Juvenile Coho Salmon and Rainbow Trout/Steelhead Distribution in the Shasta River

Lisa Thompson, Dan Drake, and Brian Hodge

University of California Cooperative Extension

9 Dec 2005

Summary

The purpose of this project is to monitor juvenile coho salmon distribution, movement, and habitat use in the Shasta River in relation to factors such as stream and riparian habitat, temperature, dissolved oxygen, water quality, macro-invertebrates, and agricultural practices. This study will assist in determining and establishing conditions suitable for coho salmon recovery in the Shasta River. The study design divides the river into reaches, because flow and other factors important to coho salmon recovery are likely to be managed at this scale (see Deas at al. 2003). Thus, the fish distribution data may be used as a baseline for comparison with distributions that may occur given potential flow and land management changes in the Shasta River. A key aim of the study is to capture and tag juvenile coho salmon with passive integrated transponder (PIT) tags. It will then be possible to monitor coho salmon distribution and movement using PIT antenna arrays strategically located along the Shasta River between Dwinnell Reservoir and the confluence with the Klamath River.

Between 8 June 2004 and 14 December 2004 minnow trapping and PIT tagging was conducted in five reaches of the river between Parks Creek and the Klamath River confluence. No coho salmon were captured in any of the sample reaches. During this time a total of 83 juvenile rainbow trout/steelhead were captured, and 67 of these were PIT tagged. In 2005 sampling efforts were focused on the canyon section of the river, to which radio tagged coho salmon spawners were tracked by CDFG in winter 2004-05. Between 16 February 2005 and 17 June 2005 a total of 40 juvenile coho salmon were caught, of which 11 were large enough to be PIT tagged. One juvenile rainbow trout/steelhead was also caught and PIT tagged. A PIT antenna is currently being operated in a side channel of the canyon to detect any PIT tagged fish that pass by the antenna.

Minnow traps baited with salmon roe have proven to be an effective and low impact method of capturing both juvenile rainbow trout/steelhead *(Oncorhynchus mykiss)* and coho salmon (*Oncorhynchus kisutch)*. Trapping experience to date has allowed the fine tuning of choice of trap locations to optimize capture of juvenile coho salmon, or of rainbow trout/steelhead , should a given species be present in a given river reach. The project has been successful in capturing and PIT tagging juvenile coho salmon.

With the proven ability to trap and PIT tag juvenile coho salmon, and the construction and field testing of PIT antennas, we are now in a position to conduct monitoring of adaptive management experiments to test the impact of best management practices on juvenile coho salmon distribution and outmigration. Such experiments could include pulse flow flushing releases, as have been conducted in the past, a number of recovery measures included in the state Recovery Strategy for Coho Salmon (*Oncorhynchus kisutch*) (CDFG 2004), and other best management practices that multi-stakeholder groups in the watershed may be interested in testing.

Introduction

Study Area

The Shasta River watershed occupies 2,058 square km within the Klamath River Basin, and has a human population of about 30,000. Land ownership in the watershed is 65% private, 5% state, and 30% federal. Agriculture, silviculture, and timber management are the most prominent land uses in the Shasta watershed. About one quarter of the watershed is flat enough to be irrigable, and this land is mainly downstream of Dwinnell Dam. About 52,000 acres are currently irrigated for at least part of the growing season (Shasta River CRMP 1997, CDFG 2003a).

Anadromous Fish Species and Status

Salmonids historically and currently present in the Shasta River watershed include Chinook salmon (*Oncorhynchus tshawytscha*), coho salmon, and rainbow trout/steelhead (Coots 1958, Leidy and Leidy 1984, Shasta River CRMP 1997, CDFG 2003a). Rainbow trout and steelhead are the same species. To avoid confusion, they will be referred to jointly as rainbow trout/steelhead for the remainder of this report. Coho salmon in the Shasta River are part of the federal Southern Oregon/Northern California evolutionary significant unit (SONC ESU) and are listed as threatened. At the state level coho salmon in the Shasta River are part of the Northern California designation, and are listed as threatened. There has been a general downward trend in coho salmon populations throughout the state from 1989 to 2001 (NMFS 2001). Coho salmon within the California part of the SONC ESU, which includes the Shasta River watershed, also showed a downward trend, although trend data for this area are limited.

There are multiple factors that may limit salmonid populations in the watershed, including water quantity (lack of flow, diversions, runoff), water quality (temperature, chemistry, turbidity, dissolved oxygen), riparian dysfunction (lack of shade, excessive nutrients), excessive sediment yield (pool and gravel quality), spawning requirements (passage, gravel, resting areas-pools), and rearing requirements (velocity, lack of woody debris, pools) (CDFG 1997, CDFG 2004, CDFG 2003a, Deas 1999, Jong 1994, Ricker 1997, Shasta River CRMP 1997).

Additional factors outside of the watershed also influence salmonid populations, such as habitat conditions in the mainstem Klamath River, Klamath River Estuary, and the ocean.

Study Objectives

The purpose of this study is to monitor juvenile coho salmon distribution, movement, and habitat use in the Shasta River in order to identify and quantify linkages between coho salmon and factors such as stream and riparian habitat, temperature, dissolved oxygen, water quality, macro-invertebrates, and agricultural practices. This study will help to determine locations of rearing of coho salmon in the Shasta River, which are currently not known (Chesney 2002). The study will also assist in determining and establishing conditions suitable for coho salmon recovery in the Shasta River.

Experimental Design and Methods

For this study the Shasta River was divided into five reaches between Dwinnell Dam and the Klamath River confluence (Fig. 1). Approximately 12 miles of the mainstem Shasta River are included in the project. This is about 25% of the river between Lake Shastina and the Shasta River Canyon. River water in the mainstem reaches is expected to integrate all the impacts occurring upstream in the watershed. The study design divides the river into reaches because flow and other factors important to coho salmon recovery are likely to be managed at this scale. For example, in the Shasta River Flow and Temperature Modeling Project (Deas at al. 2003) the river was divided into reaches, with the break points between the five reaches occurring at the locations at which reliable flow data could be collected. By adopting a similar reach design, our fish distribution data may be used as a baseline for comparison with distributions that may occur given potential flow and land management changes in the Shasta River.

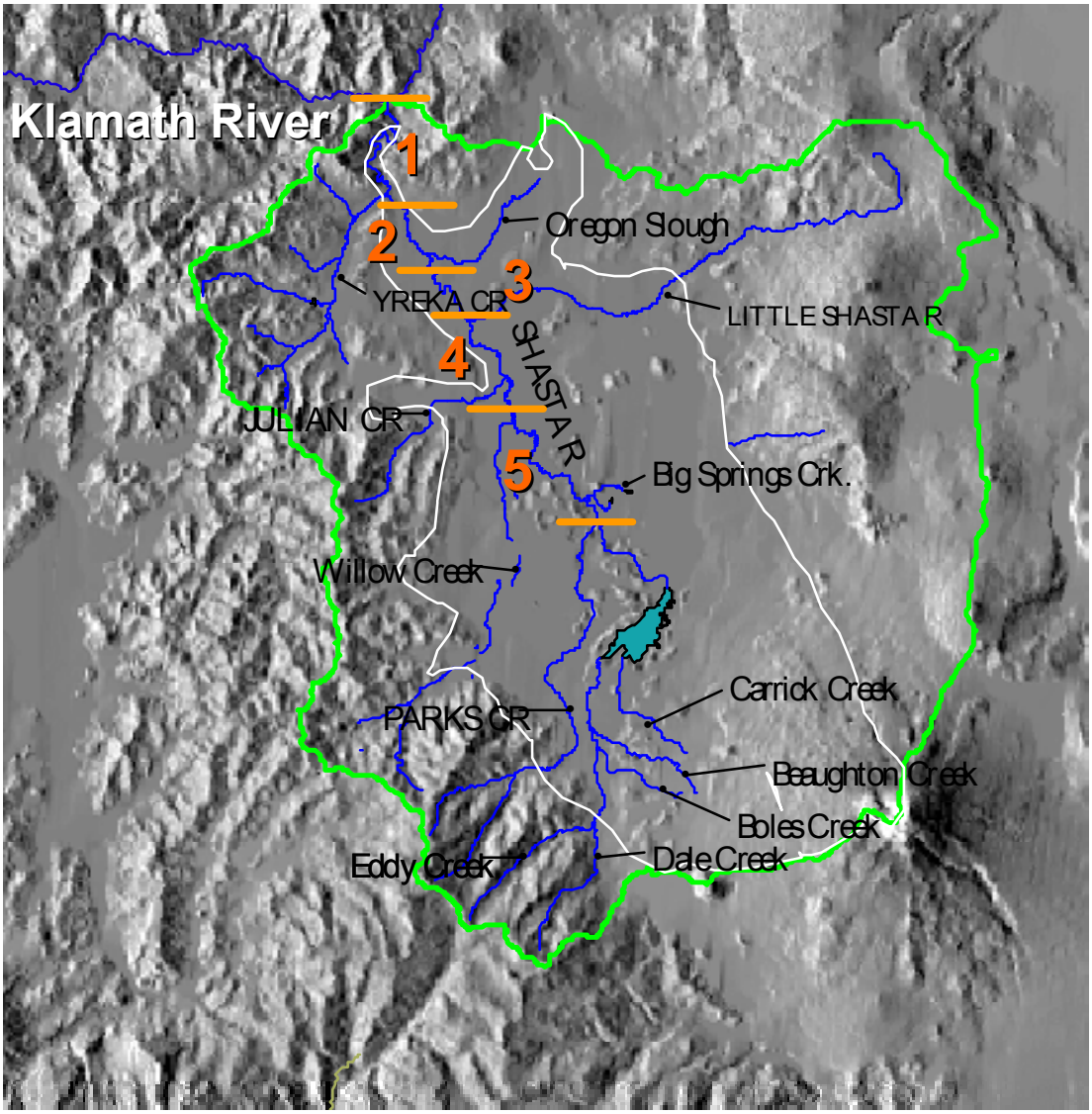

Figure 1. Map of Shasta River watershed and sample reaches.

Fish Capture

Fish were captured with standard minnow traps baited with salmon roe (Fig. 2). Other baits such as puppy chow, worms, and PowerBait® were tried. Roe and PowerBait® proved to be most effective, but roe was less expensive and faster to prepare for use in traps than PowerBait®. A range of habitat types was sampled to determine which types were preferred by coho salmon 0+ (young-of-the-year) and 1+ (fish between 1 and 2 years old), at different times of the year. Approximately twenty traps were set overnight at each sampling event, depending on the number of trapping locations available at a given reach (e.g., undercut banks, side channels, pools, downstream of boulders).

Figure 2. Setting a minnow trap in the side channel area of Reach 1 (canyon).

Fish Measurement and PIT Tagging

Passive integrated transponder (PIT) tags can be an effective method to provide fish as small as young-of-the-year salmonids with an individual mark that is re-detectable without the need to recapture the fish (Manning and Thompson 2003). Tags used for this project were cylindrical, approximately ½ inch long, and less than 1/8 inch in diameter (Destron Fearing, TX1400ST, 12mm x 2.1mm, glass encapsulated, 134.2 kHz ISO). Upon removal from the minnow traps, coho salmon were held in a 40 L cooler filled with river water, with a battery operated air stone.

Coho salmon were then transferred one at a time to a bucket containing carbon dioxide anesthetic for approximately 1-2 minutes. The anesthetic solution was produced by adding 2.67 g $NaCO_3$ (sodium bicarbonate) and 10 mL acetic acid to 10 L water. Swimming capabilities and opercular (gill cover) movement were monitored. Once coho salmon reached stage 4 anesthesia (total loss of swimming motion with weak opercular movement) they were measured for fork length and total length.

We trained in PIT tagging with Mr. W.R. Chesney, CDFG, Yreka in April, 2004, using juvenile rainbow trout/steelhead captured at the CDFG rotary screw trap (Note: These fish were released at the screw trap and are assumed to have outmigrated from the watershed). For this study rainbow trout/steelhead and coho salmon =>70 mm fork length were PIT tagged (Fig. 3). The PIT tag identification code was measured with a BioMark 2001F reader and hand held antenna. A 12 mm PIT tag was inserted into the abdominal cavity. Tag insertion was done with a specially designed 12 gage needle, or by making an incision with a scalpel and inserting the tag by hand, depending on the preference of the person doing the tagging. Measuring boards and researchers' hands were kept wet to minimize stress to fish. The tag insertion took less than 1 minute. Insertion instruments were sterilized in a Sterl-Aid cold sterilization solution for 15 minutes before use on another fish.

Figure 3. A PIT tagged juvenile coho salmon prior to being placed in the recovery cooler, Reach 1 (canyon).

After measurement and tagging, coho salmon were placed in a 40 L recovery cooler filled with river water, with a battery operated air stone, for approximately 30 minutes. Once coho salmon had fully recovered from anesthesia they were released back to the river at the location from which they were captured. Temperature and dissolved oxygen levels in the three containers were monitored with a handheld YSI temperature/dissolved oxygen meter. Water temperature was kept at ambient river temperature by adding plastic freezer packs. All containers were treated with 2-3 g rock salt/L to minimize fish stress by decreasing the osmotic gradient across the gills.

Observation of Coho Salmon and Rainbow Trout/Steelhead Distribution and Movement

Coho salmon and rainbow trout/steelhead distribution and movement were assessed through repeated trapping in the five reaches. Presence/absence and abundance per trap were noted, as well as recapture of PIT tagged fish.

PIT Antenna Arrays

We have worked with Mr. Kerry Mauro (Shasta Valley Resource Conservation District) and Mr. David Webb (Shasta Coordinated Resource Management Program, CRMP) to develop PIT antennas that could be placed at intervals along the river to track the upstream and downstream movement of PIT tagged coho salmon. A prototype antenna was tested successfully in the Shasta River in April, 2004. A single loop antenna was installed in a side channel of the Shasta River canyon in the summer of 2005, and is currently being operated, flow permitting, to detect any PIT tagged fish that pass by the antenna (Fig. 4).

Figure 4. PIT antenna operating in the side channel area of Reach 1 (canyon).

Results

2004 Results

In 2004 sampling took place between 8 June and 14 December. A total of 22 trapping trips were made and a total of 354 traps were set. Approximately 10 to 20 traps were set at a given reach, depending on the number of sub-locations suitable for operating minnow traps (e.g., behind rocks, under banks, over gravel bottom, side channels). All traps were set overnight, with the exception of the traps set at Reach 5 on 1 December 2004 for approximately 3 hours.

Fish were captured in minnow traps at all five of the reaches. No coho salmon were captured in 2004. However, rainbow trout/steelhead were captured at each reach on at least one occasion over the 2004 season (Fig. 5). Catch rates of rainbow trout/steelhead ranged between 0 and 1 fish per trap. The catch rate at Reach 4, the reach most frequently sampled, showed an increasing trend over the season. The opposite trend was seen for the capture rate of non-salmonids (Fig. 6). These results may indicate an increasing efficiency of the field crew at setting traps in order to catch salmonids as experience was gained during the field season.

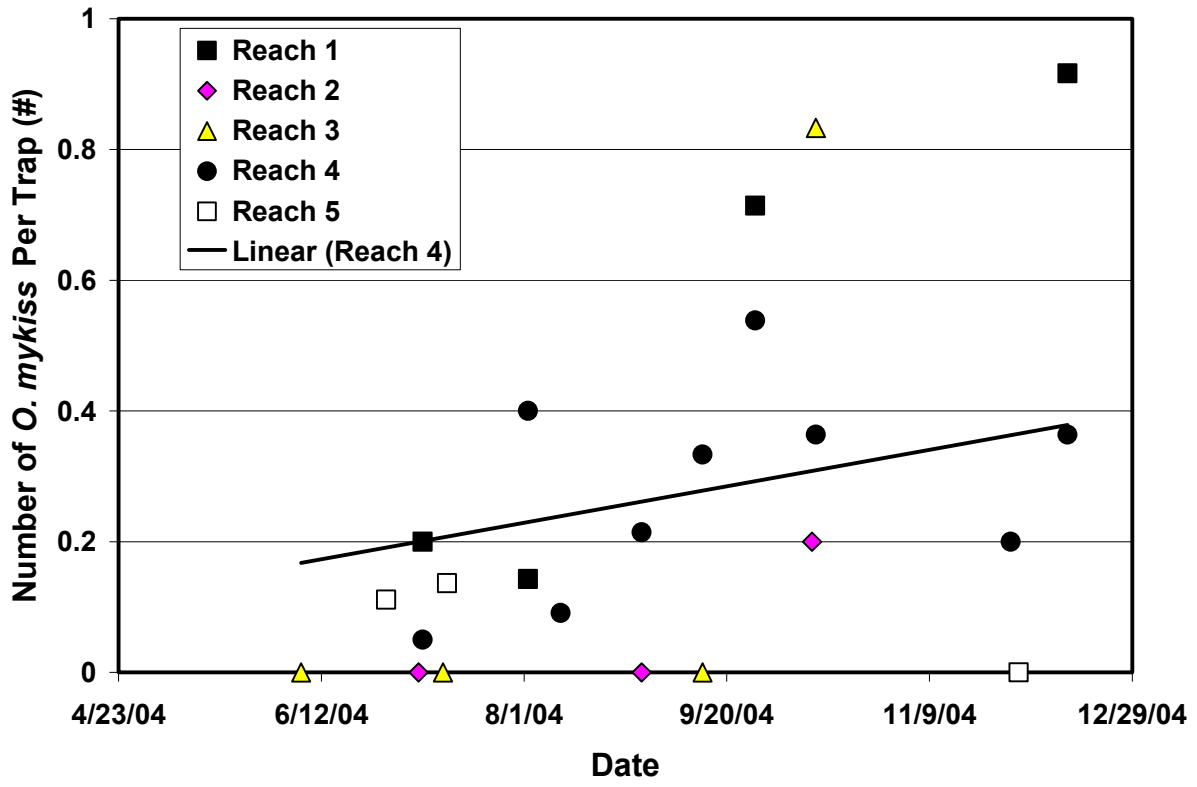

Figure 5. Total number of juvenile rainbow trout/steelhead caught per minnow trap, across the 2004 field season, by reach. Note: Reach 1 is the most downstream of our reaches, located in the canyon, while Reach 5 is our most upstream reach. The line is a regression of the catch rate at Reach 4, the reach most frequently sampled.

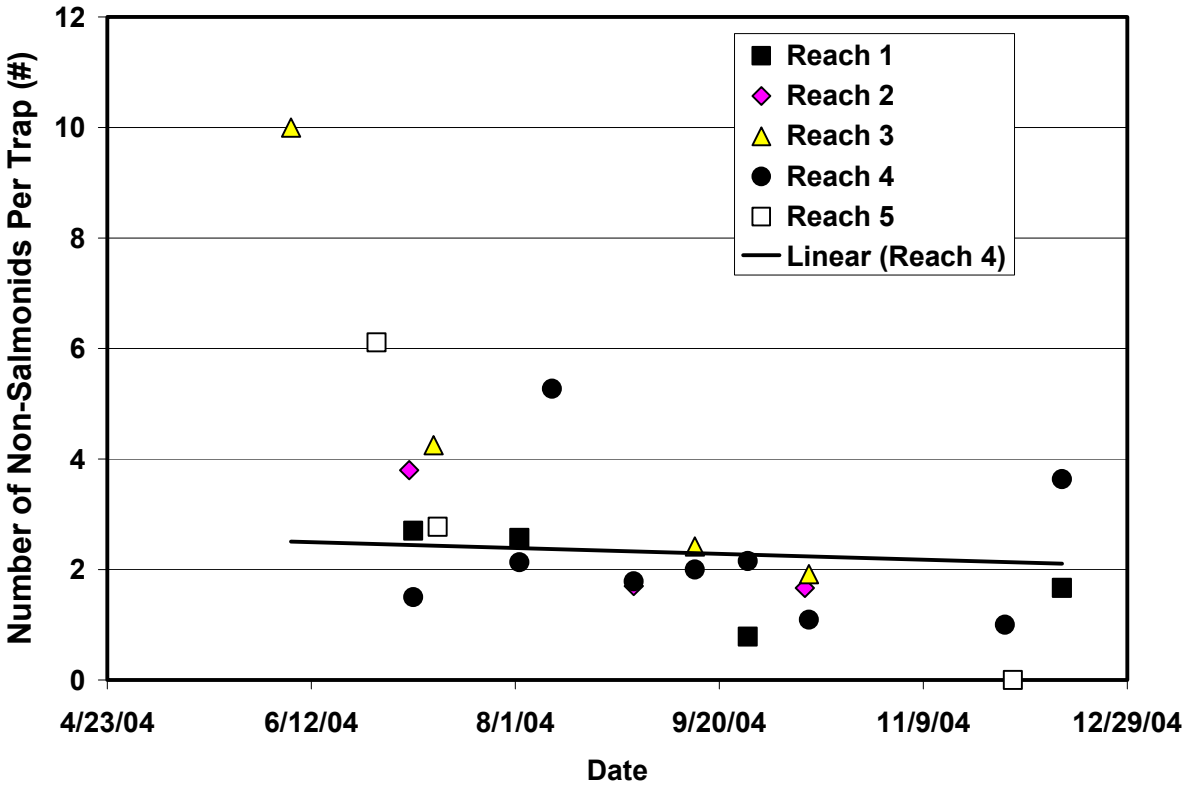

Figure 6. Total number of non-salmonid fish caught per minnow trap, across the 2004 field season, by reach. Note: Reach 1 is the most downstream of our reaches, located in the canyon, while Reach 5 is our most upstream reach. The line is a regression of the catch rate at Reach 4, the reach most frequently sampled.

Other species captured included bluegill, bullhead sp., sculpin sp., speckled dace, and sucker sp. Crayfish were also caught. Catch rates of non-salmonid fish species ranged between 0 and 10 fish per trap, not including crayfish (Fig. 6). A total of 1,012 individuals of non-salmonid species were captured.

The patterns of capture of rainbow trout/steelhead and non-salmonids at each reach, grouping the data by month, are shown in Fig. 7 and Fig. 8, respectively. Non-salmonids were captured at all reaches in all months, with the exception of Reach 5 in December. Sampling at Reach 5 in December was conducted for only about 3 hours, due to time constraints on the field crew, so there may not have been sufficient time for fish to locate and enter the traps. Rainbow trout/steelhead were caught at all sampled reaches in all months, with the exception of Reach 2 in August, Reach 3 in September, and Reach 5 in December. It is probable that no rainbow trout/steelhead were caught at Reach 5 for the same reasons as for non-salmonids.

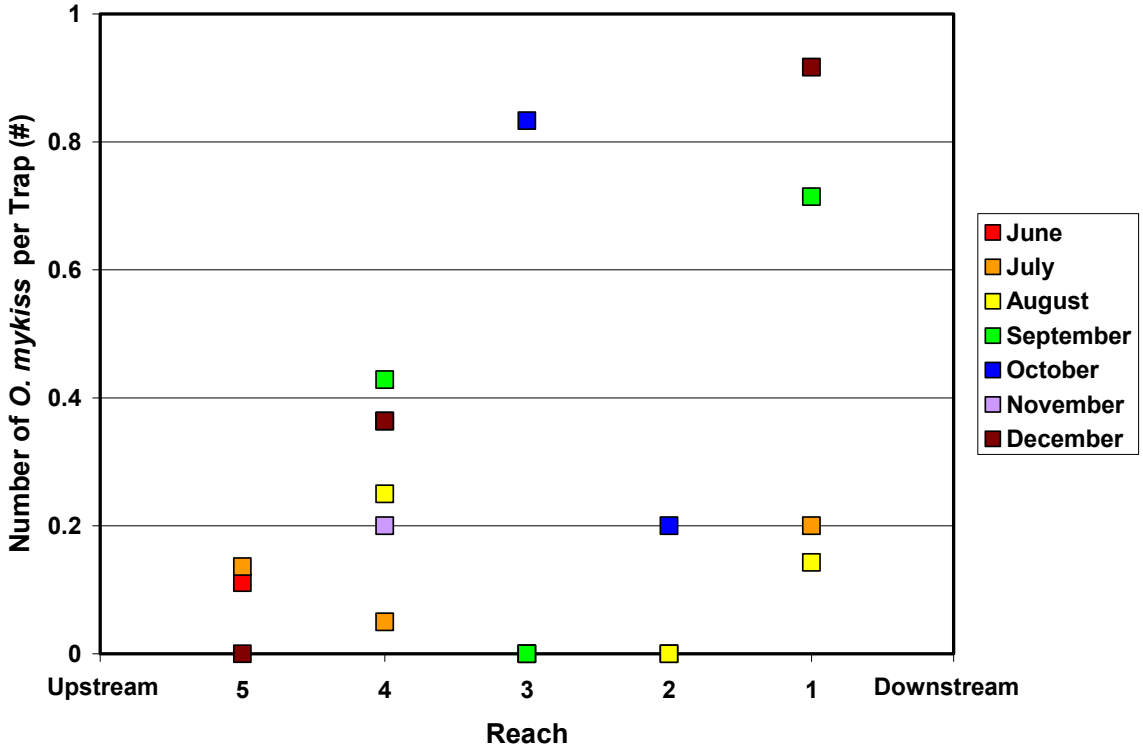

Figure 7. Total number of rainbow trout/steelhead per minnow trap, along the river, by month in 2004.

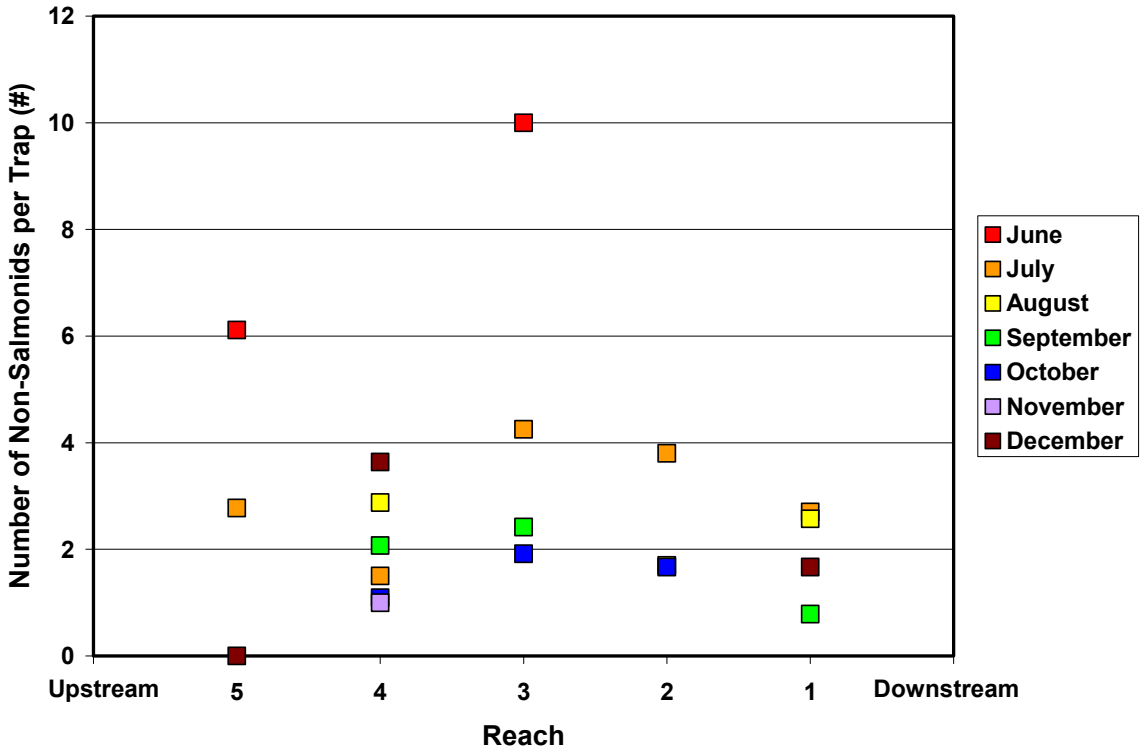

Figure 8. Total number of non-salmonid fish caught per minnow trap, along the river, by month in 2004.

Juvenile coho salmon and rainbow trout/steelhead appeared to have different micro-habitat preferences, as evidenced by differing trap efficiency depending on the velocity and cover available adjacent to traps. Coho salmon (0+ and 1+ ages) were more likely to be captured in low velocity, back water and side channel locations (e.g., Fig. 2). In contrast, rainbow trout/steelhead were more likely to be captured in locations adjacent to higher velocity, higher gradient areas, such as downstream of boulders in mid-channel (Fig. 9).

Figure 9. Typical location at which rainbow trout/steelhead may be trapped.

During the course of the trapping, a total of 83 rainbow trout/steelhead were captured, and of these, 67 were PIT tagged (Fig. 10). Not all captured rainbow trout/steelhead were tagged because early in the season the focus of the research was the capture of coho salmon, and saving tags for them. In addition, some of the captured rainbow trout/steelhead were very small, and insertion of a PIT tag seemed an undue risk. Because no coho salmon were captured, none were PIT tagged in 2004.

2005 Results

Coho salmon spawners were radio-tracked by CDFG in winter 2004-05, and were observed to spawn in two main areas of the river: 1) the Shasta River Canyon, and 2) in the mainstem and some tributaries upstream of the confluence with Big Springs Creek (W.R. Chesney, CDFG,

pers. comm.). In 2005 the focus of the research was shifted to Reach 1, the canyon, in order to trap coho salmon in the downstream area used by the spawners. Access has not yet been obtained for the upstream reaches to which coho spawners were radio-tracked.

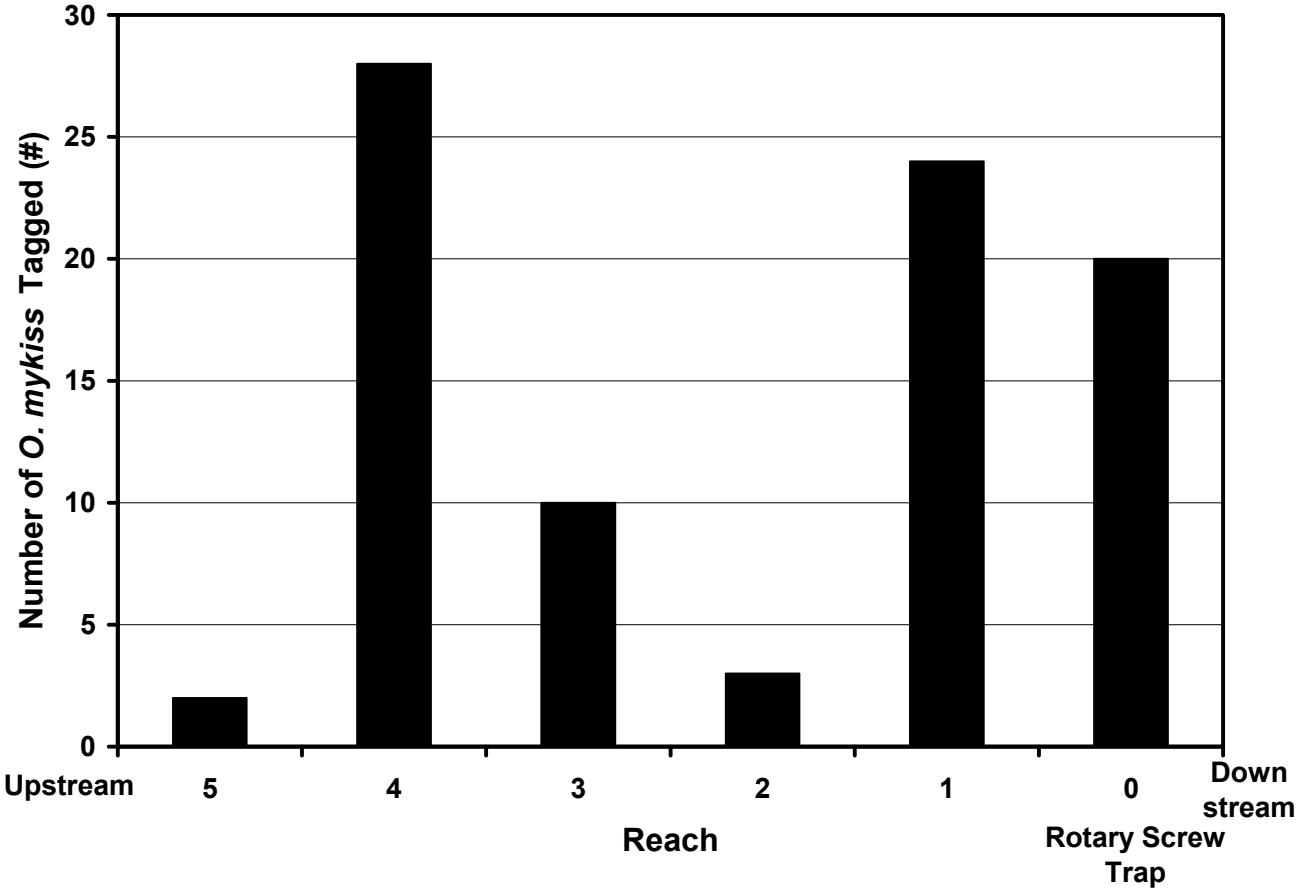

Figure 10. Number of juvenile rainbow trout/steelhead PIT tagged in 2004, at each reach along the river.

A total of 40 juvenile coho salmon were captured at Reach 1 in 2005 between 16 February and 17 June. Of these, 11 fish were of adequate size to be PIT tagged. Six of the PIT tagged coho salmon were captured in a side channel on river left, with access to the main river. Another 5 PIT tagged coho salmon 1+ were captured in an apparently isolated pool, also located on river left, near but not connected to the side channel. Some of the fish in the isolated pool were re-detected on subsequent sampling trips, using a mobile PIT antenna. However, the some or all of fish may have escaped the pool during a high water event subsequent to tagging (W.R. Chesney, CDFG, Yreka, pers. comm.). During sampling conducted after the rain event/high water no 1+ coho salmon were detected in the "isolated" pool, but several young-of-the-year coho salmon were captured. Cooler water may have attracted coho salmon to the isolated pool, since water temperatures were cooler than in the mainstem in mid-summer (W.R. Chesney, CDFG, Yreka, pers. comm.).

2004-2005 Summary

A total of 494 traps were set between 8 June 2004 and 17 June 2005. A total of 1,772 fish of non-salmonid species were captured. A total of 40 juvenile coho salmon were captured. Coho salmon were only captured in Reach 1 (Table 1). A total of 84 rainbow trout/steelhead were captured. Rainbow trout/steelhead were captured in all five reaches, but not on all sample dates (Table 2). More rainbow trout/steelhead were captured in Reach 4 than in other reaches, but Reach 4 also experienced more sampling effort across the summer, so the number of fish trapped in any given reach does not represent a fish density index. The main focus of sampling efforts in this early stage of the project was to test the ability of traps to capture coho salmon, so efforts were not evenly divided amongst the reaches. A summary of the number of coho salmon and rainbow trout/steelhead captured by reach is shown in Figure 11.

Table 1. Number of coho salmon captured in minnow traps, sorted by reach and date.

Sum of Coho salmon	Reach					
Date trap out	1	2	3	4	5	Grand Total
6/8/2004			0			0
6/29/2004					0	0
7/7/2004		0				0
7/8/2004	0			0		0
7/13/2004			0			0
7/14/2004					0	0
8/3/2004	0			0		0
8/11/2004				0		0
8/31/2004		0		0		0
9/15/2004			0	0		0
9/28/2004	0			0		0
10/12/2004		0				0
10/13/2004			0	0		0
11/30/2004				0		0
12/1/2004					0	0
12/14/2004	0			0		0
2/16/2005	1				0	1
2/24/2005	1					1
3/8/2005	1					1
3/23/2005	2					2
4/5/2005	3					3
4/27/2005	17					17
6/17/2005	15					15
Grand Total	40	0	0	0	0	40

A total of 68 rainbow trout/steelhead were PIT tagged, plus an additional 20 rainbow trout/steelhead were PIT tagged and released during the PIT tagging practice session at the CDFG rotary screw trap. A total of 11 coho salmon were PIT tagged. Four of the PIT tagged rainbow trout/steelhead, and one of the tagged coho salmon were later recaptured (For code numbers of PIT tagged fish, please contact the authors). This represents 5.9% of rainbow trout/steelhead tagged in Reaches 1-5, and 0.9% of coho salmon tagged in Reach 1. None of the

20 rainbow trout/steelhead tagged at the rotary screw trap were recaptured; they are assumed to have been in the process of outmigrating, and no longer in the river. All recaptures occurred at the reach from which the fish was originally captured and tagged, and within approximately one to two months from the original capture date.

Table 2. Number of rainbow trout/steelhead captured in minnow traps, sorted by reach and date.

Sum of Rainbow Trout/Steelhead	Reach					
Date trap out	1	2	3	4	5	Grand Total
6/8/2004			0			0
6/29/2004					3	3
7/7/2004		0				0
7/8/2004	2			1		3
7/13/2004			0			0
7/14/2004					3	3
8/3/2004	2			6		8
8/11/2004				1		1
8/31/2004		0		3		3
9/15/2004			0	5		5
9/28/2004	10			7		17
10/12/2004		3				3
10/13/2004			10	8		18
11/30/2004				4		4
12/1/2004					0	0
12/14/2004	11			4		15
2/16/2005	1				0	1
2/24/2005	0					0
3/8/2005	0					0
3/23/2005	0					0
4/5/2005	0					0
4/27/2005	0					0
6/17/2005	0					0
Grand Total	26	3	10	39	6	84

Discussion

Fish Distribution

We caught no coho salmon in 2004. However, the juvenile coho salmon 0+ cohort available for trapping in 2004 is likely to have been relatively small, based on outmigrant trapping performed by the California Department of Fish and Game between 2001 and 2003 (Chesney 2002, Chesney 2003, Chesney and Yokel 2003). By using coho salmon 1+ outmigration numbers from the following spring to back-calculate approximate coho salmon 0+ numbers the previous summer, coho salmon 0+ in-river numbers would be expected to be low in 2000 and 2001, and higher in 2002. Assuming subsequent cohorts followed the same pattern, low in-river numbers would be expected in 2003 and 2004, and higher numbers in 2005. Thus, it is not surprising that coho salmon 0+ were captured in 2005. Based on outmigrant data from previous years, we would expect in-river captures of coho salmon 0+ to be low in 2006 and 2007.

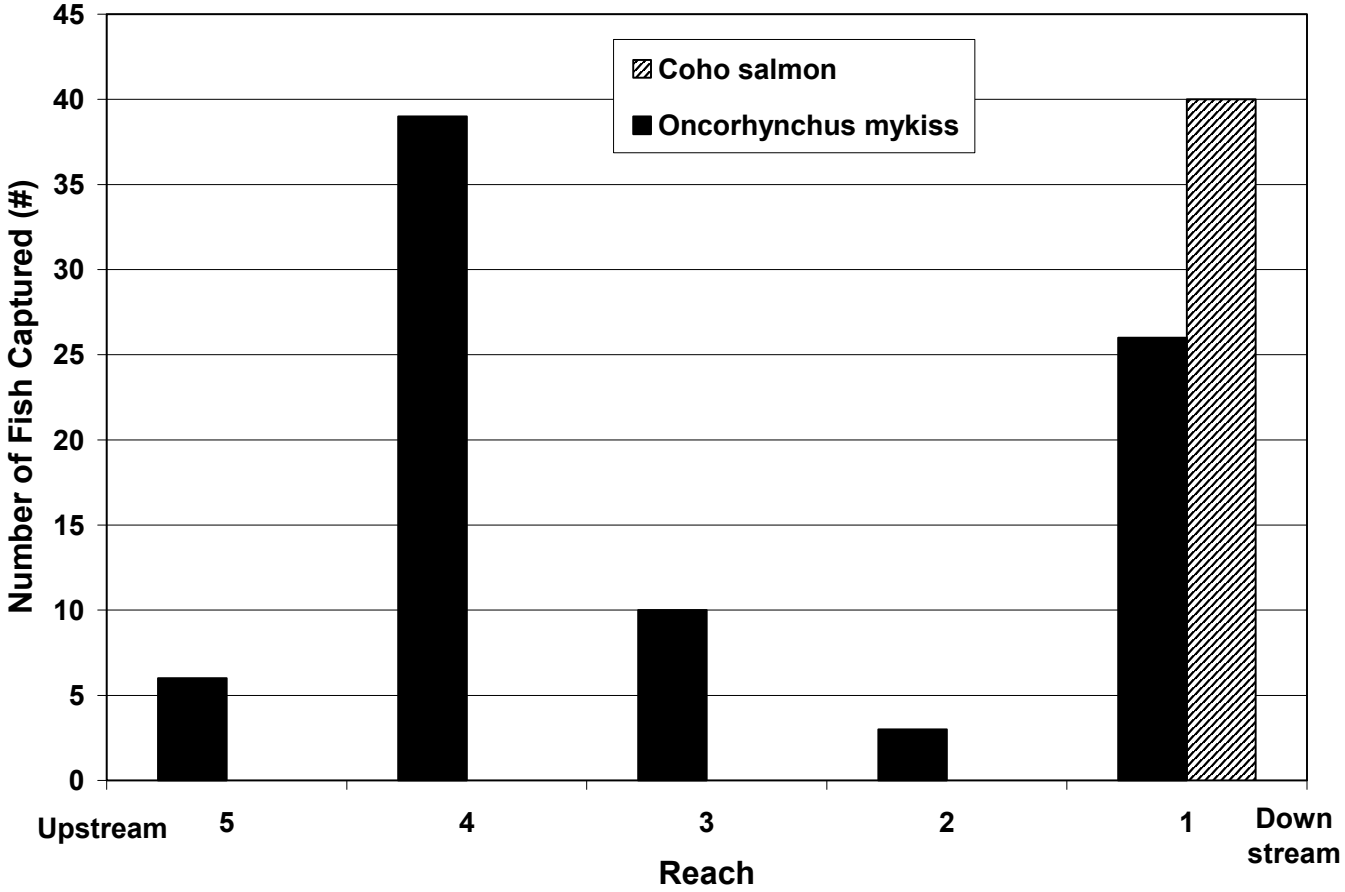

Figure 11. Total number of coho salmon and rainbow trout/steelhead captured in each reach between 8 June 2004 and 17 June 2005.

Coho salmon 1+ were caught in the canyon in spring 2005, but no coho salmon 1+ (i.e., fish in the previous cohort) were captured in the canyon in 2004. However, sampling in 2004 began in June, due to the timing of permits and MOU for the project, and time necessary to assemble and train field assistants. Thus the 2004 sampling period may have started after coho salmon 1+ had already emigrated from the canyon area.

The source of the coho salmon 1+ caught in the canyon in spring 2005 is uncertain, since no coho salmon 0+were captured there in 2004. It is possible that these fish moved into the canyon during the cooler winter months, after over summering in cooler locations upstream, or in other Klamath River tributaries.

Rainbow trout/steelhead were captured in all five reaches in at least some months of the study. The lack of captures of rainbow trout/steelhead at Reaches 2 and 3 in late summer indicate that the species may have been absent from those reaches at that time, potentially due to high water temperatures and low overnight dissolved oxygen levels. However, it should be stressed that sampling methods such as minnow trapping can prove conclusively only the presence of a species in a reach, not its absence. Individuals of a particular species may be present in a reach, yet choose not to enter the traps. The reasons for this are uncertain, but may include water

temperatures high or low enough to preclude activities such as feeding, or the presence of natural food sources in enough abundance that fish are not attracted to the bait in the traps.

Project Status

This report addresses preliminary results of what is intended to be a long term project. Thus far the project has been successful in attracting the interest and participation of riparian private landowners in the Shasta River watershed, allowing research to proceed in each of the identified reaches along the length of the river between Dwinnell Dam and the Klamath River confluence. Minnow traps baited with salmon roe have proven to be an effective and low impact method of capturing both juvenile rainbow trout/steelhead and coho salmon. Trapping experience to date has allowed the fine tuning of choice of trap locations to optimize capture of juvenile coho salmon, or of rainbow trout/steelhead, should a given species be present in a given river reach. The project has been successful in capturing and PIT tagging juvenile coho salmon.

Future Research and Outreach

We have the supplies to construct 2 PIT antenna arrays each capable of sampling the river at a typical width of 20 – 30'. Each array will be comprised of 4-5 antenna loops set side by side to span the river. This is necessary because the small PIT tags suitable for juvenile fish have a limited detection range. The antenna arrays will provide information on movement and migration timing within different sections of the river. Passage past the PIT antenna arrays will not cause any take of juvenile coho salmon, nor any other organisms in the river.

With the proven ability to trap and PIT tag juvenile coho salmon, and the construction and field testing of PIT antennas, we are now in a position to conduct monitoring of adaptive management experiments to test the impact of best management practices on juvenile coho salmon distribution and outmigration. Such experiments could include pulse flow flushing releases, as have been conducted in the past, a number of recovery measures included in the state Recovery Strategy for Coho Salmon (*Oncorhynchus kisutch*) (CDFG 2004), and other best management practices that multi-stakeholder groups in the watershed may be interested in testing. This work would be expected to complement projects that may arise from the recent state-federal initiative to develop a coastal salmonid monitoring program for California (CDFG 2003b).

Preliminary results of this study have been presented at venues such as meetings of the Shasta Valley Resource Conservation District, meetings of the Scott and Shasta Valleys Coho Salmon Recovery Team, and annual UC Cooperative Extension Growers meetings in Yreka, CA. We anticipate the presentation and publication of ongoing results and analyses as these become available.

Acknowledgments

We thank Mr. Bill Chesney, Mr. David Webb, Dr. J.J. Cech, Mr. Bill Jong, Mr. Mark Pisano, Mr. Jim Whelan, Mr. Donald Flickinger, and Mr. Mark Hampton for their advice on the experimental design and methods used in this project. We gratefully acknowledge Mr. Kerry Mauro for his initiative and efforts in the design, construction, and field testing of the PIT antennas, and thank Mr. Seth Ricker for his advice on PIT antenna components, and field designs. We express our appreciation to the landowners who provided

access to their properties for data collection. Funding for this project was provided by the University of California Division of Agriculture and Natural Resources, and the University of California Cooperative Extension.

References

CDFG. 1997. A biological needs assessment for anadromous fish in the Shasta River, Siskiyou County, California. CDFG Report. 29 p.

CDFG. 2003a. Shasta Valley Hydrologic Area. Report prepared for the State Wide Coho Recovery Team, April, 2003.

CDFG. 2003b. California Coastal Salmonid Restoration Monitoring and Evaluation Program: Interim Restoration Effectiveness and Validation Monitoring Protocols, March 2003. Effectiveness section by Harris et al., and Validation section by Duffy et al.

CDFG. 2004. Recovery strategy for California coho salmon (*Oncorhynchus kisutch*). Report to the California Fish and Game Commission, February 2004. Species Recovery Strategy 2004-1. Department of Fish and Game, The Resources Agency, State of California.

Chesney, W.R. 2002. Annual Report, Shasta and Scott River juvenile salmonid outmigrant study, 2000-2001. Project 2a1, Department of Fish and Game, The Resources Agency, State of California. January 2002. 38 p.

Chesney, W.R. and E.M. Yokel. 2003. Annual Report, Shasta and Scott River juvenile salmonid outmigrant study, 2001-2002. Project 2a1, Department of Fish and Game, The Resources Agency, State of California. January 2003. 44 p.

Chesney, W.R. 2003. CDFG, Steelhead Research and Monitoring Program, Rotary Trap Catch Summary for Shasta and Scott River, Julian Weeks 7 – 23 2002, 2003. Department of Fish and Game, The Resources Agency, State of California. July 2003. 10 p.

Coots, M. 1958. Shasta River King salmon count, 1957. DFG Inland Fisheries Administrative Report Number 58-4.

Deas, M.L. 1999. Water quality: report on limiting factors: Shasta River, California. 20 p.

Deas, M., A. Abbot, and A. Bale. 2003. Shasta River Flow and Temperature Modeling Project. Watercourse Engineering, Inc., Report prepared for the Shasta Valley Resource Conservation District and the California Department of Fish and Game. 166 p.

Jong, H.W. 1994. Chinook salmon spawning habitat quality evaluation studies. CDFG Report. 17 p.

Leidy, R.A., and G.R. Leidy. 1984. Life stage periodicities of anadromous salmonids in the Klamath River Basin, Northwestern California. US Fish and Wildlife Service, Division of Ecological Services, Sacramento, California.

Manning, D., and L.C. Thompson. 2003. Potential marking and tagging techniques. Report to the Russian River Coho Recovery Workgroup: Monitoring and Evaluation Committee. October, 2003. 12 pp.

NMFS. 2001. Status review update for coho salmon (*Oncorhynchus kisutch*) from the Central California Coast and the California portion of the Southern Oregon/Northern California Coasts Evolutionarily Significant Units. Southwest Fisheries Science Center, Santa Cruz Laboratory, National Marine Fisheries Service. 40 p.

Ricker, S.J. 1997. Evaluation of salmon and steelhead spawning habitat quality in the Shasta River Basin, 1997.

Shasta River Coordinated Resources Management and Planning Committee. 1997. Shasta Watershed Restoration Plan.