencies during these times averaged 17%. During the higher flow events, we found that, at least in YR 2003, 1+ steelhead tended to not out-migrate as evidenced by high trap efficiencies and low catches of unmarked fish. Daily captures within the trapping period expressed as a percentage of the total 1+ steelhead catch in YR 2003, ranged from 0 – 3.8%. In combination with relatively high trap efficiencies, such small percentages suggest that nights missed trapping (n = 11) did not influence the total catch to any large degree.

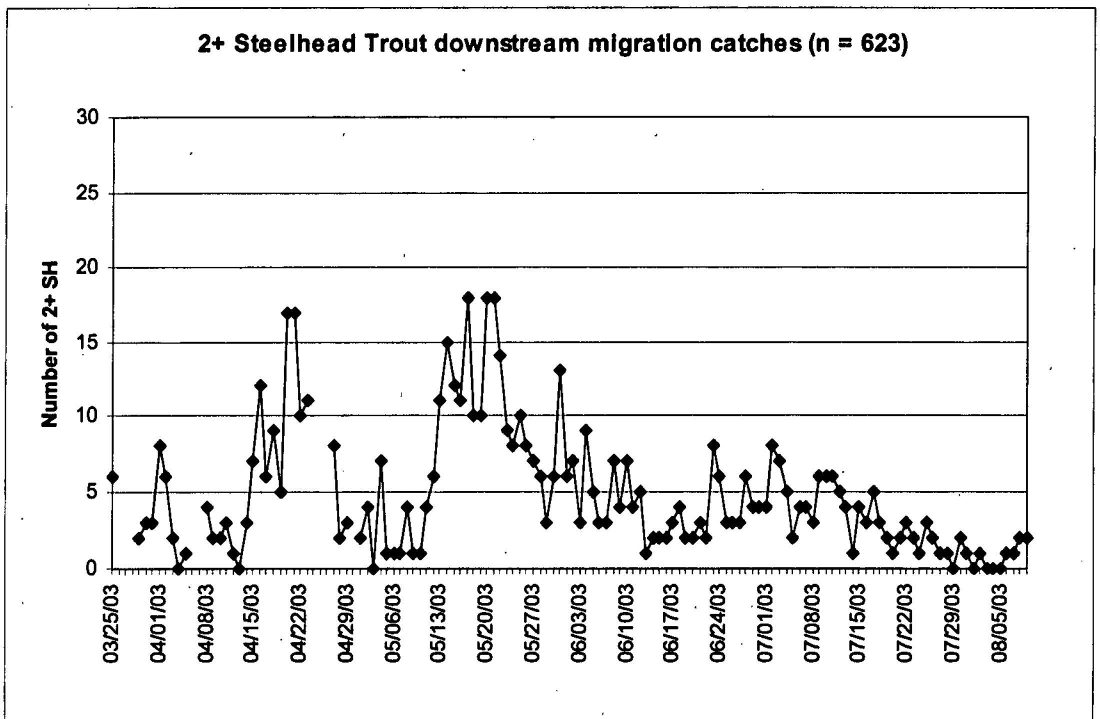


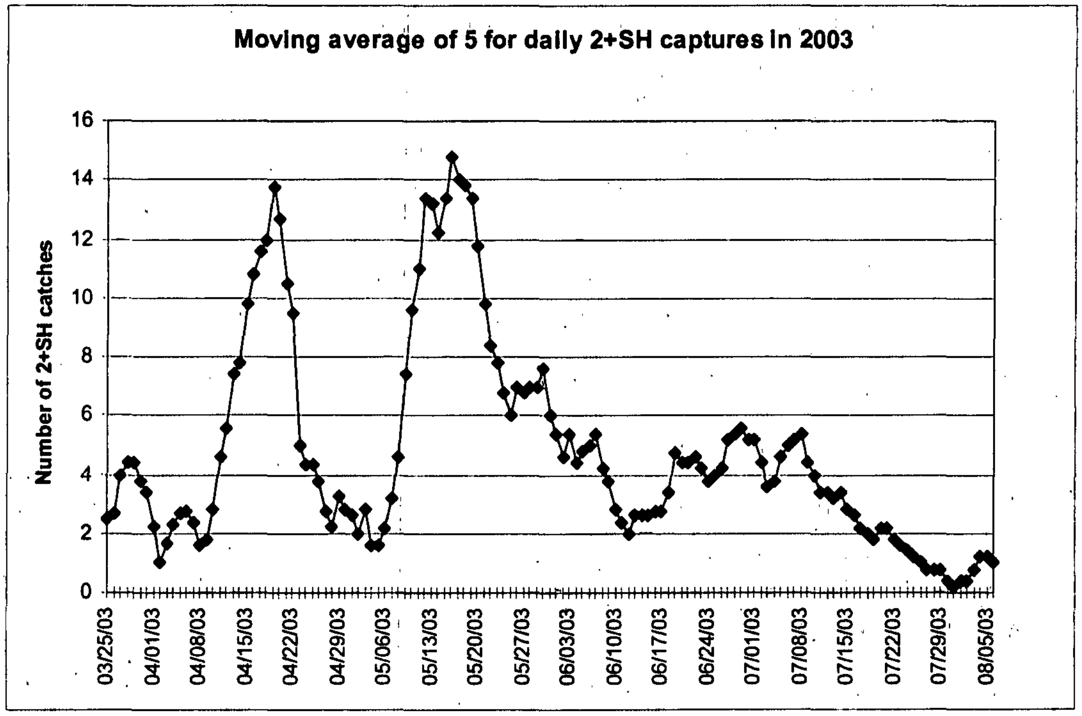
Appendix 5. Daily catch distribution for 2+ steelhead trout, 2003.

2+ steelhead daily catches in YR 2003 (as in other study years) were more variable over time than other species at age (see figure below). The highest daily peak catches in YR 2003 occurred on: April 20 (n = 17) and May 17 (n = 18). The highest daily peak catch in YR 2002 occurred on 5/16/02 (n = 41), and in YR 2001, the highest peak catch occurred on 4/7/01 (n = 45). In YR 2000, the highest peak catch occurred on 4/6/00 (n = 35).

The catch distribution in YR 2003 shows three general groupings in the months of April, May, and June/early to mid July. The second figure below (moving average of 5) more readily shows this grouping.

Daily 2+ steelhead captures expressed as a percentage of total catch in YR 2003 ranged from 0 – 2.9%. In combination with relatively high trap efficiencies throughout the trapping period (eg 19.7%), such small daily catch percentages indicate the nights missed trapping (n = 11) did not influence the total catch to any large degree.




Moving average of 5 for daily 2+SH captures in 2003
Number of 2+SH catches
0
2
4
6
8
10
12
14
16
03/25/03
04/01/03
04/08/03
04/15/03
04/22/03
04/29/03
05/06/03
05/13/03
05/20/03
05/27/03
06/03/03
06/10/03
06/17/03
06/24/03
07/01/03
07/08/03
07/15/03
07/22/03
07/29/03
08/05/03

Appendix 6. Critical review of population estimate methods, model choice, and mark-recapture data with respect to 2+ steelhead trout by Phil Law (Biometrician, California Department of Fish and Game).

To: Phil Bairrington, Steelhead Research and Monitoring Program (Northern California - North Coast Region

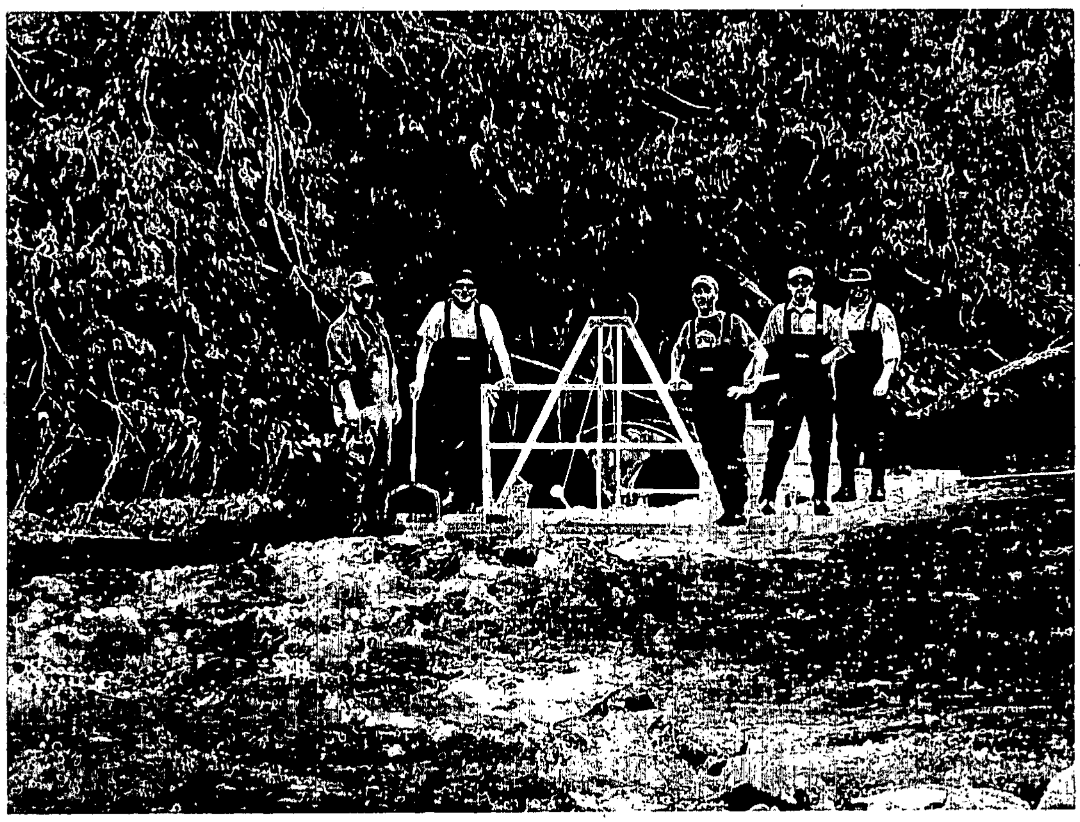
From: Philip Law, Biometrics Unit, MR, Belmont, Ca.

Re: Michael Sparkman's Mark/Recapture Study

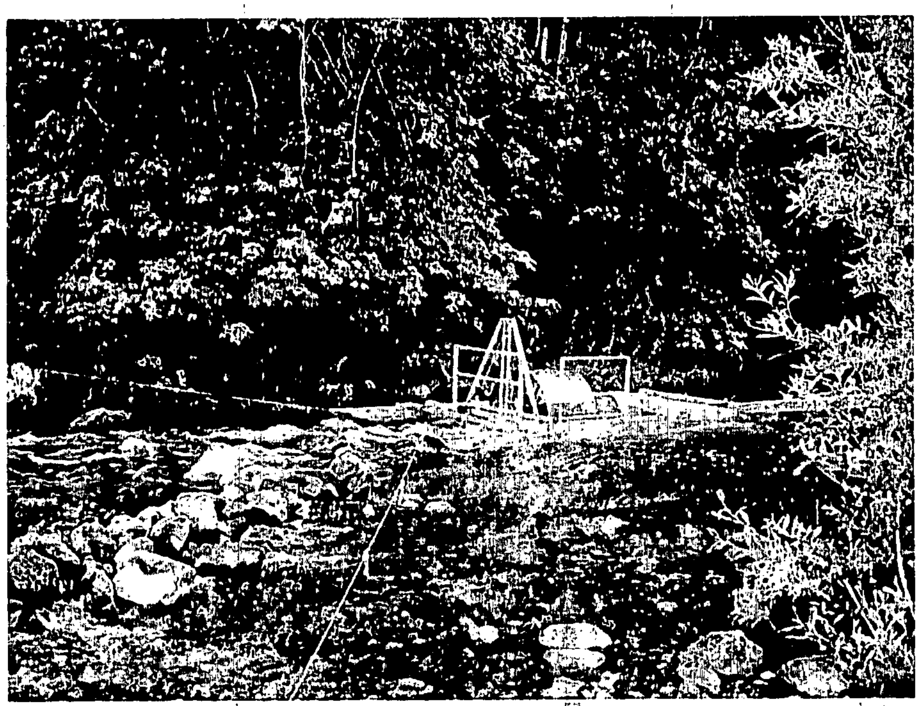
I have studied Carlson's Simple Stratified Design for Mark-Recapture Estimation of Salmon Smolt Abundance and Michael Sparkman's 2003 Redwood Creek RST spreadsheet results. I found Carlson's algorithm to be a straight forward application of Petersen's method for temporally stratified capture-recapture regiments. The one sample design is particularly advantageous for its resource economy provided care is taken to ensure model assumptions are met. Carlson and associates used their design for the Akalura Lake study which included a weir count for verification of model estimates. They also carried out parametric bootstrap analysis of their data and found good agreements with their model population count and variance estimates.

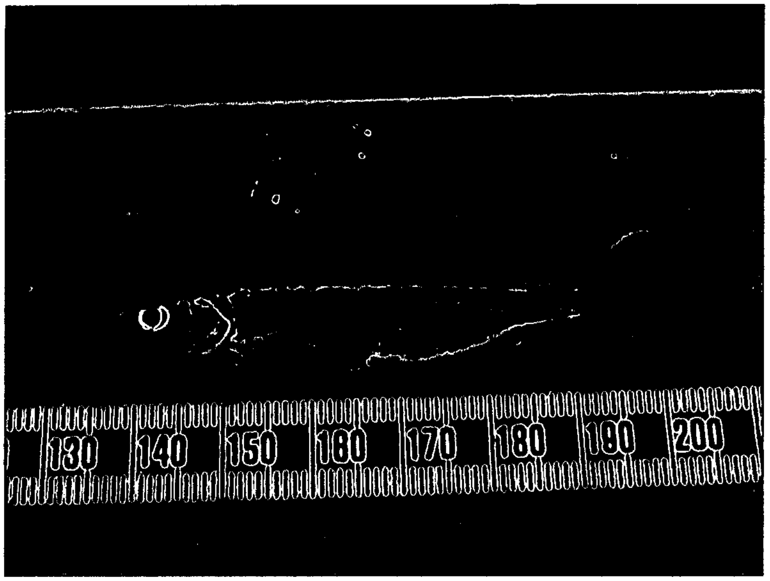
To the extent that Sparkman's survey conforms to Carlson's one sample design, it is entirely appropriate for him to use the Simple Stratified Design for Mark-Recapture Estimation for his data. Sparkman found most fish sampled pass through the trap location within one day of release from a site which is greater than 100 m upstream to ensure complete mixing of marked and unmarked fish. He had used multiple markings and found stragglers which crossed strata to be minimal and they were censored from the analysis. The numbers were so small that they were considered anomalies and their elimination should cause little impact on the overall population estimation. The independence of strata are preserved and the over total and variance estimates can be obtained through summing of their respective estimates across all strata. Sparkman listed the six assumptions and the precautions taken or reasons for their validity for his study. Equality of capture rates between marked and unmarked fish was the most crucial assumption. Temporal stratification of relatively short duration of a week makes such assumption acceptable. Sparkman's spreadsheet apparently used Carlson's formulation correctly to calculate the stratum and overall estimates.

Sparkman has also showed me DARR (Darroch Analysis with Rank-Reduction) as an alternate to population estimation. DARR combines adjacent strata of sparse capture recapture data to achieve rank reduction. It is data driven based on the structure of the capture-recapture data matrix. Such automated data amalgamation is probably motivated to ameliorate assumption violations of sparse data matrix. It may have value for studies with scarcities of data. However, the imposition of homogeneity of various rates within amalgamated stratum may not be biologically justifiable. Even adjacent stratum may have rather distinct characteristics. DARR seems to be rather sensitive to presence of stragglers. A small number of stragglers can sometimes give biologically inconsistent estimates. I see no compelling reason to adopt DARR for Sparkman's analysis unless detail knowledge of the underlying algorithms of DARR convinces me otherwise.

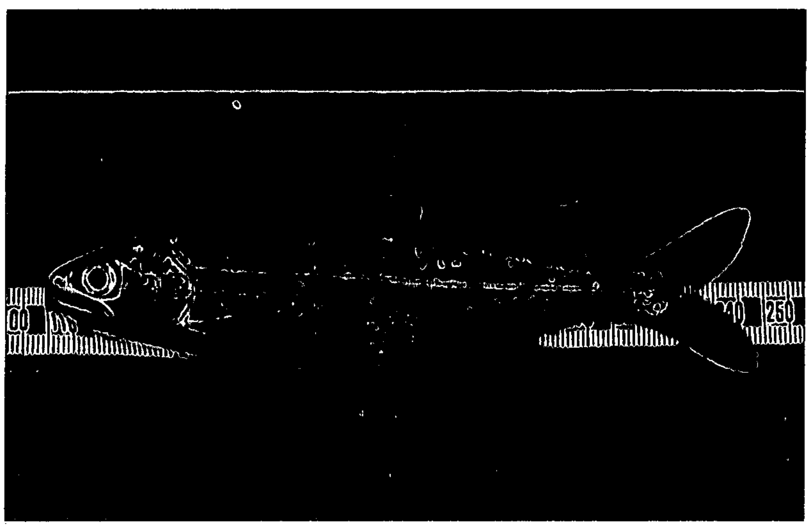


The 'crew' (Margo Williams and Mike Sparkman not shown) above includes (from left to right): Pat Moorhouse, Mike Gillmore, Damon Zeller, Forrest Cottrell, and Todd Newhouse.

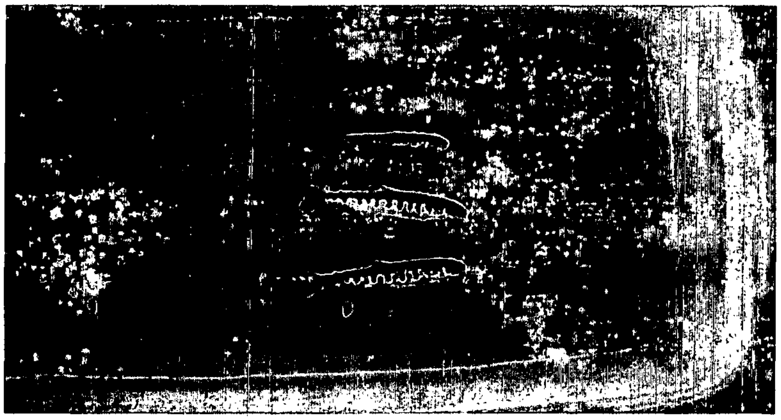




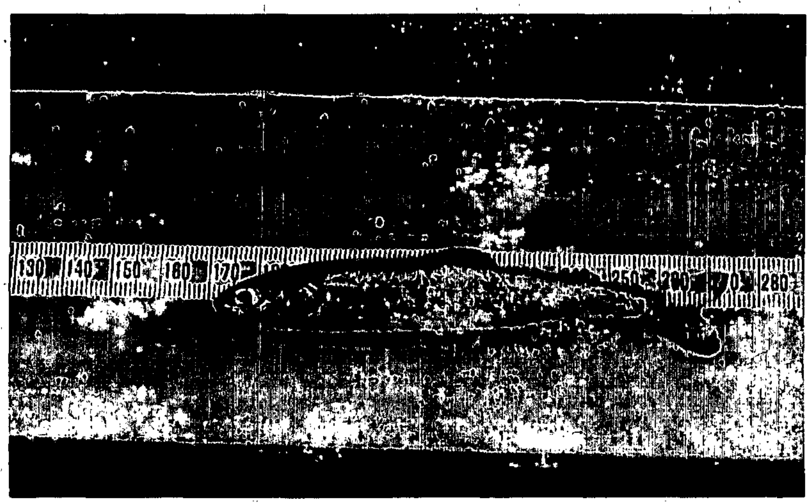
0+ Chinook with partial fin clip (lower caudal); Fork Length is 34 – 87 mm.



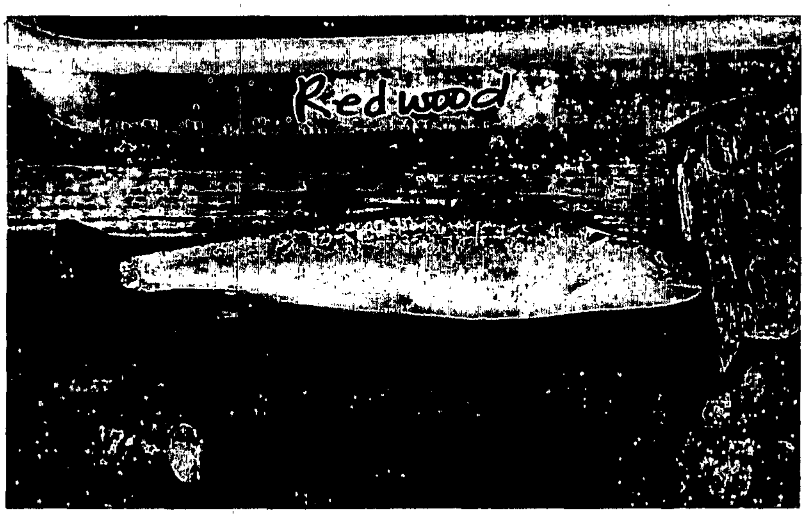
1+ Chinook Salmon, Fork Length = 70 – 148 mm



0+ Steelhead Trout, Fork Length is 24 – 69 mm.



1+ Steelhead Trout, Fork Length is 57 – 119 mm.



2+ Steelhead Trout, Fork Length 120 – 220 mm.