Greenwood Creek

Juvenile Salmonid Out-migrant Trapping Update (2002)

Introduction

The only anadromous salmonid species found within Greenwood Creek is steelhead trout (*Oncorhynchus mykiss*). On 7 June 2000, the National Marine Fisheries Service listed steelhead within this evolutionarily significant unit as threatened under the Endangered Species Act. Mendocino Redwood Company (MRC) is assessing the status of steelhead within Greenwood Creek. This is being achieved through juvenile steelhead distribution surveys (MRC 2002a) and out-migrant trapping. Out-migrant trapping produces data regarding the outmigration timing, community structure, and abundance of steelhead. Repeating out-migrant trapping in the future may identify temporal trends in steelhead abundance. This information will aid MRC in focusing restoration efforts and developing timber management strategies.

Study Area

Greenwood Creek is a fourth order coastal stream in Mendocino County, California. The drainage area of Greenwood Creek is 16,448 acres. MRC owns 59% of this area; the remainder is predominantly timberland owned by other private landowners. Logging and associated road construction has been the predominant activity in the basin since the early 1900’s. The basin's elevation ranges from 0-2297 ft. above sea level. The topography is steep, and rocks are highly sheered. During this study, stream width at the trap site ranged from 22-34 ft. (mean = 25 ft.) and stream discharge ranged from 1.5-13.4 CFS (mean = 6.2 CFS). The trap was located approximately .75 miles upstream from the Pacific Ocean (Fig. 8).

Methods

A downstream migrant trap was operated in Greenwood Creek, Mendocino County, Ca. from 17 March - 30 May 2001. The trap consisted of a full-channel weir with a 1-m opening on the left bank to allow for passage of adult fish (Fig. 1). At the apex of the weir, water flowed into a 20-cm diameter section of PVC pipe. Fish were concentrated into this 20-m long pipe and transported into a live box. A Mcbain ramp was used to dissipate the high pressure of the water before it entered the live box, thus reducing potential injury to the fish (fig. 2). Fish were removed from the live box every morning and anesthetized with CO_2 by placing the fish in a 5-gal. bucket containing approximately 4-gal. of water and 2 dissolved Alka-Seltzer™ tablets. The species and fork length (to the nearest mm) of each fish was recorded. Steelhead were classified as young of the year (YOY), presmolt (parr), or smolt. YOY were distinguishable by their relatively small size compared to presmolts. Presmolts had pronounced parr marks and were larger than YOY. Finally, fish silver in color with blackened fin tips and no parr marks were identified as smolts. Parr and smolts were assumed to be one year of age or older (age 1+). Age 1+ steelhead are referred to as “out-migrants”. However, it is uncertain what percentage of these fish actually entered the ocean. Up to 30 smolts and 30 presmolts were given a fin clip daily. Types of fin clips were rotated in a 4-week cycle. After being handled, the fish were placed in a 5-gal. bucket containing approximately 4-gal. of aerated water to recover. Marked fish were released in random locations, 75-100 ft. above the trap. Assuming that fish emigrated past or into the trap within 3 weeks, this methodology allowed for fish to have a discreet mark every week. Recapture data was used to estimate trap efficiency using Darroch Analysis with Rank-Reduction (DARR) (Bjorkstedt, 2000). An estimate of trap efficiency allowed for an estimation of the total steelhead outmigration during trapping.

Flows were taken daily in a riffle directly downstream of the trap using a Swoffer™ Model 2100 flow meter. This was achieved by dividing the stream's width into either 1 or 2 foot cells, recording the velocity and area of the water in each of these cells, and summing the volume of water traveling through the cells. Water temperature, dissolved oxygen, and pH were measured daily with a Horiba™ U10 Water Quality Checker. A temperature probe (Hobo™**)** was placed in a riffle directly downstream of the trap. The probe recorded the water temperature every 2 hours continuously over the trapping period.

Figure 1. Full channel weir funneling water and fish into PVC pipe.

Figure 2. A Mcbain ramp funneling water into a live box.

Data Analysis

To calculate the total abundance of out-migrants (± 1 standard deviation) captures and recaptures were totaled by week and analyzed using DARR. DARR is a software application that analyzes mark-recapture data using a modified form of Darroch analysis (Darroch 1961). Assumptions associated with this analysis are listed below. Relationships between physical stream variables and the estimated number of steelhead out-migrants were analyzed using Pearson correlation.

Assumptions

To increase the accuracy of our out-migrant abundance estimate the following assumptions have to be met (adapted from Bjorkstedt 2000):

1. Marked and unmarked fish were well mixed;
2. All individuals exposed to capture at a given time had equal probability of being captured;
3. Marked individuals were unambiguously identified;
4. Marked individuals experience negligible (or known) mortality;
5. Marks were retained for the duration of the experiment (In this case, until they migrated past or through trap);
6. Marked fish resumed migration in a minimum of 3 weeks.

Results

Steelhead

A total of 2564 age 1+ steelhead were captured throughout the trapping period. The total annual migration is estimated at 7755 ± 491 individuals. Estimated trap efficiency ranged from 10%-74% (mean = 35%). Steelhead migrated throughout the trapping period. The peak of the migration occurred during the sixth week of trapping (20 April – 26 April) (fig. 3). A total of 164 YOY were captured. The YOY captures began during week 4 (6 April – 12 April) and continued throughout the study (Fig. 4).

Steelhead lengths ranged from 26-211 mm (mean = 94 mm). Length frequency histograms show a clear bimodal relationship between the length of YOY and age 1+ steelhead. YOY steelhead lengths ranged from 26-43mm (mean = 31 mm). And age 1+ steelhead lengths ranged from 54-211 mm (mean = 98 mm) (Fig. 5, Table 1).

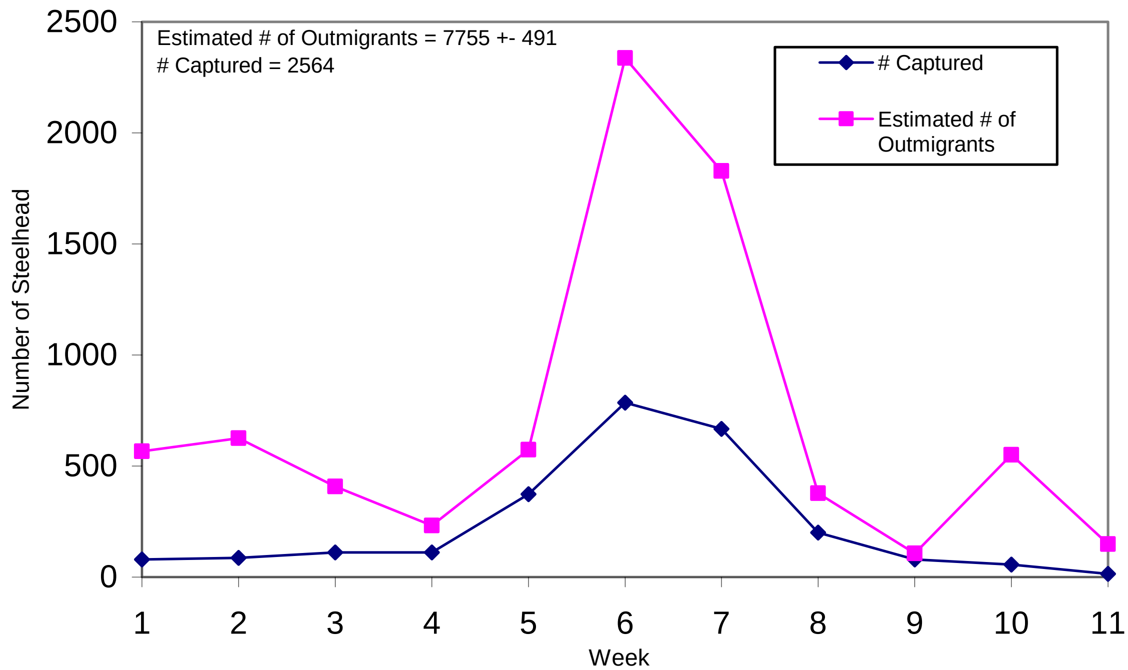

Figure 3. Number of age 1+ steelhead captured and estimated number of age 1+ steelhead out-migrant in Greenwood Creek, 17 March - 30 May 2001.

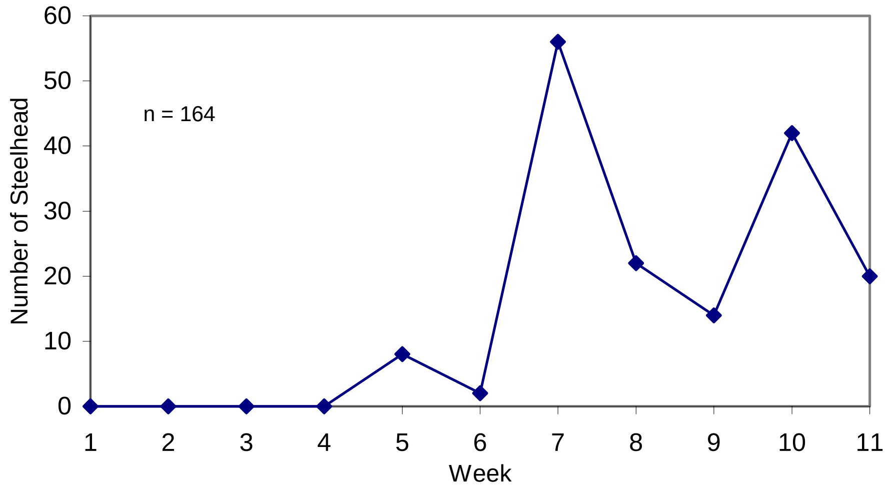

Figure 4. Number of steelhead YOY captured in Greenwood Creek, 17 March - 30 May 2001.

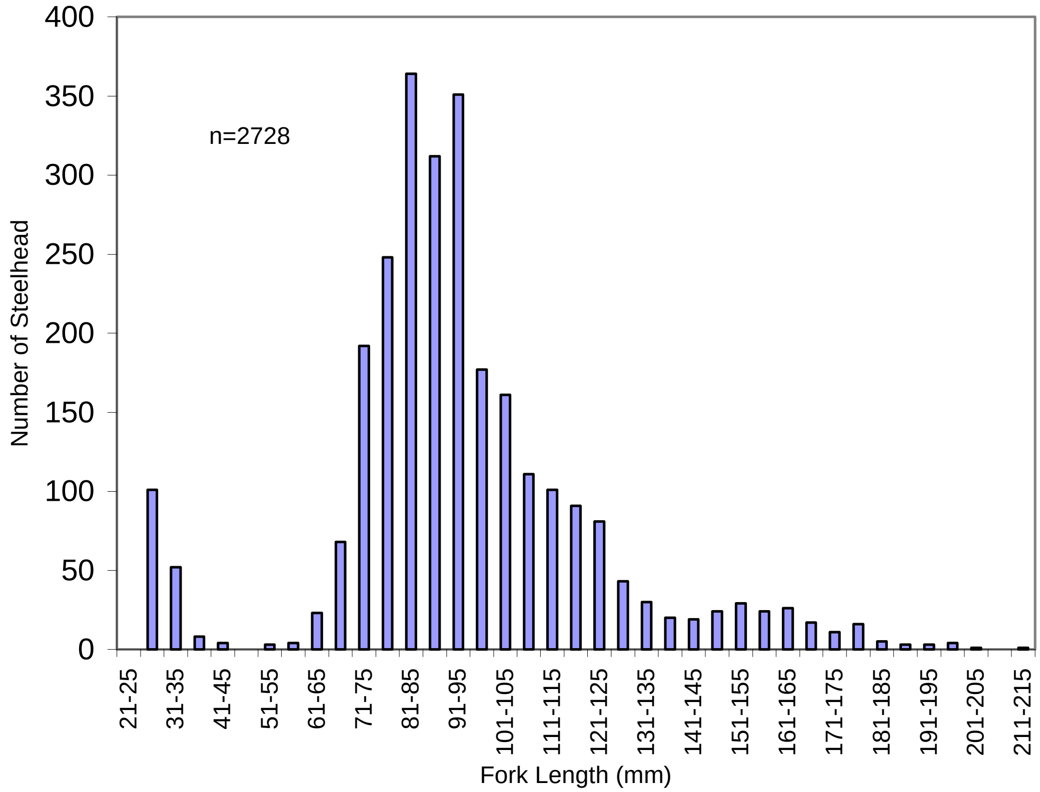

Figure 5. Length frequency of steelhead captured in Greenwood Creek,
17 March – 30 May, 2001.

Table 1. Weekly lengths (by 5 mm size classes) of steelhead captured in Greenwood Creek, 17 March - 30 May 2001.

	Dates											
Fork Length (mm)	3/17 - 3/22	3/23 - 3/29	3/30 - 4/5	4/6 - 4/12	4/13 - 4/19	4/20 - 4/26	4/27 - 5/3	5/4 - 5/10	5/11 - 5/17	5/18 - 5-24	5/25 - 5/30	Total
26-30					7	2	37	16	7	21	11	101
31-35					1		19	6	7	14	5	52
36-40										6	2	8
41-45								1		1	2	4
46-50												0
51-55	1		1		1							3
56-60		1				1	2					4
61-65	2	2			2	12	3	2				23
66-70	3	1	6	3	13	22	16	4				68
71-75	2	11	6	4	36	81	41	9	2			192
76-80	2	5	14	12	46	84	62	14	5	4		248
81-85	2	2	6	9	61	130	111	23	8	9	3	364
86-90	2	4	8	8	42	97	90	34	15	11	1	312
91-95	1	7	6	11	44	118	94	42	14	14		351
96-100	3	1	4	7	24	42	58	21	11	6	1	178
101-105	3	5	3	8	26	42	45	13	7	7	2	161
106-110	2	2	6	9	18	31	20	6	7	5	4	110
111-115	4	4	3	5	9	36	26	9	4		1	101
116-120	5	3	3	6	12	24	25	9	2		2	91
121-125	6	8	4	4	4	23	25	5	1		1	81
126-130	2	3	5	2	4	9	15	3				43
131-135	2	1	3	1	2	7	11	3				30
136-140			3	2	2	6	5	2				20
141-145	5	1	3	3		2	5					19
146-150	4	2	5	4	3	3	3					24
151-155	1	7	2	3	7	4	3	1	1			29
156-160	1	2	4	7	4	3	1		2			24
161-165	7	4	6	2	4	2	1					26
166-170	2	3	5		5	1	1					17
171-175	3	2	1		1	3	1					11
176-180	6	2	2	1	2		3					16
181-185	3	2										5
186-190	1	1			1							3
191-195	1					1						2
196-200	1	1	2			1						5
201-205	1											1
206-210												0
211-215	1											1
											n = 2728	

Mortalities and Non-salmonid Species

In addition to salmonids, prickly sculpin (*Cottus asper*), coastrange sculpin (*C. aleuticus*), three-spine sticklebacks (*Gasterosteus aculeatus*), california roach (*Lavinia symmetricus*), foothill yellow legged frogs (*Rana boylii*), pacific giant salamanders (*Dicamptodon tenebrosus*), and signal crayfish (*Pacifastacus leniusculus*) were captured (Table 2). Mortalities were recorded daily.

Table 2. Total organisms captured and total trap-related mortalities at Greenwood Creek, 17 March - 30 May 2001.

Species	# Captured	# of Mortalities	Mortalities
Steelhead Trout (*Oncorhynchus mykiss*) Young of the Year	164	9	5%
Steelhead Trout (*O. mykiss*) Age 1+	2564	11	0.4%
Coastrange Sculpin (*Cottus aleuticus*)	145	0	0%
Prickly Sculpin (*C. asper*)	357	4	1%
Three Spine Stickleback (*Gasterosteus aculeatus*)	38	3	8%
California Roach (*Lavinia symmetricus*)	416	21	5%
Crayfish (*Pacifastacus leniusculus*)	6	0	0%
Foothill Yellow Legged Frog (*Rana boylii*)	17	0	0%
Pacific Giant Salamander (*Dicamptodon tenebrosus*)	20	0	0%

Physical Parameters

Throughout the study, stream temperature ranged from 6.2-18.3 °C. (mean = 11.4 °C) and stream discharge ranged from 1-17 CFS (mean = 6 CFS). Dissolved oxygen measurements ranged from 7.4-12.3 mg./l. (mean = 10.5 mg./l.) and pH ranged from 6.8-8.1 (mean = 7.7). Figures 6-7 present weekly averages of stream temperature, dissolved oxygen and discharge. No significant correlation was found between these physical parameters and the migration rate of age 1+ steelhead.

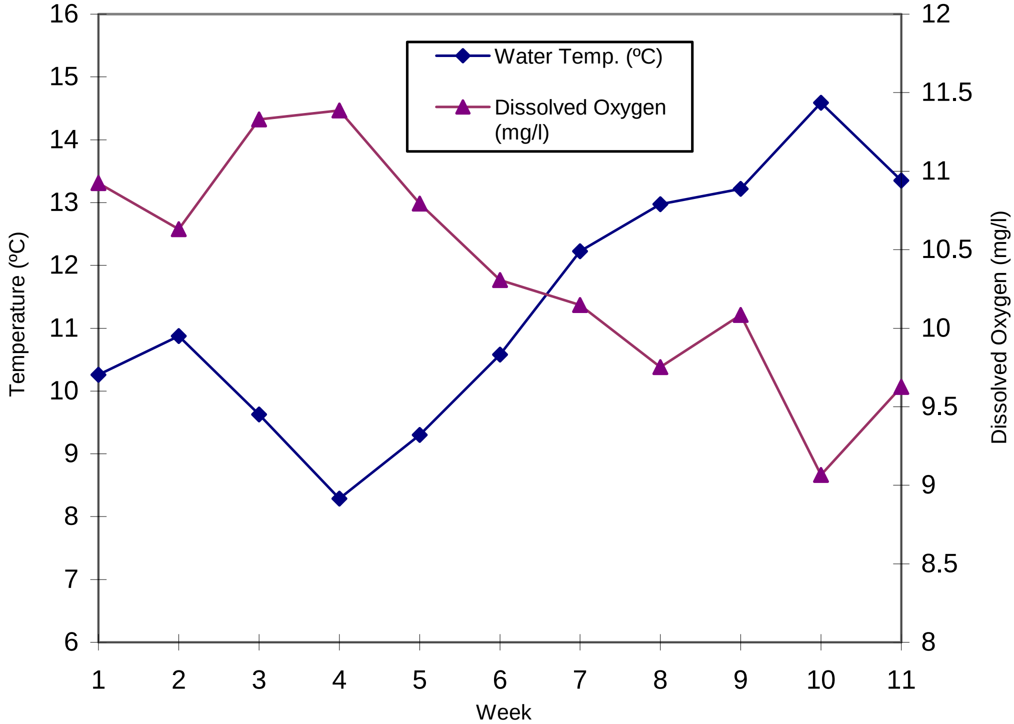

Figure 6. Mean weekly water temperature and dissolved oxygen of Greenwood Creek during out-migrant trapping, 17 March - 30 May 2001.

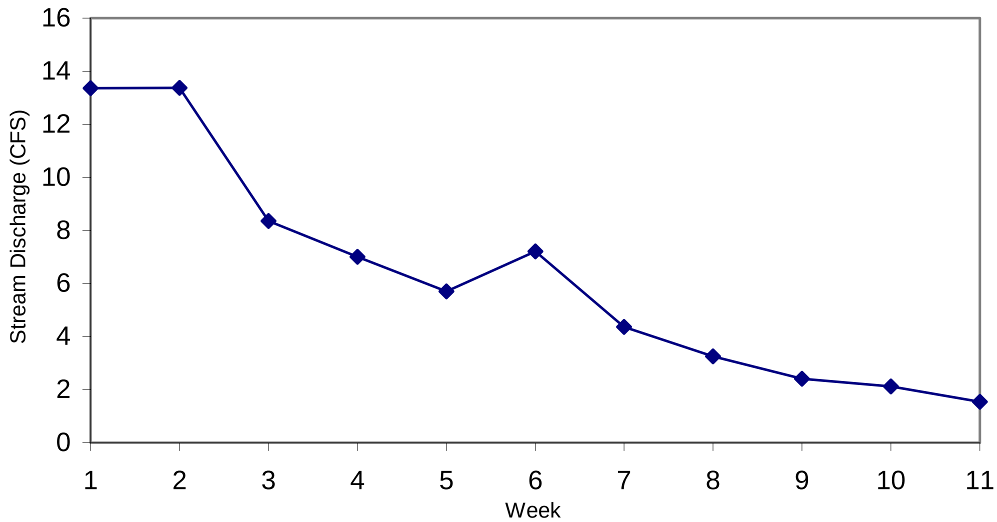

Figure 7. Mean weekly stream discharge of Greenwood Creek during out-migrant trapping, 17 March - 30 May 2001.

Discussion

Out-migrant trapping is a tool being used extensively in northern California to estimate juvenile salmonid population sizes. Most traps function poorly in extremely low or high flow conditions. Hence, the traps are frequently installed too late or removed too early to capture the entire salmonid migration. In this study, a majority of the steelhead migration appears to have been captured (fig. 3). Another problem associated with out-migrant trapping is the difficulty in gauging how well the necessary assumptions (pg. 3) are being met. Due to these limitations, the population estimates generated by trapping frequently misrepresent the actual abundance of out-migrants. However, if population estimates are standardized by time and watershed size, an abundance index may be developed. Table 3 presents data collected during 2001 in seven coastal streams. The traps operated during approximately the same time interval. In order to standardize the data by watershed size, the population estimates were divided by the acreage of watershed being trapped. The ranges presented represent the upper and lower confidence limits of the population estimates. The data was collected by either the California Department of Fish and Game (CDFG) (Harris and Knechtle 2002) or MRC (MRC 2002b). The methods employed by CDFG were similar to MRC's methods. The primary difference was the use of fyke net traps by CDFG verses the use of pipe traps by MRC. Both CDFG and MRC used DARR software to generate the population estimates. When interpreting this information, it is important to consider the data limitations previously discussed. Additionally, all watersheds are unique and should not be expected to support equal densities of salmonids. Of the seven watersheds presented in table 3, the number of steelhead out-migrants per acre in Greenwood Creek was relatively low.

Monitoring of Greenwood Creek should continue in order to further address the status of steelhead. Ideally out-migrant trapping should be conducted for a minimum of three years. In the short term, this allows for various steelhead cohorts to be sampled. In the long term, trends in steelhead abundance may be identified.

Table 3. Abundance index of steelhead out-migrants from coastal streams in Mendocino County, Ca. during the spring / summer of 2001.

Scource	Watershed	Population Estimate	Watershed Area Trapped (acres)	**Steelhead / Acre**	Dates
CDFG	Hare Creek	1651 +- 204	3808	**.38-.49**	3/19 - 5/30
MRC	*Greenwood Creek*	*7755 +- 491*	*16448*	***.44-.50***	*3/17 - 5/30*
CDFG	Little River	1882 +- 110	3040	**.58-.66**	3/19 - 5/30
CDFG	Caspar Creek	3146 +- 383	4160	**.66-.85**	3/19 - 5/30
MRC	Cottaneva Creek	10126 +- 1679	10579	**.80 - 1.12**	3/16 - 5/31
MRC	Elk Creek	21738 +- 3248	18074	**1.02-1.38**	3/12 - 5/30
CDFG	Wages Creek	9984 +- 5094	7040	**.69-2.14**	3/19 - 5/30

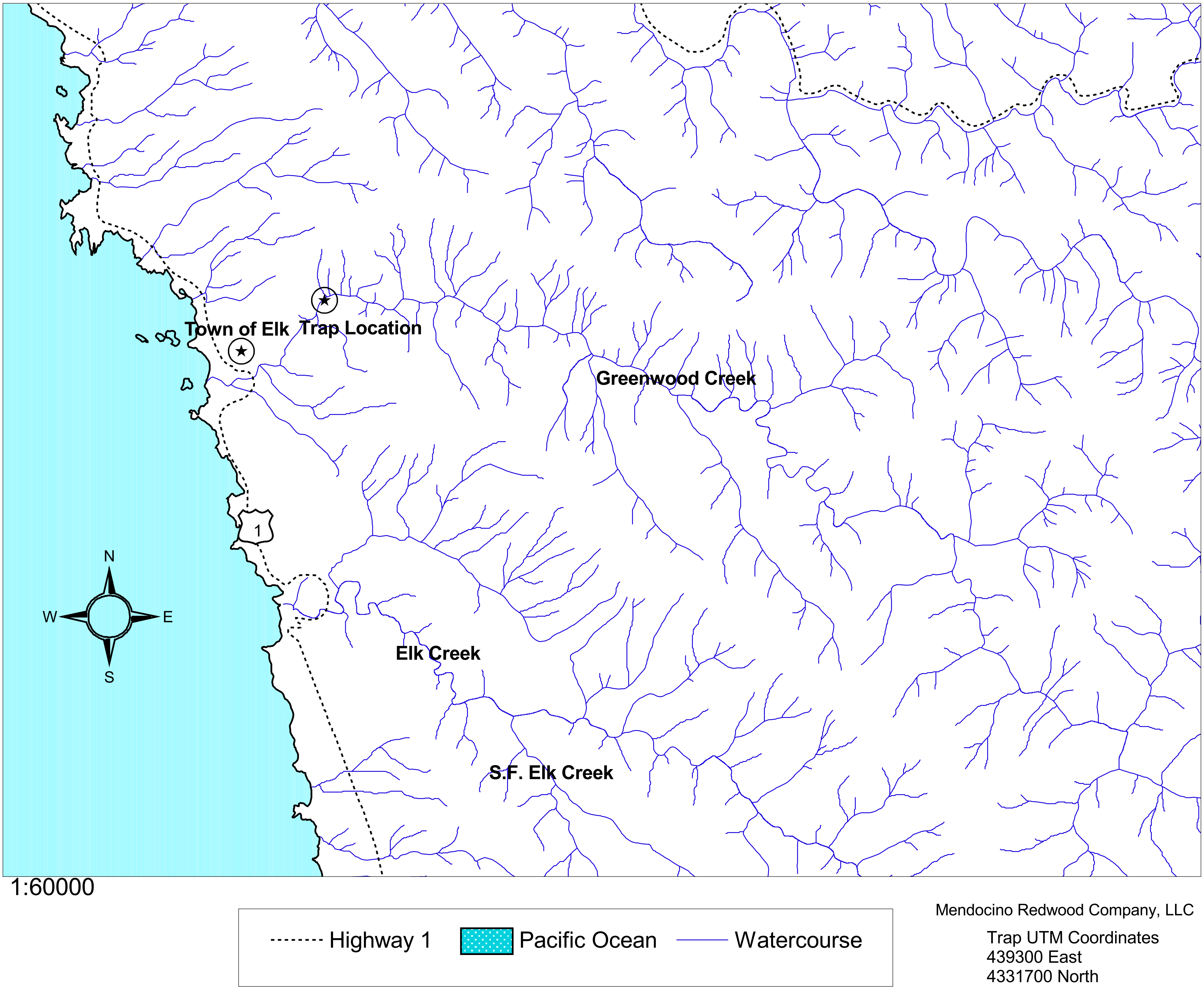

Figure 8. Location of out-migrant trap operated in Greenwood Creek, Mendocino County California.

References:

Bjorkstedt, E.P. 2000. DARR (Darroch analysis with rank-reduction): A method for analysis of stratified mark-recapture data from small populations, with application to estimating abundance of smolts from out-migrant trap data. U.S. Dep. Commer., NOAA, NMFS, SWFSC, Admin. Rep., Santa Cruz, SC-00-02. 28 pp.*

Darroch J.N. 1961. The two sample capture recapture census when tagging and sampling are stratified. Biometrika 48: 241-260.

Harris S. and M. Knechtle 2002. Inland and Anadromous Sport Fish Management and Research. Annual Performance Report, Federal Aid in Sport Fish Restoration Act. Project 22, North Central District Salmon and Steelhead Management. Job number 2, downstream (out) migration of juvenile salmon and steelhead. July 1, 2000 through June 30, 2001.

Mendocino Redwood Company 2002a. Aquatic Species Distribution on Mendocino Redwood Company Forestlands. Mendocino Redwood Company, LLC, P.O. Box 285, Fort Bragg California 95437.

Mendocino Redwood Company 2002b. Out-migrant Trapping Annual Update (2002). Mendocino Redwood Company, LLC, P.O. Box 285, Fort Bragg California 95437.

* The use of DARR does not constitute NMFS certification of the data or results.

Elk Creek

Juvenile Salmonid Out-migrant Trapping Update (2002)

Introduction

Historically, Elk Creek contained steelhead trout (*Oncorhynchus mykiss*) and coho salmon (*O. kisutch*). Steelhead are currently present. The current presence of coho salmon is uncertain. The National Marine Fisheries Service has listed these fish runs as threatened under the endangered species act. Steelhead were listed on 7 June 2000, and coho were listed on 31 Oct.1996. Mendocino Redwood Company (MRC) is assessing the status of salmonids within Elk Creek. This is being achieved through juvenile salmonid distribution surveys (MRC 2002a) and out-migrant trapping. Out-migrant trapping produces data regarding the out-migration timing, community structure, and abundance of salmonids. Repeating out-migrant trapping in the future may identify temporal trends in salmonid abundance. This information will aid MRC in focusing restoration efforts and developing timber management strategies.

Study Area

Elk Creek is a 27,206 acre coastal watershed in Mendocino County, California. MRC owns 69% of this area; the remainder is predominantly timberland managed by other private land owners. Logging and associated road construction has been the predominant activity in the basin since the early 1900's. The watershed's elevation ranges from 0-2736 ft. above sea level. The topography is steep, and rocks are highly sheered. During this study, stream width ranged from 23-33 ft. (mean = 26 ft.) at the trap site, and stream discharge ranged from 6-33 CFS (mean = 14 CFS). The trap was located approximately .5 miles upstream from the Pacific Ocean (fig. 8).

Methods

A pipe trap was fished continuously between 12 March and 30 May 2001 in Elk Creek (Figs. 1, 2). The trap consisted of a full-channel weir with a 1 m opening to allow for passage of adult fish. At the apex of the weir, water flowed into a 20-cm diameter section of PVC pipe. Fish were concentrated into this 20-m long pipe and transported into a live box. A Mcbain ramp was used to dissipate the high pressure of the water before it entered the live box, thus reducing potential injury to the fish. To minimize predation of young of the year (YOY) by larger fish, a fry box was attached to the back of the live box. The fry box was constructed of 7-mm mesh screen framed with wood.

Fish were removed from the live box every morning and anesthetized with CO_2 by placing the fish in a five-gallon bucket containing approximately 4-gal. of water and 2 dissolved Alka-Seltzer™ tablets. The species and fork length (to the nearest mm) of each fish was recorded. Salmonids were classified as YOY, presmolt (parr), or smolt based upon coloration. YOY were distinguishable by their relatively small size compared to presmolts. Presmolts had pronounced parr marks and were larger than YOY. Finally, fish silver in color with blackened fin tips and no parr marks were identified as smolts. Up to 30 presmolts and 30 smolts were given a fin clip each day. Presmolts and smolts were assumed to be one year of age or older (1+ steelhead). Age 1+ steelhead are referred to as “out-migrants”. However, it is uncertain what percentage of these fish actually entered the ocean. Types of fin clips were rotated in a 4-week cycle. After being handled, the fish were placed in a 5-gal. bucket containing approximately 4-gal. of aerated water to recover. Marked fish were released in random locations, 100-150 ft. above the trap. Assuming that fish emigrated past or into the trap within 3 weeks, this methodology allowed for fish to have a discreet mark every week. Recapture data was used to estimate trap efficiency using Darroch Analysis with Rank-Reduction (DARR) (Bjorkstedt, 2000).

Flows were taken daily in a riffle directly upstream of the trap using a Swoffer™ Model 2100 flow meter. This was achieved by dividing the stream’s width into either 1 or 2 foot cells, recording the velocity and area of the water in each of these cells, and summing the volume of water traveling through the cells. Water temperature, dissolved oxygen, and pH were measured daily with a Horiba™ U10 Water Quality Checker. A temperature probe (Hobo™**)** was placed in a riffle directly downstream of the trap. The probe recorded the water temperature every 2 hours continuously over the trapping period.

Figure 1. Weir funneling water and fish into PVC pipe.

Figure 2. Water leaving PVC pipe and entering live box.

Data Analysis

To calculate the total abundance of out-migrants ($\pm$ 1 standard deviation) captures and recaptures were totaled by week and analyzed using DARR. DARR is a software application that analyzes mark-recapture data using a modified form of Darroch analysis (Darroch 1961). Assumptions associated with this analysis are listed below. Relationships between physical stream variables and the estimated number of steelhead out-migrants were analyzed using Pearson correlation.

<u>Assumptions</u>

To increase the accuracy of our out-migrant abundance estimate, the following assumptions must be met (adapted from Bjorkstedt 2000):

1. Marked and unmarked fish were well mixed;
2. All individuals exposed to capture at a given time had equal probability of being captured;
3. Marked individuals were unambiguously identified;
4. Marked individuals experience negligible (or known) mortality;
5. Marks were retained for the duration of the experiment (In this case, until they migrated past or through trap);
6. Marked fish resumed migration in a minimum of 3 weeks.

Results

Steelhead

A total of 2598 age 1+ steelhead were captured throughout the trapping period. The annual migration is estimated at 21738 ± 3248 individuals (Fig. 3). Estimated trap efficiency ranged from 4%-40% (mean = 15%). Steelhead migrated throughout the trapping period. It would have been beneficial to leave the trap in longer because steelhead were still migrating at the time of trap removal. This negatively biased our estimate of annual out-migrants. A total of 421 YOY were captured (Fig. 4). The YOY captures began during week 4 (30 March – 5 April) and continued throughout the study.

Steelhead lengths ranged from 23-220 mm (mean = 87 mm). Length frequency histograms show a bimodal relationship between the length of YOY and age 1+ steelhead. YOY steelhead lengths ranged from 23-54 mm (mean = 30 mm). Age 1+ steelhead lengths ranged from 55-220 mm (mean = 96 mm) (Fig. 5, table 1).

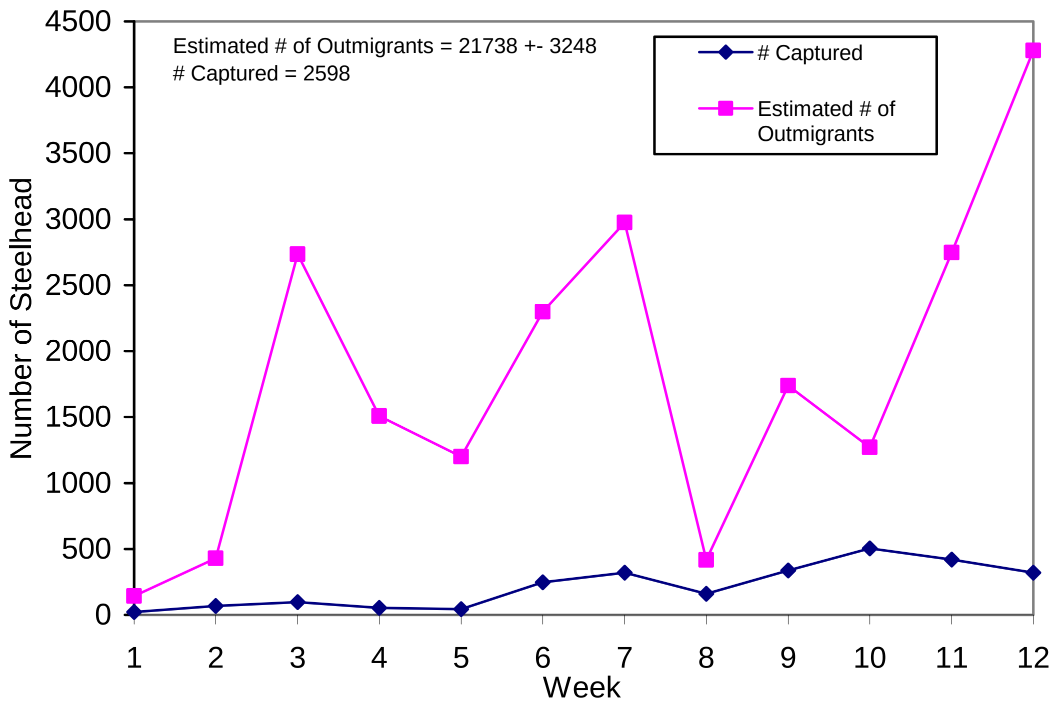

Figure 3. Number of age 1+ steelhead captured and estimated number of age 1+ steelhead out-migrants in Elk Creek, 12 March - 30 May 2001.

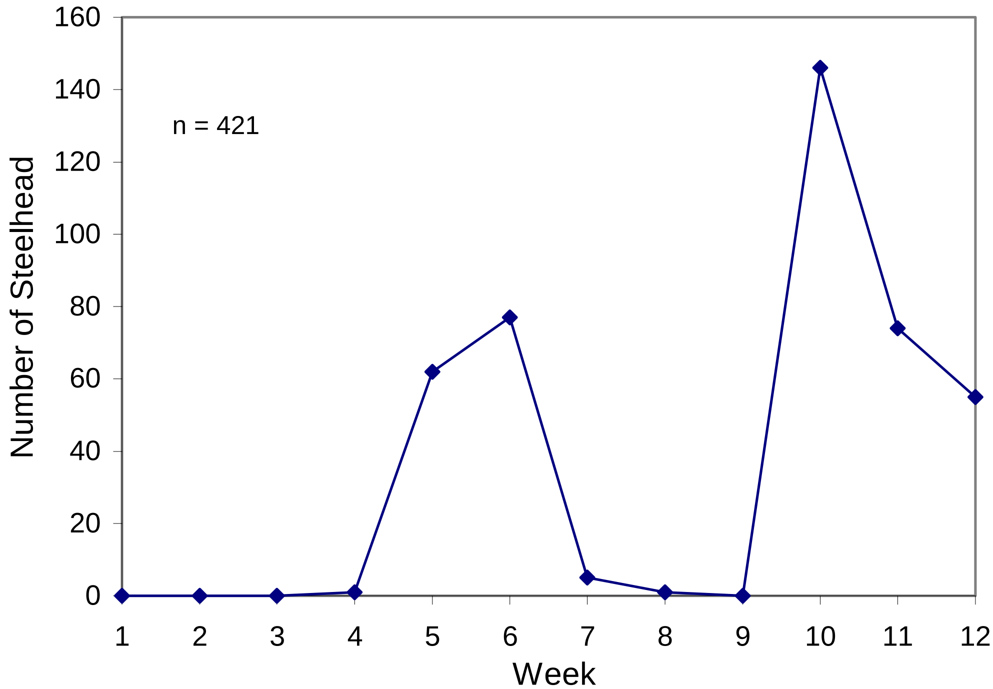

Figure 4. Number of steelhead YOY captured in Elk Creek, 12 March - 30 May, 2001.

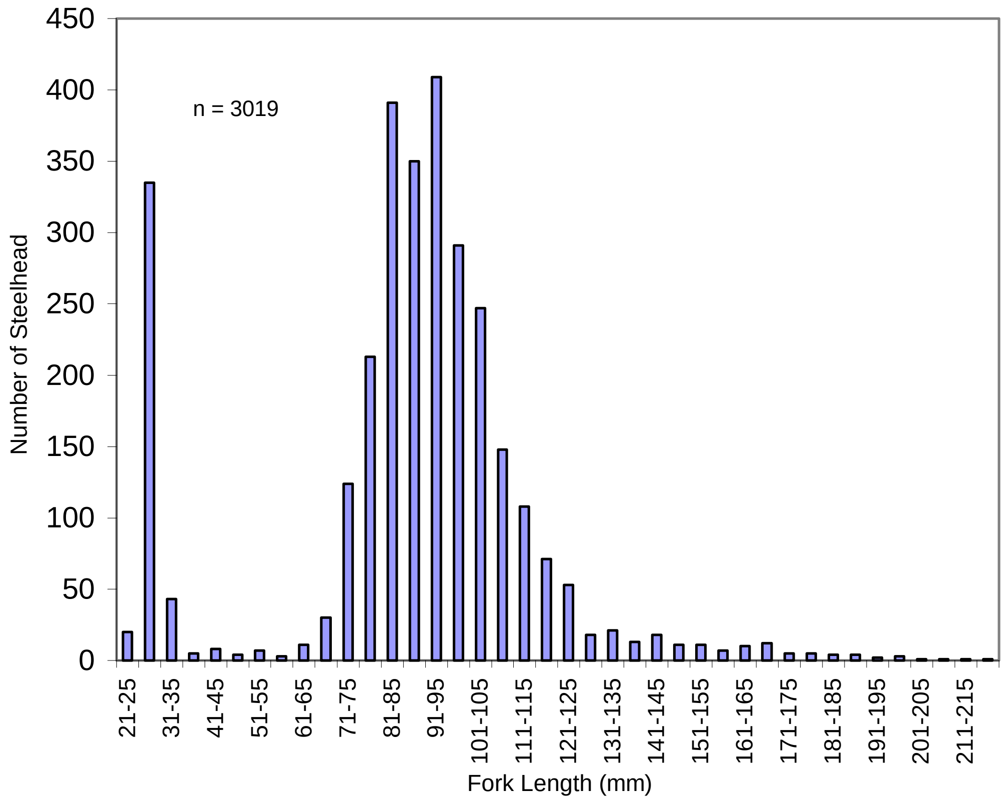

Figure 5. Length frequency of steelhead captured in Elk Creek, 12 March – 30 May 2001.

Table 1. Weekly lengths (by 5 mm size classes) of steelhead captured in Elk Creek, 12 March - 30 May 2001.

	Dates												
Fork Length (mm)	3/12 - 3/15	3/16 - 3/22	3/23 - 3/29	3/30 - 4/5	4/6 - 4/12	4/13 - 4/19	4/20 - 4/26	4/27 - 5/3	5/4 - 5/10	5/11 - 5/17	5/18 - 5/24	5/25 - 5/30	Total
21-25										18	1	1	20
26-30				1	52	72	5	1		116	56	34	337
31-35					10	5				11	10	5	41
36-40										1	2	2	5
41-45											2	6	8
46-50											1	3	4
51-55									1		2	4	7
56-60		1						1		1			3
61-65		3	2	1		2	2					1	11
66-70		6	4	1	1	3	7	3		3	1	1	30
71-75	1	5	10	3	1	9	23	14	14	20	17	7	124
76-80	2	9	5	8	3	18	30	18	31	46	30	13	213
81-85	1	9	13	8	6	30	45	28	48	108	61	34	391
86-90		8	12	7	4	34	46	23	44	83	49	40	350
91-95		4	13	6	4	32	53	35	57	85	69	51	409
96-100		7	6	3	1	25	35	9	47	58	60	40	291
101-105		3	4	3	3	21	26	8	42	37	52	48	247
106-110		1	3	3	6	16	20	7	15	28	26	23	148
111-115	1	1		1	3	13	11	4	11	16	22	25	108
116-120		1	1		3	12	9	3	6	6	15	15	71
121-125		1	2	1	1	6	9	1	5	7	12	8	53
126-130					1	2		2	6	3		4	18
131-135		1		1	1	4	1	1	5		1	6	21
136-140			1		1	1	1	1	4	1	1	2	13
141-145	1		1	5		5	1	1			4		18
146-150			2	1	1	1	1			3		2	11
151-155	1		2			5	1	1				1	11
156-160	1	1	4		1								7
161-165	3	1	2	1	1	2							10
166-170		2	4		1	5							12
171-175		2	1			2							5
176-180	3	1	1										5
181-185	2		2										4
186-190	2		1	1									4
191-195		1	1										2
196-200	2	1											3
201-205	1												1
206-210			1										1
211-215	1												1
216-220	1												1
Total	23	69	98	55	105	325	326	161	336	651	494	376	n=3019

MORTALITIES AND NON-SALMONID SPECIES

In addition to salmonids, prickly sculpin (*Cottus asper*), coastrange sculpin (*C. aleuticus*) three-spine sticklebacks (*Gasterosteus aculeatus*), foothill yellow legged frogs (*Rana boylii*), pacific giant salamanders (*Dicamptodon tenebrosus*), and pacific lamprey (*Lampetra tridentata*) were captured. Mortalities were recorded daily (Table 2).

Table 2. Total organisms captured and total trap-related mortalities at Elk Creek, 12 March-30 May 2001.

Species	# Captured	# of Mortalities	% Mortalities
Steelhead (*Oncorhynchus mykiss*) Young of the Year	421	19	5%
Steelhead Age 1+	2598	21	1%
Coastrange Sculpin (*Cottus aleuticus*)	570	1	.2%
Prickly Sculpin (*C. asper*)	1632	2	.1%
Three Spine Stickleback (*Gasterosteus aculeatus*)	12	1	8%
Pacific Giant Salamander (*Dicamptodon tenebrosus*)	3	1	33%
Pacific Lamprey Larvae (*Lampetra tridentata*)	9	0	0%
Adult Pacific Lamprey	11	0	0%
Foothill Yellow Legged Frog (*Rana boylii*)	16	0	0%

Physical Parameters

Throughout the study, stream temperature ranged from 7.8-14.1 °C. (mean = 10.7 °C) and stream discharge ranged from 5-37 CFS (mean = 13 CFS). Dissolved oxygen measurements ranged from 8.4-11.4 mg./l. (mean = 9.6 mg./l.) and pH ranged from 6.1-7.7 (mean = 7.2). Figures 6 and 7 display weekly averages of stream temperature, dissolved oxygen and discharge. The statistical relationship between these physical parameters and the number of age 1+ steelhead out-migrants was analyzed. The number of weekly out-migrants was negatively correlated with mean weekly stream discharge ($r = -.54$, $p = .03$, $n = 12$), and positively correlated with mean weekly stream temperature ($r = .48$, $p = .05$, $n = 12$). This may be explained by Baggerman's (1960) suggestion that salmonid emigration is stimulated by a combination of decreasing flow, increasing water temperature, and increasing photoperiod.

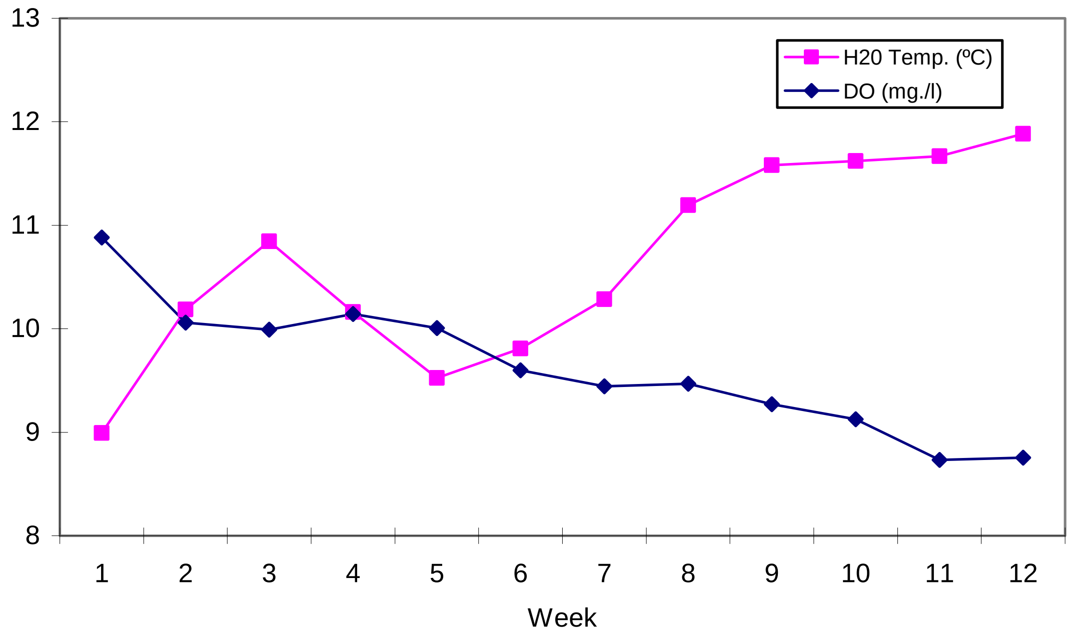

Figure. 6   Dissolved oxygen and water temperature of Elk Creek, 12 March - 30 May 2001.

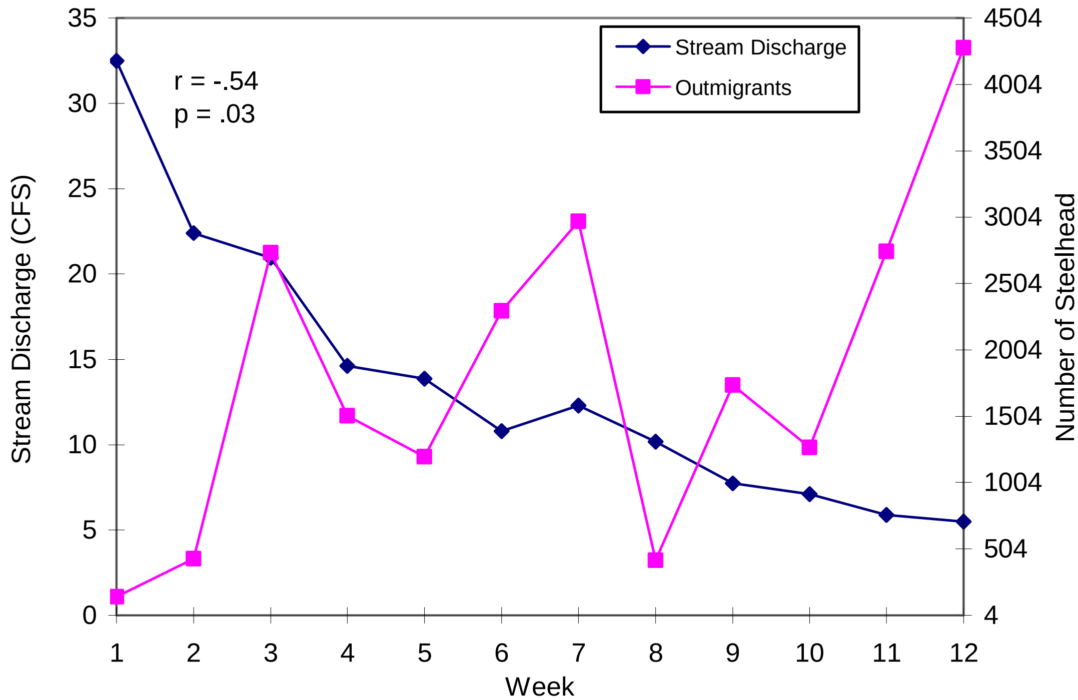

Figure 7. Mean weekly stream discharge and estimated number of steelhead out-migants in Elk Creek, 12 March - 30 May 2001

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Discussion

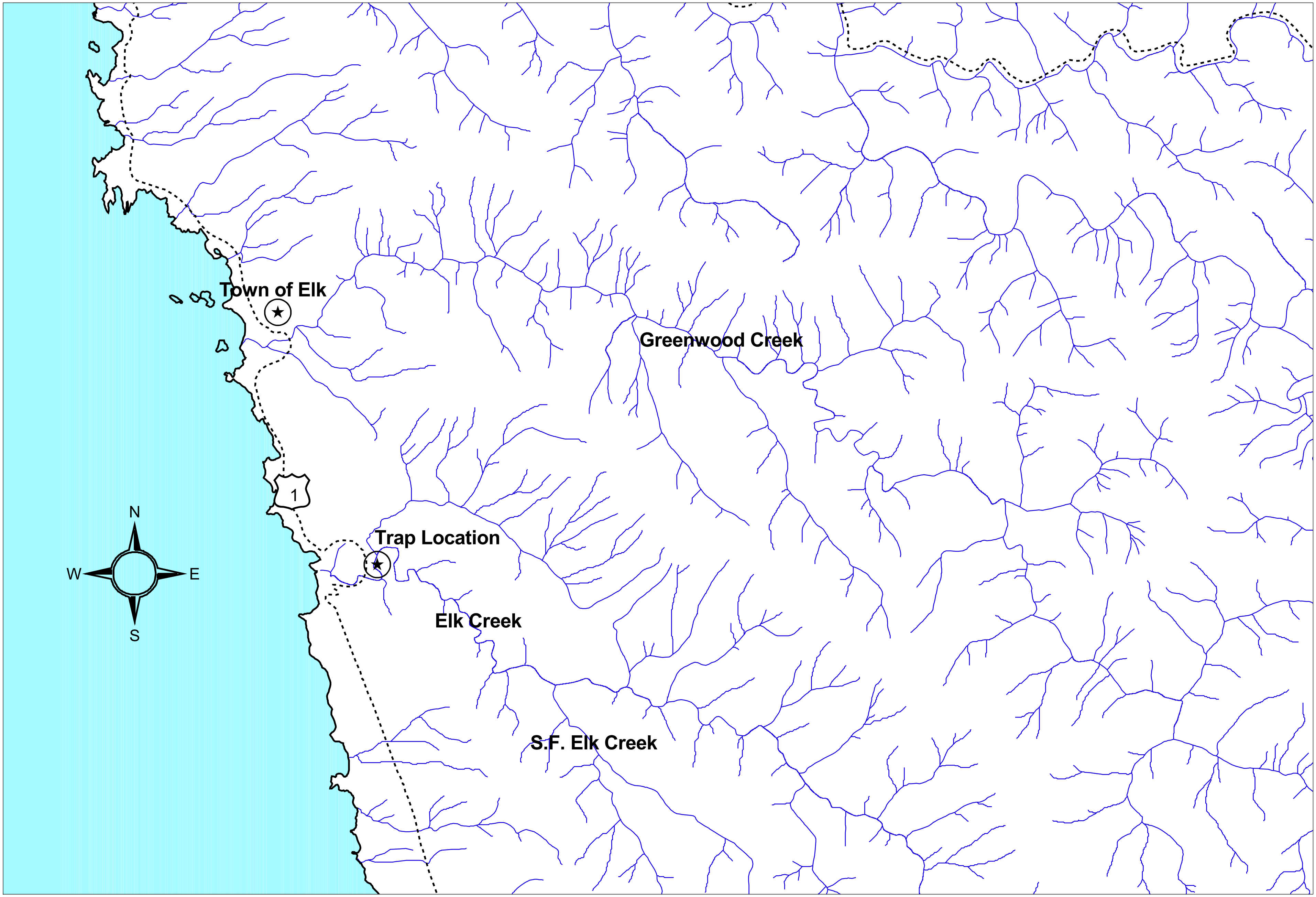
Out-migrant trapping is a tool being used extensively in northern California to estimate juvenile salmonid population sizes. Most traps function poorly in extremely low or high flow conditions. Hence, the traps are frequently installed too late or removed too early (as in this case) to capture the entire salmonid migration. Another problem associated with out-migrant trapping is the difficulty in gauging how well the necessary assumptions (pg. 3) are being met. Due to these limitations, the population estimates generated by trapping frequently misrepresent the actual abundance of out-migrants. However, if population estimates are standardized by time and watershed size, an abundance index may be developed. Table 3 presents data collected during 2001 in seven coastal streams. The traps operated during approximately the same time interval. In order to standardize the data by watershed size, the population estimates were divided by the acreage of watershed being trapped. The ranges presented represent the upper and lower confidence limits of the population estimates. The data was collected by either the California Department of Fish and Game (CDFG) (Harris and Knechtle 2002) or MRC (MRC 2002b). The methods employed by CDFG were similar to MRC's methods. The primary difference was the use of fyke net traps by CDFG verses the use of pipe traps by MRC. Both CDFG and MRC used DARR software to generate the population estimates. When interpreting this information, it is important to consider the data limitations previously discussed. Additionally, all watersheds are unique and should not be expected to support equal densities of salmonids. Of the seven watersheds presented in table 3, the number of steelhead out-migrants per acre in Elk Creek was relatively high.

Coho were not captured during this study. Furthermore, coho were not observed during juvenile salmonid distribution surveys in 2000 and 2001 (MRC 2002a). These findings indicate that the 2000 and 2001 coho year classes (cohorts) are either absent from the Elk Creek watershed or are occurring at extremely low densities.

Monitoring of Elk Creek should continue in order to determine if coho are present, and to further address the status of steelhead. Ideally out-migrant trapping should be conducted for a minimum of three years. In the short term, this allows for various salmonid cohorts to be sampled. In the long term, trends in salmonid abundance may be identified.

Table 3. Abundance index of steelhead out-migrants from coastal streams in Mendocino County, Ca. during the spring / summer of 2001.

Scource	Watershed	Population Estimate	Watershed Area Trapped (acres)	**Steelhead / Acre**	Dates
CDFG	Hare Creek	1651 +- 204	3808	**.38-.49**	3/19 - 5/30
MRC	Greenwood Creek	7755 +- 491	16448	**.44-.50**	3/17 - 5/30
CDFG	Little River	1882 +- 110	3040	**.58-.66**	3/19 - 5/30
CDFG	Caspar Creek	3146 +- 383	4160	**.66-.85**	3/19 - 5/30
MRC	Cottaneva Creek	10126 +- 1679	10579	**.80 - 1.12**	3/16 - 5/31
MRC	*Elk Creek*	*21738 +- 3248*	*18074*	***1.02-1.38***	*3/12 - 5/30*
CDFG	Wages Creek	9984 +- 5094	7040	**.69-2.14**	3/19 - 5/30



1:60000

Highway 1 | Pacific Ocean | Watercourse

Mendocino Redwood Company, LLC

Trap UTM Coordinates
439550 East
4328250 North

Figure 8. Location of out-migrant trap operated in Elk Creek, Mendocino County California.

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Bjorkstedt, E.P. 2000. DARR (Darroch analysis with rank-reduction): A method for analysis of stratified mark-recapture data from small populations, with application to estimating abundance of smolts from out-migrant trap data. U.S. Dep. Commer., NOAA, NMFS, SWFSC, Admin. Rep., Santa Cruz, SC-00-02. 28p. [1]

Darroch J.N. 1961. The two sample capture recapture census when tagging and sampling are stratified. Biometrika 48: 241-260.

Harris S. and M. Knechtle 2002. Inland and Anadromous Sport Fish Management and Research. Annual Performance Report, Federal Aid in Sport Fish Restoration Act. Project 22, North Central District Salmon and Steelhead Management. Job number 2, downstream (out) migration of juvenile salmon and steelhead. July 1, 2000 through June 30, 2001.

Mendocino Redwood Company 2002a. Aquatic Species Distribution on Mendocino Redwood Company Forestlands. Mendocino Redwood Company, LLC, P.O. Box 285, Fort Bragg California 95437.

Mendocino Redwood Company 2002b. Out-migrant Trapping Annual Update (2002). Mendocino Redwood Company, LLC, P.O. Box 285, Fort Bragg California 95437.

[1] The use of DARR does not constitute National Marine Fisheries Service certification of data or results.

Hollow Tree Creek

Juvenile Salmonid Out-migrant Trapping Update (2002)

Introduction

The anadromous salmonid species found within Hollow Tree Creek are steelhead trout (*Oncorhynchus mykiss*), coho salmon (*O. kisutch*), and chinook salmon (*O. tshawytscha*). The National Marine Fisheries Service has listed these fish runs as threatened under the endangered species act. Steelhead were listed on 7 June 2000, coho were listed on 31 Oct. 1996, and chinook were listed on 16 Sept. 1999. Activities in the basin have included logging (beginning around 1890), associated road construction, and woody debris removal (1960's- 1980's). In an attempt to increase salmonid rearing habitat, the California Department of Fish and Game (CDFG) and the California Conservation Corps have placed instream structures throughout the watershed (1986-current). Furthermore, a hatchery was established by the Salmon Restoration Association in 1979 to help reestablish decreasing chinook populations. Studies conducted by CDFG and Mendocino Redwood Co. (MRC 2002) have monitored the distribution of juvenile and adult salmonids. However, quantitative, watershed level analysis of salmonid populations has not been conducted. MRC has addressed this by beginning out-migrant trapping of juvenile salmonids. Out-migrant trapping data will indicate outmigration timing, community structure, and abundance of salmonids. By performing out-migrant trapping for a minimum of three years, all year classes of coho salmon will be monitored. Future trapping may give insight into long term population trends. This information will aid MRC in focusing restoration efforts, and developing timber management strategies.

Study Area

Hollow Tree Creek is a fourth order tributary to South Fork Eel River in Mendocino County, California. The confluence of Hollow Tree Creek and the S. Fork Eel River is approximately 100 stream miles from the Pacific Ocean. The trap was placed approximately 8 miles above this confluence (Fig. 21). The creek's drainage area is comprised of 27,206 acres. MRC owns 69% of this area; the remainder is predominantly timberland managed by other private land owners. The watershed's elevation ranges from 698 to 2,995 ft. above sea level. Mean annual precipitation is approximately 69 inches/year. The topography is steep, and rocks are highly sheered.

Methods

A rotary screw trap (E.G. Solutions™) (Fig. 1) was fished in Hollow Treek Creek during the spring of 2000 and 2001.The trap consisted of a stainless steel, 2-mm-mesh cone, supported by aluminum pontoons. The diameter of the cone's entrance was five feet. It sampled approximately 8.6 ft.^^{2} of water. Fish and amphibians passed through the cone and entered a live box.

Fish were removed from the live box every morning and anesthetized with CO_2 by placing the fish in a 5-gal. bucket containing approximately 4-gal. of water and 2 dissolved Alka-Seltzer™ tablets. The species and length (to the nearest mm) of each fish (fork length) and amphibian (snout-vent length) was recorded. Steelhead were classified as young-of-the-year (YOY), presmolt (parr), or smolt, based upon appearance. YOY were distinguishable by their relatively small size compared to presmolts. Presmolts had pronounced parr marks and were larger than YOY. Finally, fish silver in color with blackened fin tips and no parr marks were identified as smolts. Coho were identified as YOY or smolts based upon size. All presmolts and smolts were assumed to be one year of age or older (age 1+). Age 1+ fish are referred to as "out-migrants". However, it is uncertain what percentage of these fish actually entered the ocean. Within each species, up to thirty parr and thirty smolts were given a fin clip daily. Types of fin clips were rotated in a 4-week cycle. Chinook typically enter the ocean during their first year of life, hence all chinook captured were considered YOY. Due to their small size, chinook were not marked. After being handled the fish were placed in a 5-gal. bucket containing approximately 4-gal. of oxygenated water to recover. Marked fish were released in random locations 75-100 ft. above the trap. Assuming that fish emigrated past or into the trap within 3 weeks, this methodology allowed for fish to have a discreet mark every week. Recapture data was used to estimate trap efficiency using Darroch Analysis with Rank-Reduction (DARR) (Bjorkstedt, 2000).

Flows were taken daily in a riffle directly upstream of the trap using a Swoffer™ Model 2100 flow meter. This was achieved by dividing the streams width into 2-foot cells, recording the velocity and area of the water in each of the cells, and summing the volume of water traveling through the cells. Temperature was recorded daily with a hand-held thermometer, and with a temperature probe (Hobo™) placed in a riffle directly upstream of the trap. The probe recorded the water temperature every 2 hours continuously over the trapping period.

Figure 1. Rotary screw trap on Hollow Tree Creek.

Data Analysis

To calculate the total abundance of out-migrants (± 1 standard deviation), captures and recaptures were totaled by week and analyzed using DARR (Bjorkstedt 2000). DARR is a software application that analyzes mark-recapture data using a modified form of Darroch analysis (Darroch 1961). Assumptions associated with this analysis are listed below. The relationship between physical parameters and the number of out-migrant was analyzed using Pearson correlation.

<u>Assumptions</u>

To increase the accuracy of our out-migrant abundance estimates the following assumptions have to be met (adapted from Bjorkstedt 2000):

1. Marked and unmarked fish were well mixed;
2. All individuals exposed to capture at a given time had equal probability of being captured;
3. Marked individuals were unambiguously identified;
4. Marked individuals experienced negligible (or known) mortality;
5. Marks were retained for the duration of the experiment (In this case, until they migrated past or through trap);
6. Marked fish resumed migration in a minimum of 3 weeks.

Year 1 Results: 18 March-9 June 2000

Steelhead

A total of 1458 age 1+ steelhead were captured. The total annual outmigration is estimated at 11758 ± 5344 individuals (Fig. 2). Estimated trap efficiency ranged from 9-31% (mean = 22%) throughout the trapping period. The peak of the migration was between week 3 and 5 (1 April - 21 April). A total of 3272 YOY were captured (Fig.3).

Steelhead fork lengths ranged from 22-171 mm (mean = 60 mm). YOY lengths ranged from 22-66 mm (mean = 40), and age 1+ steelhead lengths ranged from 46-171 mm. (mean = 76mm) (Fig. 4, Table 1).

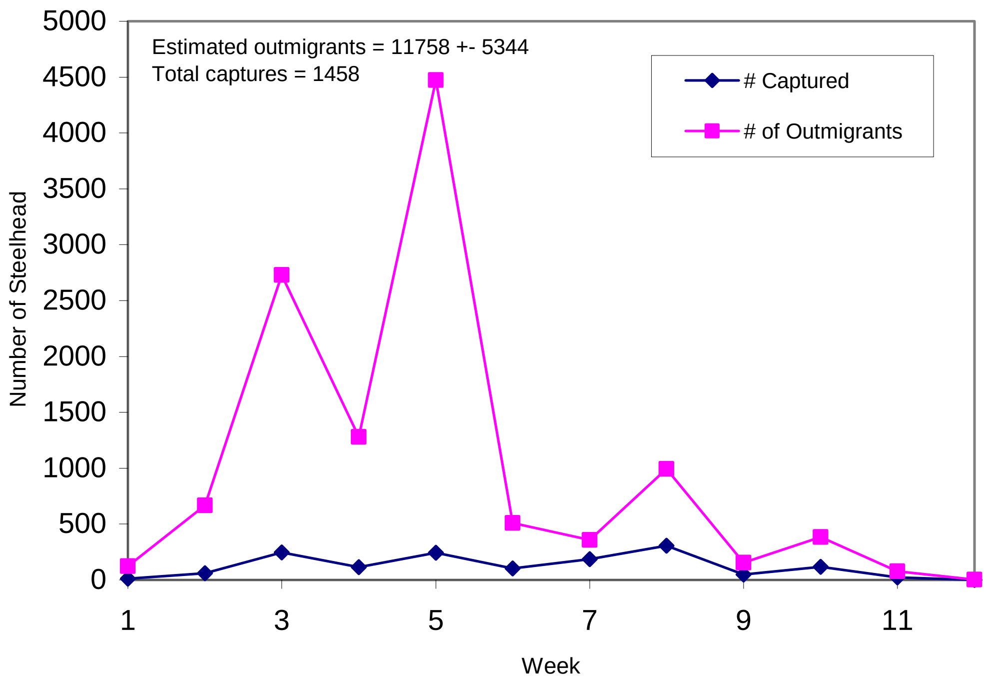


Figure 2. Number of age 1+ steelhead captured and estimated number of age 1+ steelhead out-migrants in Hollow Tree Creek, 18 March - 6 June 2000.

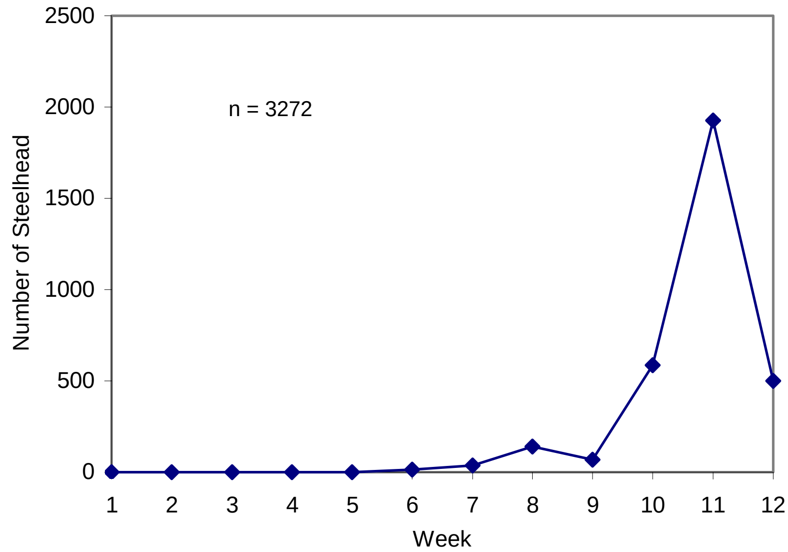


Figure 3. Number of steelhead YOY captured in Hollow Tree Creek, 18 March - 6 June 2000.

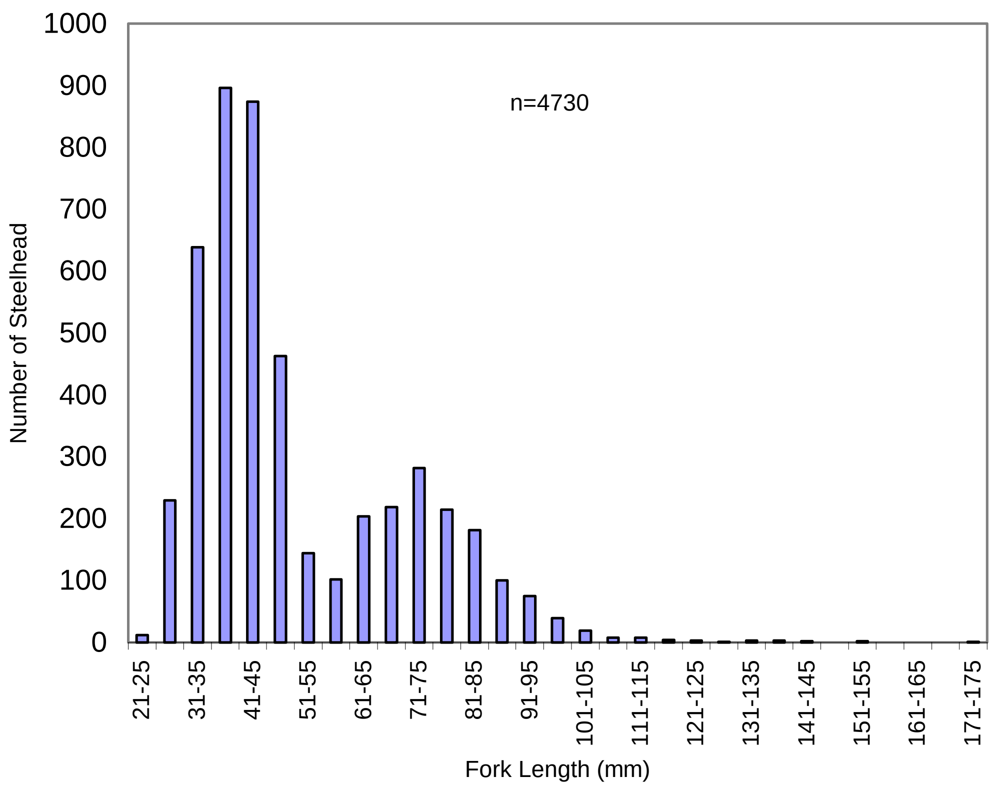


Figure 4. Length frequency of steelhead captured in Hollow Tree Creek, 18 March - 6 June 2000.

Table 1. Weekly lengths (by 5 mm. size class) of steelhead captured in Hollow Tree Creek, 18 March – 6 June, 2000.

	Dates											
Fork Length (mm)	3/18-3/24	3/25-3/31	4/1-4/7	4/8-4/14	4/15-4/21	4/22-4/28	4/29-5/5	5/6-5/12	5/13-5/19	5/20-5/26	5/27-6/2	6/3-6/6	Total
21-25						1	1	2	1	2	5		12
26-30						5	10	43	15	75	64	18	230
31-35						6	15	64	30	146	281	97	639
36-40						1	7	22	18	157	543	148	896
41-45								4	3	138	589	140	874
46-50	1		1		1				1	52	348	59	463
51-55	2	2	4	2	4	2	4	3		18	74	29	144
56-60	1	8	16	7	9	4	10	18		5	17	7	102
61-65	2	9	38	17	27	18	42	35	3	5	7	1	204
66-70	1	8	38	21	35	15	33	48	7	10	3		219
71-75	2	9	55	14	36	21	45	64	6	28	2		282
76-80	1	12	32	9	39	9	22	52	14	22	3		215
81-85		7	25	16	37	13	9	45	8	20	2		182
86-90	1	2	15	9	24	7	8	18	4	6	6		100
91-95		1	11	6	14	6	9	13	2	9	4		75
96-100		1	2	6	8	1	4	9	2	6			39
101-105		1	3	3	6			2	1	3			19
106-110			2		2		2	2					8
111-115			1		2	1		3			1		8
116-120					2						1	1	4
121-125								1		1	1		3
126-130				1									1
131-135			1	1				1					3
136-140					1				1	1			3
141-145					1		1						2
146-150													0
151-155						2							2
156-160													0
161-165													0
166-170													0
171-175					1								1
Total	11	60	244	112	249	112	222	449	116	704	1951	500	n=4730

Coho

A total of 2929 coho smolts were captured. The smolt outmigration is estimated at 35178 ± 3996 individuals (Fig. 5). Estimated trap efficiency ranged from 3-67% (mean = 21%) throughout the trapping period. Based upon beginning and ending captures, it is likely that a majority of the annual migration occurred during the trapping period. A total of 404 YOY were captured (Fig. 6).

Coho fork lengths ranged from 23-130 mm (mean = 60 mm) (Fig. 7, Table 2). YOY lengths ranged from 23-65 mm (mean = 39 mm), and smolt lengths ranged from 49-130 mm (mean = 81 mm).

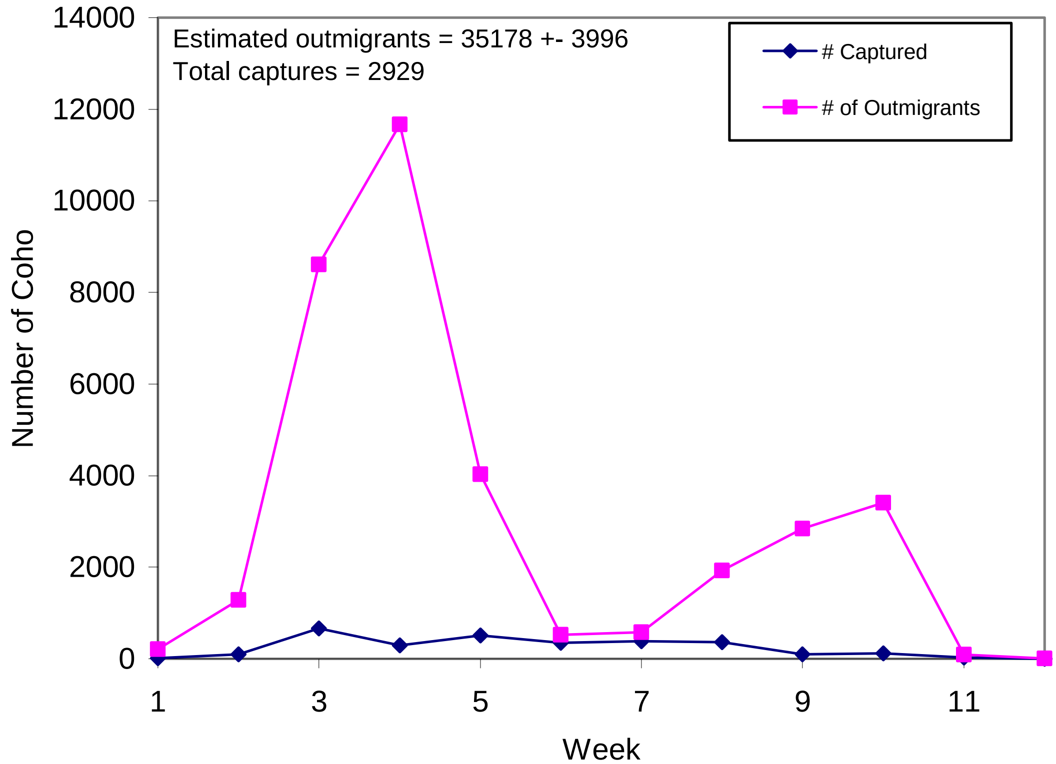


Figure 5. Number of coho smolts captured and estimated number of coho smolt out-migrants in Hollow Tree Creek, 18 March - 6 June 2000.

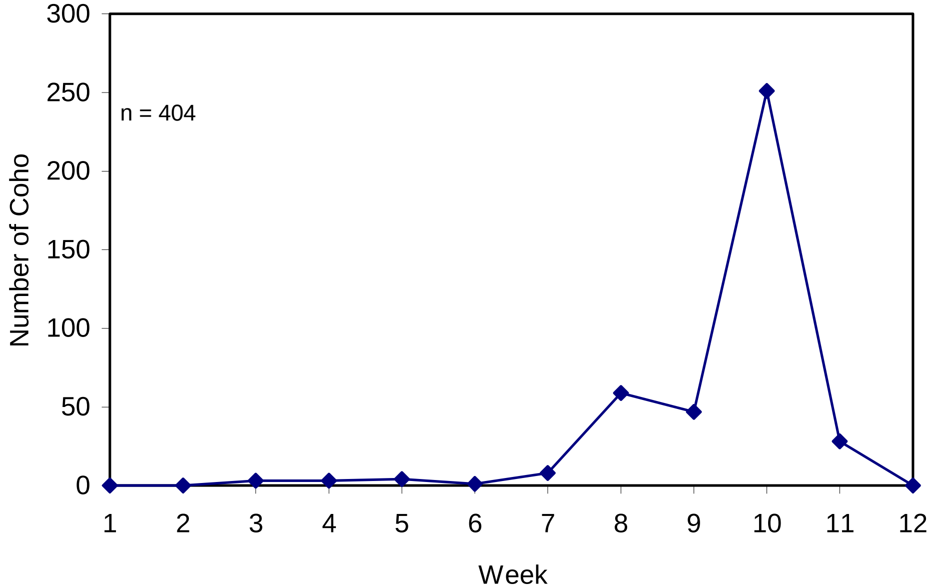


Figure 6. Number of coho YOY captured in Hollow Tree Creek, 18 March – 6 June 2000.

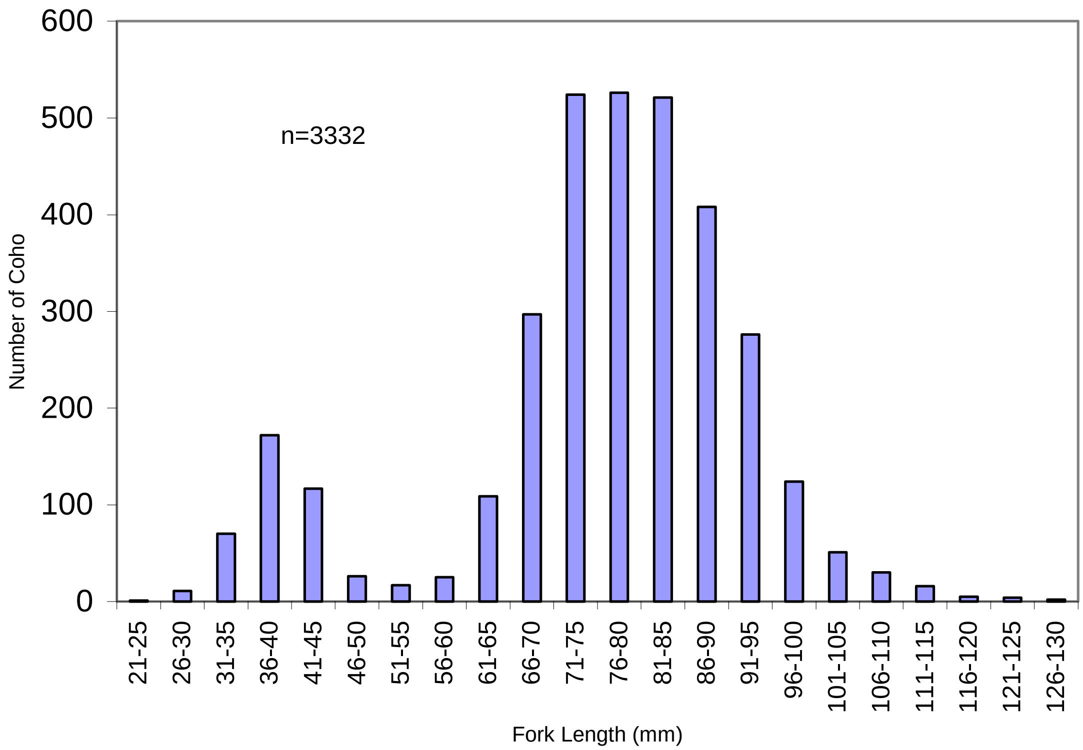


Figure 7. Length frequency of coho captured in Hollow Tree Creek, 18 March - 6 June 2000.

Table 2. Weekly lengths (by 5 mm. size class) of coho captured in Hollow Tree Creek, 18 March – 6 June, 2000.

	Dates												
Fork Length (mm)	3/18-3/24	3/25-3/31	4/1-4/7	4/8-4/14	4/15-4/21	4/22-4/28	4/29-5/5	5/6-5/12	5/13-5/19	5/20-5/26	5/27-6/2	6/3-6/6	Total
21-25											1		1
26-30					1		3		5	2			11
31-35			1	3	1	1	1	11	15	34	3		70
36-40			2		2		4	32	22	100	10		172
41-45								13	6	88	10		117
46-50				1						23	2		26
51-55			2		3	2			1	7	2		17
56-60	1		6	4	5	2		3	2	2			25
61-65	2	12	26	18	9	7	18	14	1	2			109
66-70	2	10	82	23	62	34	47	29	3	4	1		297
71-75	4	20	136	51	96	55	75	69	6	10	2		524
76-80	5	17	129	53	79	75	72	65	17	11	3		526
81-85		18	115	57	89	62	67	68	16	26	3		521
86-90		9	96	40	65	61	51	46	12	24	4		408
91-95	1	7	46	31	45	23	33	42	20	19	8	1	276
96-100	1	5	16	12	23	16	9	18	9	13	2		124
101-105			8	1	14	6	8	5	5	3	1		51
106-110			1	3	8	2	4	7	3	2			30
111-115		1			6	2	2	2	2	1			16
116-120				1	3				1				5
121-125					1	2		1					4
126-130					1				1				2
Total	16	99	666	298	513	350	394	425	147	371	52	1	n=3332

Chinook

A total of 2128 chinook were captured (Fig. 8). Chinook were captured throughout the study. Chinook lengths ranged from 22-104 mm. (mean = 46 mm.) (Fig. 9, Table 3).

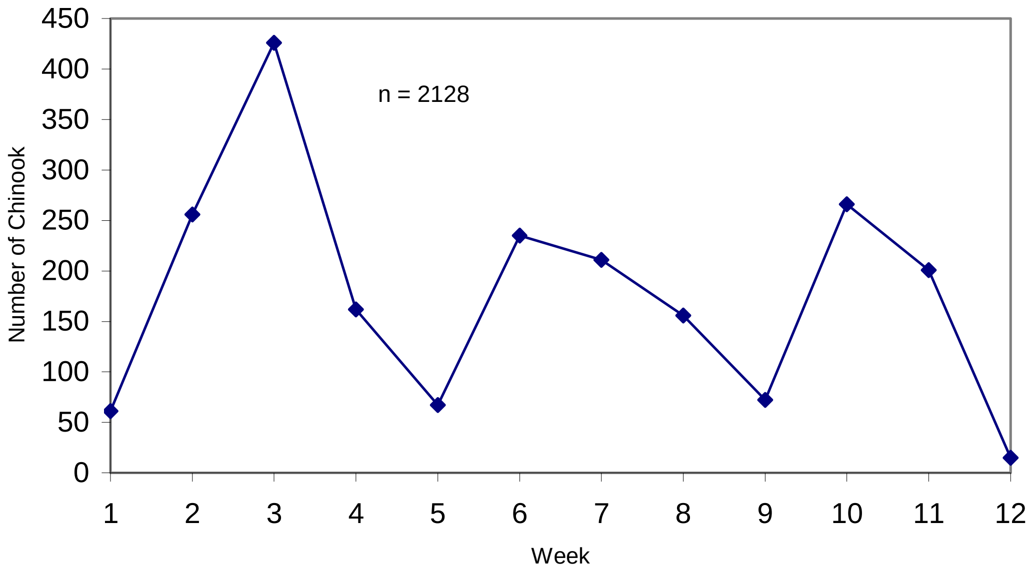


Figure 8. Number of chinook captured in Hollow Tree Creek, 18 March - 6 June 2000.

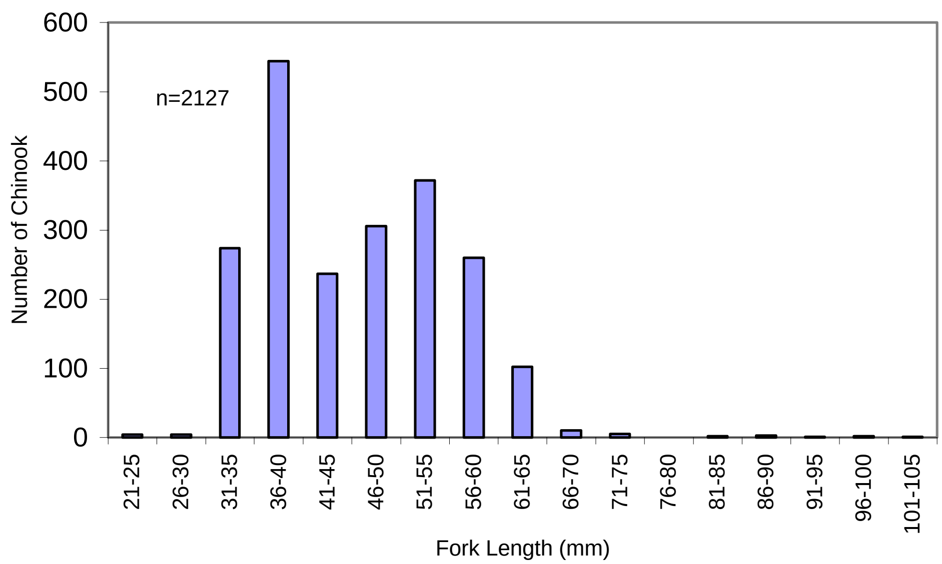


Figure 9. Length frequency of chinook captured in Hollow Tree Creek, 18 March - 6 June 2000.

Table 3. Weekly lengths (by 5 mm. size class) of chinook captured in Hollow Tree Creek, 18 March – 6 June, 2000.

	Dates												
Fork Length (mm)	3/18-3/24	3/25-3/31	4/1-4/7	4/8-4/14	4/15-4/21	4/22-4/28	4/29-5/5	5/6-5/12	5/13-5/19	5/20-5/26	5/27-6/2	6/3-6/6	Total
21-25		2		1							1		4
26-30		1	1	1							1		4
31-35	2	87	130	47	3		2		1	1	1		274
36-40	33	132	267	83	9	8	6	1	1	3	1		544
41-45	22	31	22	20	24	68	34	9	1	4	2		237
46-50	1	1	1	9	13	118	81	45	8	17	10	2	306
51-55			1	1	11	34	71	91	32	86	45		372
56-60			1		2	5	17	9	25	125	73	3	260
61-65		1	1			1		1	4	29	57	8	102
66-70											8	2	10
71-75		1			1	1				1	1		5
76-80													0
81-85					2								2
86-90			1		2								3
91-95			1										1
96-100	1										1		2
101-105	1												1
Total	60	256	426	162	67	235	211	156	72	266	201	15	n=2127

Mortalities and Non-salmonid Species

In addition to salmonids, california roach (*Lavinia symmetricus*), three-spine stickleback (*Gasterosteus aculeatus*), pacific lamprey (*Lampetra tridentata*), foothill yellow legged frogs (*Rana boylii*), pacific giant salamanders (*Dicamptodon tenebrosus*), california newts (*Taricha torosa*), and a sacramento sucker (*Castomus occidentalis*) were captured. Mortalities were recorded daily (Table 4).

Table 4. Total organisms captured and total trap-related mortalities at Hollow Tree Creek, 18 March – 6 June 2000.

Species	# Captured	# Mortalities	% Mortalities
Coho Salmon (*Oncorhynchus kisutch*) Young of the Year	404	2	0.5%
Coho Salmon Smolts	2929	4	0.1%
Chinook Salmon (*O. tshawytscha*) Young of the Year	2128	34	2%
Steelhead Trout (*O. mykiss*) Young of the Year	3272	7	0.2%
Age 1+ Steelhead Trout	1458	4	0.3%
California Roach (*Lavinia symmetricus*)	11	2	18%
Pacific Lamprey (*Lampetra tridentata*) Ammocetes	22	4	18%
Pacific Lamprey Adults	275	0	0%
Sacramento Sucker (*Castomus occidentalis*)	1	0	0%
Three Spine Stickleback (*Gasterosteus aculeatus*)	5	3	60%
California Newt (*Taricha torosa*)	25	0	0%
Foothill Yellow Legged Frog (*Rana boylii*)	26	0	0%
Pacific Giant Salamander (*Dicamptodon tenebrosus*)	12	0	0%

Physical Parameters

Stream discharge ranged from 33-122 CFS (mean = 49 CFS), and stream temperature ranged from 7.7-16.7 °C. (mean = 11.8 °C). Statistical relationships were analyzed between the migration rate of out-migrants and stream temperature / stream discharge, no significant correlations were found.

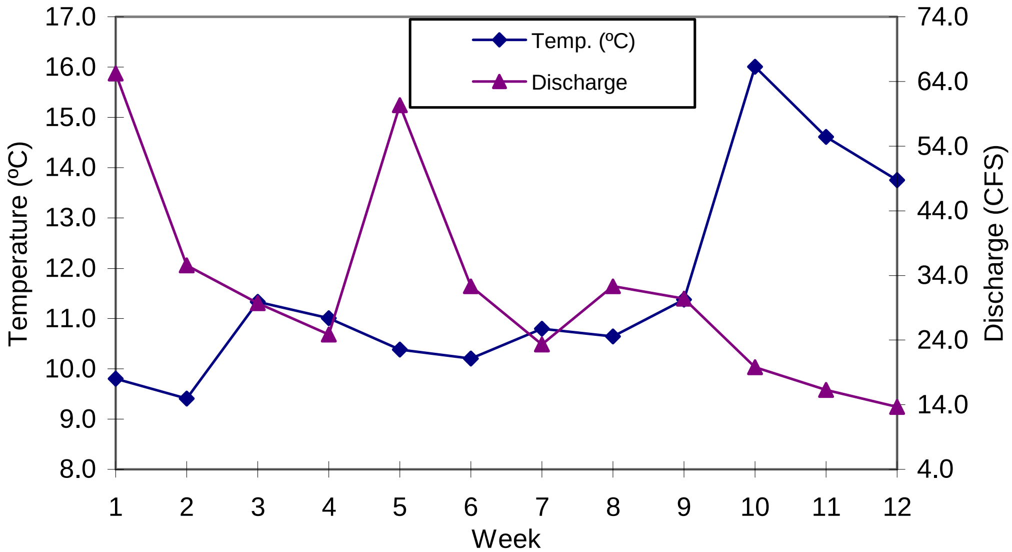


Figure 10. Mean weekly water temperature and stream discharge of Hollow Tree Creek during out-migrant trapping, 18 March - 6 June 2000.

Year 2 Results: 2 March-31 May 2001

Steelhead

A total of 3083 age 1+ steelhead were captured. The annual outmigration is estimated at 24818 ± 2177 individuals (Fig. 11). Estimated trap efficiency ranged from 9-17% (mean = 13%) throughout the trapping period. The peak of the migration occurred during week 8 (20 April – 26 April). A total of 105 YOY were captured (Fig.12).

Steelhead fork lengths ranged from 27-209 mm (mean = 77 mm) (Fig. 13, Table 5). YOY lengths ranged from 27-54 mm (mean = 39 mm), and age 1+ steelhead lengths ranged from 46-209 mm (mean = 78 mm).

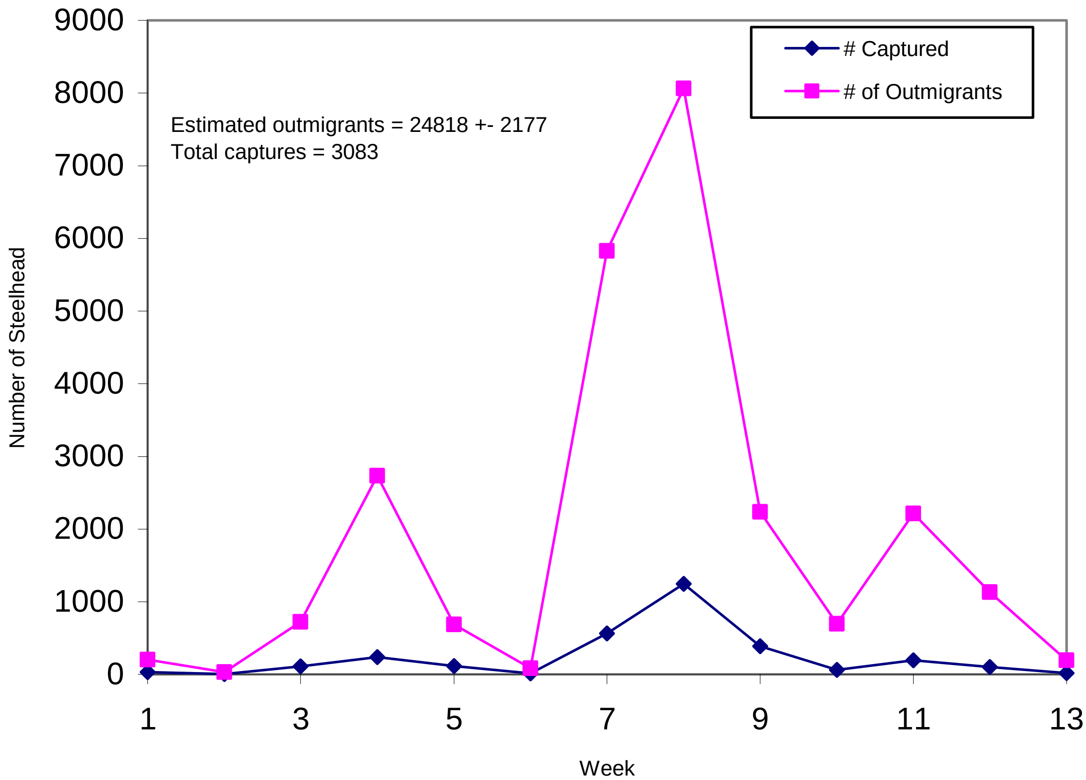


Figure 11. Number of age 1+ steelhead captured and estimated number of age 1+ steelhead out-migrants in Hollow Tree Creek, 2 March – 31 May 2001.

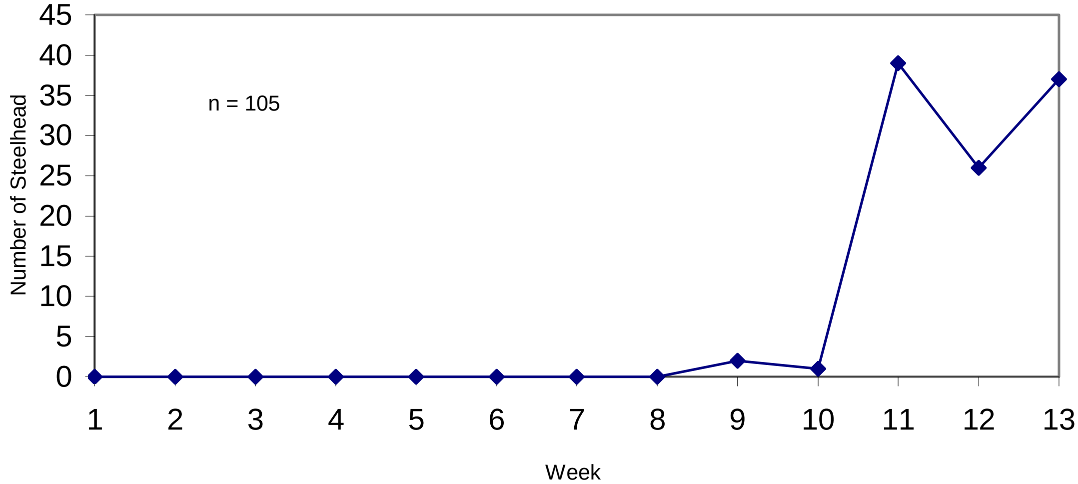


Figure 12. Number of steelhead YOY captured in Hollow Tree Creek, 2 March - 31 May 2001.

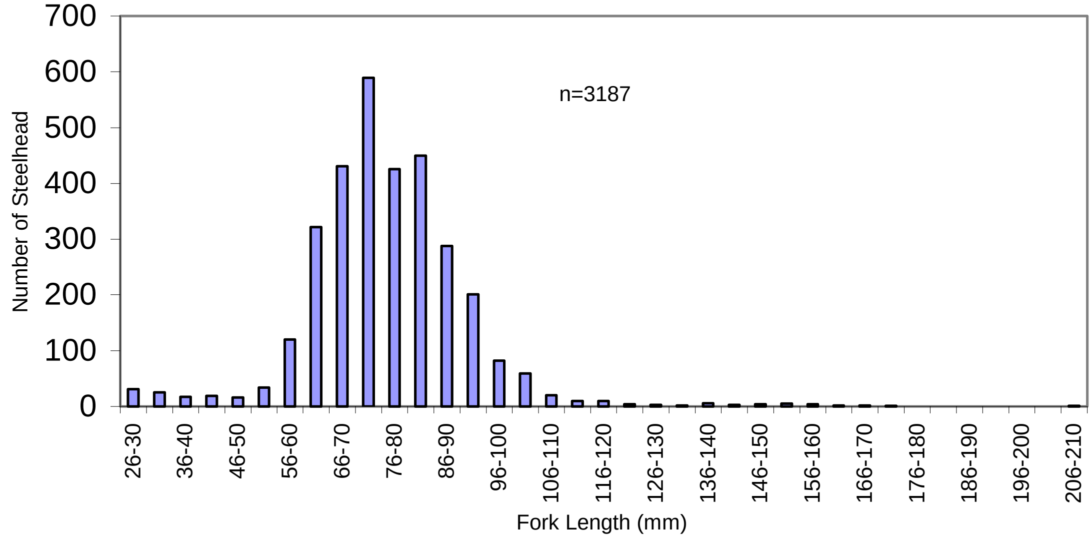


Figure 13. Length frequency of steelhead captured in Hollow Tree Creek, 2 March - 31 May 2001.

Table 5. Weekly lengths (by 5 mm. size class) of steelhead captured in Hollow Tree Creek, 2 March – 31 May, 2001.

	Dates													
MM	3/2-3/8	3/9-3/15	3/16-3/22	3/23-3/29	3/30-4/5	4/6-4/12	4/13-4/19	4/20-4/26	4/27-5/3	5/4-5/10	5/11-5/17	5/18-5/24	5/25-5/31	Total
26-30									1		14	7	9	31
31-35								1	1	1	5	10	7	25
36-40											10	3	4	17
41-45											10	4	5	19
46-50	3			2								1	10	16
51-55	7		3	10	3		4		2			1	4	34
56-60	7		17	17	8		21	35	10	1	4			120
61-65	4		25	37	10	1	65	124	33	11	9	3		322
66-70	3		15	38	21	1	101	177	46	7	18	4		431
71-75	1		14	38	19	4	109	260	79	11	36	16	2	589
76-80	1	3	11	26	12	2	78	176	58	7	32	18	2	426
81-85	4	1	7	24	20	3	73	163	72	8	43	28	4	450
86-90		1	4	14	8	1	49	130	33	9	22	14	3	288
91-95			5	13	6		31	95	29	4	13	5		201
96-100			1	5	2		11	31	15		9	6	2	82
101-105			1	3	2	2	8	31	6	2	4			59
106-110			1	1	1		3	7	1	1	1	3	1	20
111-115				1				8				1		10
116-120			1		1		4	3				1		10
121-125							2	1	1					4
126-130			2	1										3
131-135			1	1										2
136-140	1			3	1								1	6
141-145							1		1		1			3
146-150							1	1	1		1			4
151-155			1	2			1		1					5
156-160					1		2	1						4
161-165				1	1									2
166-170			2											2
171-175											1			1
176-180														0
181-185														0
186-190														0
191-195														0
196-200														0
201-205														0
206-210								1						1
Total	31	5	111	237	116	14	564	1245	390	62	233	125	54	n=3187

Coho

A total of 4498 coho smolts were captured (Fig. 14). Migration peaks occurred during weeks 4 (23 March-29 March) and 7(13 April-19 April). The total smolt outmigration is estimated at 35976 ± 4614 individuals. Estimated trap efficiency ranged from 6-99% (mean = 23%) throughout the trapping period. A total of 10 YOY were captured.

Coho fork lengths ranged from 40-131 mm (mean = 85 mm). YOY lengths ranged from 40-55 mm (mean = 46 mm), and smolt lengths ranged from 55-131mm (mean = 86) (Fig. 15, Table 6).

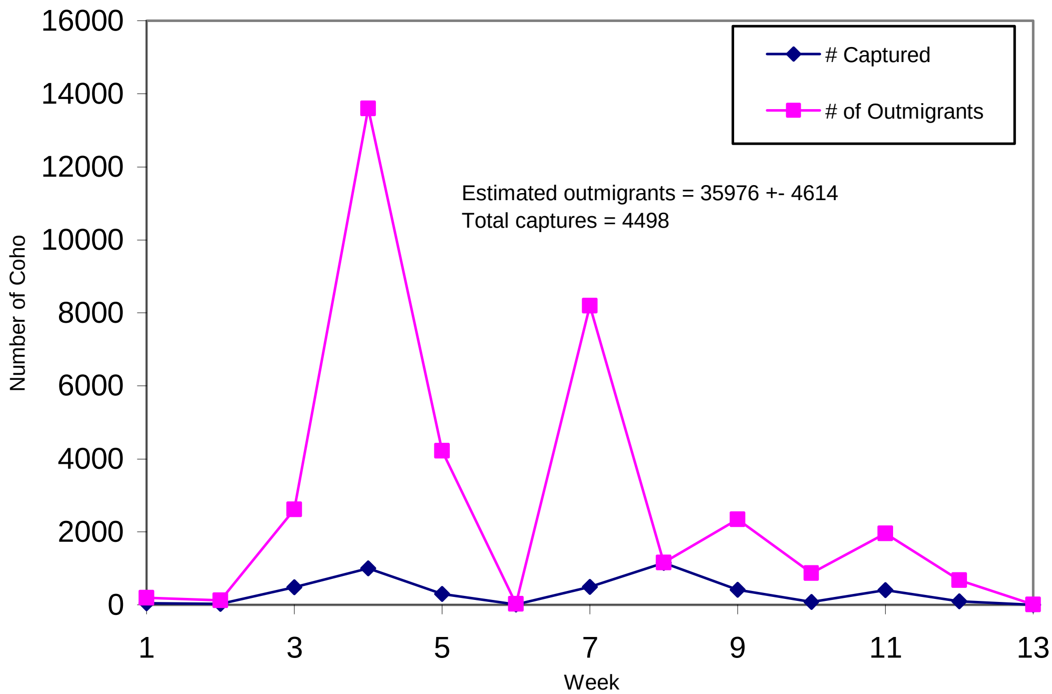


Figure 14. Number of coho smolts captured and estimated number of coho smolt out-migrants in Hollow Tree Creek, 2 March - 31 May 2001.

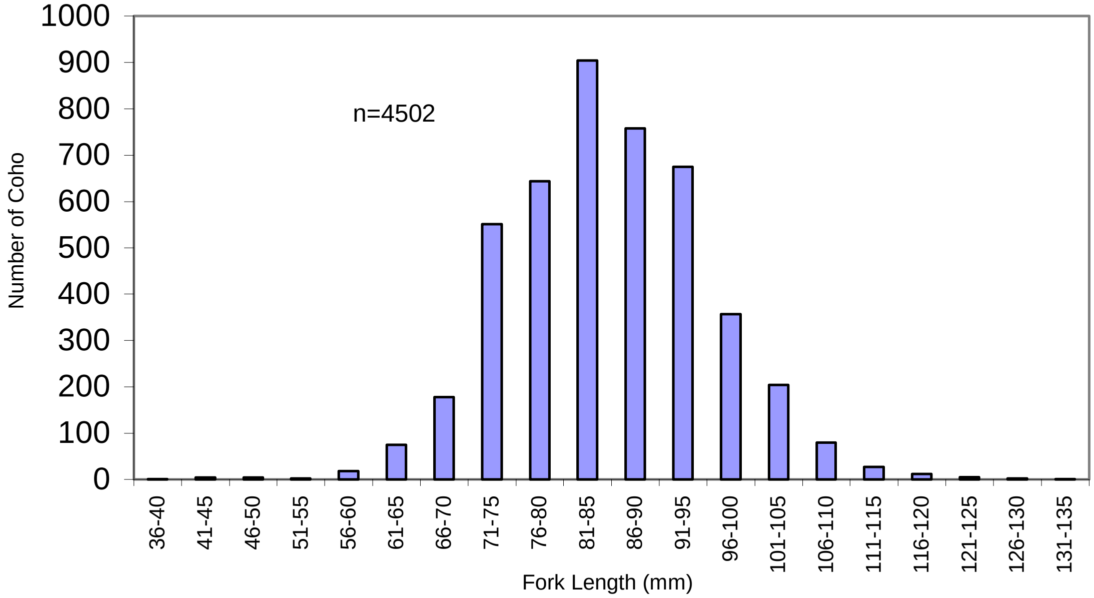


Figure 15. Length frequency of coho captured in Hollow Tree Creek, 2 March - 31 May, 2001.

Table 6. Weekly lengths (by 5 mm. size class) of coho captured in Hollow Tree Creek, 2 March – 31 May 2001.

	Dates													
MM	3/2-3/8	3/9-3/15	3/16-3/22	3/23-3/29	3/30-4/5	4/6-4/12	4/13-4/19	4/20-4/26	4/27-5/3	5/4-5/10	5/11-5/17	5/18-5/24	5/25-5/31	Total
36-40													1	1
41-45										4				4
46-50												3	1	4
51-55					1							1		2
56-60	1		2	12			1	1		1				18
61-65	3		19	33	6		6	6	2					75
66-70	5	3	12	84	16	1	13	30	12		2			178
71-75	11	6	63	213	39	2	48	110	39	4	16			551
76-80	11	8	78	169	40	2	55	185	50	3	37	6		644
81-85	6	3	89	203	48	3	117	222	83	18	95	17		904
86-90	6	2	88	141	52	2	80	181	77	19	89	21		758
91-95	2	5	68	83	51	2	79	171	74	21	92	27		675
96-100		1	39	37	22	1	38	118	44	7	40	9	1	357
101-105			19	12	16		38	72	13	2	19	13		204
106-110			3	4	5		13	28	8	2	14	3		80
111-115				1	1		4	17	3	1				27
116-120							1	5	3		2	1		12
121-125								4			1			5
126-130							1	1						2
131-135								1						1
Total	45	28	480	992	297	13	494	1152	408	82	407	101	3	n=4502

Chinook

A total of 46 chinook were captured. Chinook were captured between weeks 9 and 13 (27 April-31 May) (Fig. 16). Chinook fork lengths ranged from 35-60 mm (mean = 50 mm) (Fig. 17, Table 7).

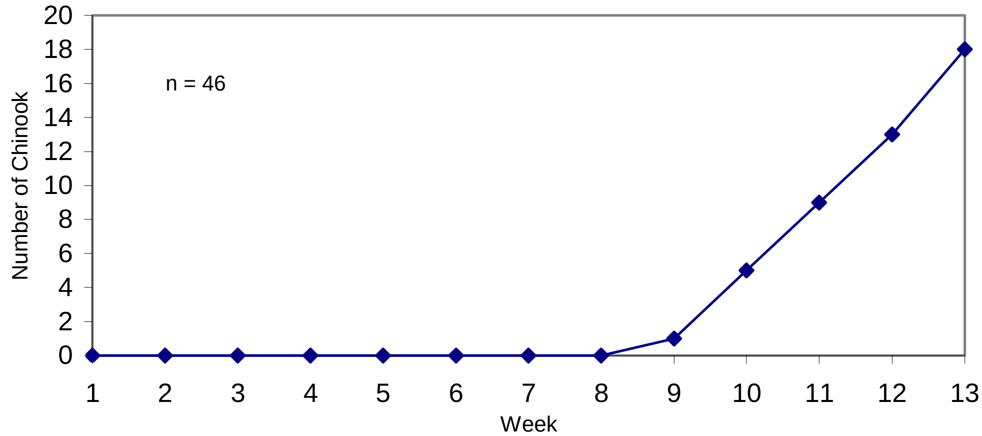


Figure 16. Number of chinook captured in Hollow Tree Creek, 2 March - 31 May, 2001.

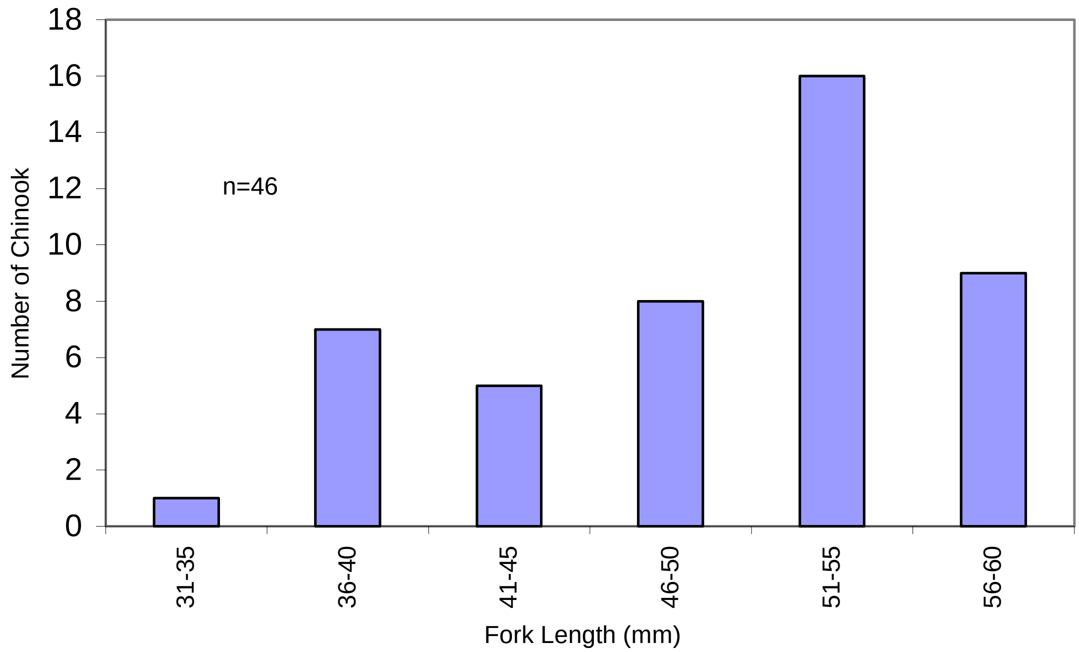


Figure 17. Length frequency of chinook captured in Hollow Tree Creek, 2 March - 31 May, 2001.

Table 7. Weekly lengths (by 5 mm. size class) of chinook captured in Hollow Tree Creek, 2 March – 31 May, 2001.

	Dates					
Fork Length (mm)	4/27-5/3	5/4-5/10	5/11-5/17	5/18-5/24	5/25-5/31	Total
31-35		1				1
36-40	1	1	3	2		7
41-45		3	2			5
46-50			3	4	1	8
51-55			1	4	11	16
56-60				3	6	9
Total	1	5	9	13	18	n=46

Mortalities and Non-salmonid Species

In addition to salmonids, three-spine sticklebacks (*Gasterosteus aculeatus*), california roach (*Lavinia symmetricus*), pacific lamprey (*Lampetra tridentata*), california newts (*Taricha tarosa*), rough skinned newts (*T. granulosa*), pacific giant salamanders (*Dicamptodon tenebrosus*), foothill yellow legged frogs (*Rana boylii*) and a sacramento sucker (*Castomus occidentalis*) were captured. Mortalities were recorded daily (Table 8).

Table 8. Total organisms captured and total trap-related mortalities at Hollow Tree Creek, 2 March – 31 May, 2001.

Species	# Captured	# Mortalities	% Mortalities
Coho Salmon (*Oncorhynchus kisutch*) Young of the Year	10	0	0%
Coho Salmon Smolts	4498	12	0.3%
Chinook Salmon (*O. tshawytscha*) Young of the Year	49	0	0%
Steelhead Trout (*O. mykiss*) Young of the Year	105	2	2%
Age 1+ Steelhead Trout	3083	10	0.3%
California Roach (*Lavinia symmetricus*)	34	0	0%
Pacific Lamprey (*Lampetra tridentata*) Ammocetes	49	1	2%
Pacific Lamprey Adults	5	0	0%
Sacramento Sucker (*Castomus occidentalis*)	1	0	0%
Three Spine Stickleback (*Gasterosteus aculeatus*)	41	0	0%
California Newt (*Taricha torosa*)	14	0	0%
Foothill Yellow Legged Frog (*Rana boylii*)	15	0	0%
Pacific Giant Salamander (*Dicamptodon tenebrosus*)	7	0	0%
Rough Skinned Newt (*Taricha granulosa*)	15	0	0%

Physical Parameters

Stream discharge ranged from 8-293 CFS (mean = 43 CFS), and stream temperature ranged from 6.2-18.7 °C. (mean = 11 °C). Dissolved oxygen ranged from 8.8-11.6 mg./l (mean = 10.6 mg./l.) and pH ranged from 5.1-7.9 (mean = 7.0). Stream discharge and pH were negatively correlated (r = -.75, n = 13, p = .001) (Fig. 18, 19). No significant correlation was found between these physical parameters and the migration rate of age 1+ steelhead.

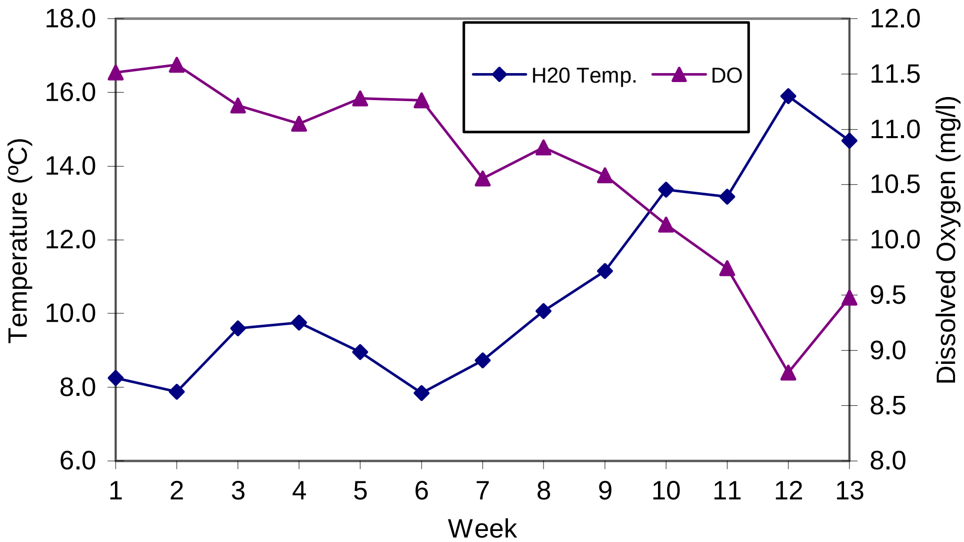


Figure 18. Mean weekly water temperature and dissolved oxygen of Hollow Tree Creek, 2 March - 31 May 2001.

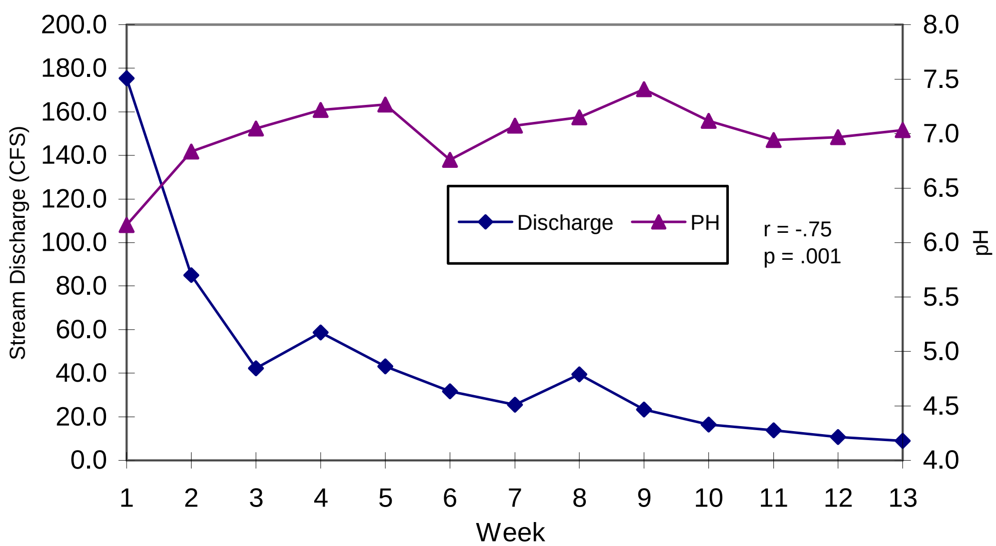


Figure 19. Mean weekly stream discharge and pH of Hollow Tree Creek, 2 March - 31 May 2001.

Discussion

In depth analysis of the data is being postponed until the third year of data is collected (after the summer of 2002). It should be noted that a significantly lower number of chinook were captured in year 2 than in year 1 (fig. 8, 16). This may be related to higher rainfall during year 1 (1999-2000) than year 2 (2000-2001) (fig. 20) (California Department of Water Resources, 2002). The limited rainfall during year 2 may have delayed the upstream migration of adult chinook and hence the subsequent downstream migration of juveniles. It is likely that juvenile chinook continued to migrate after the trap was removed.

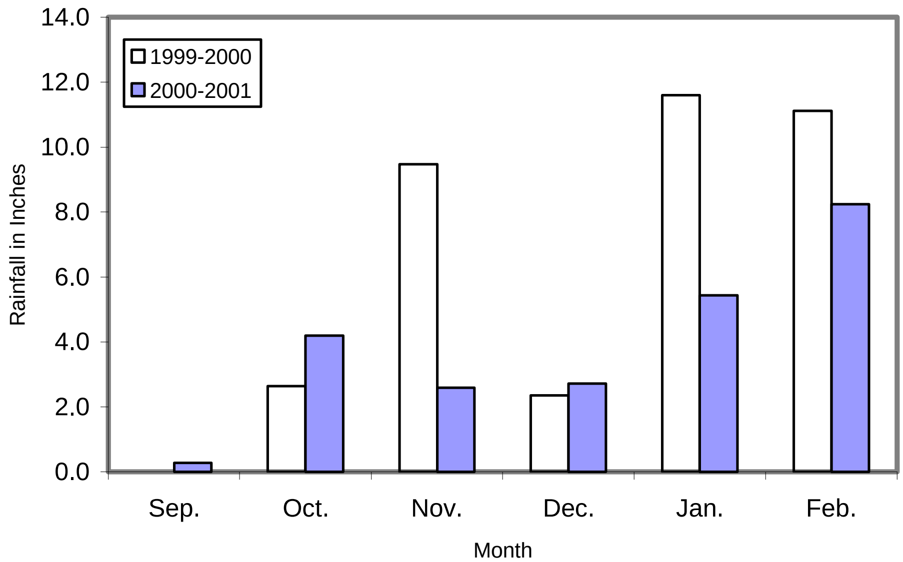
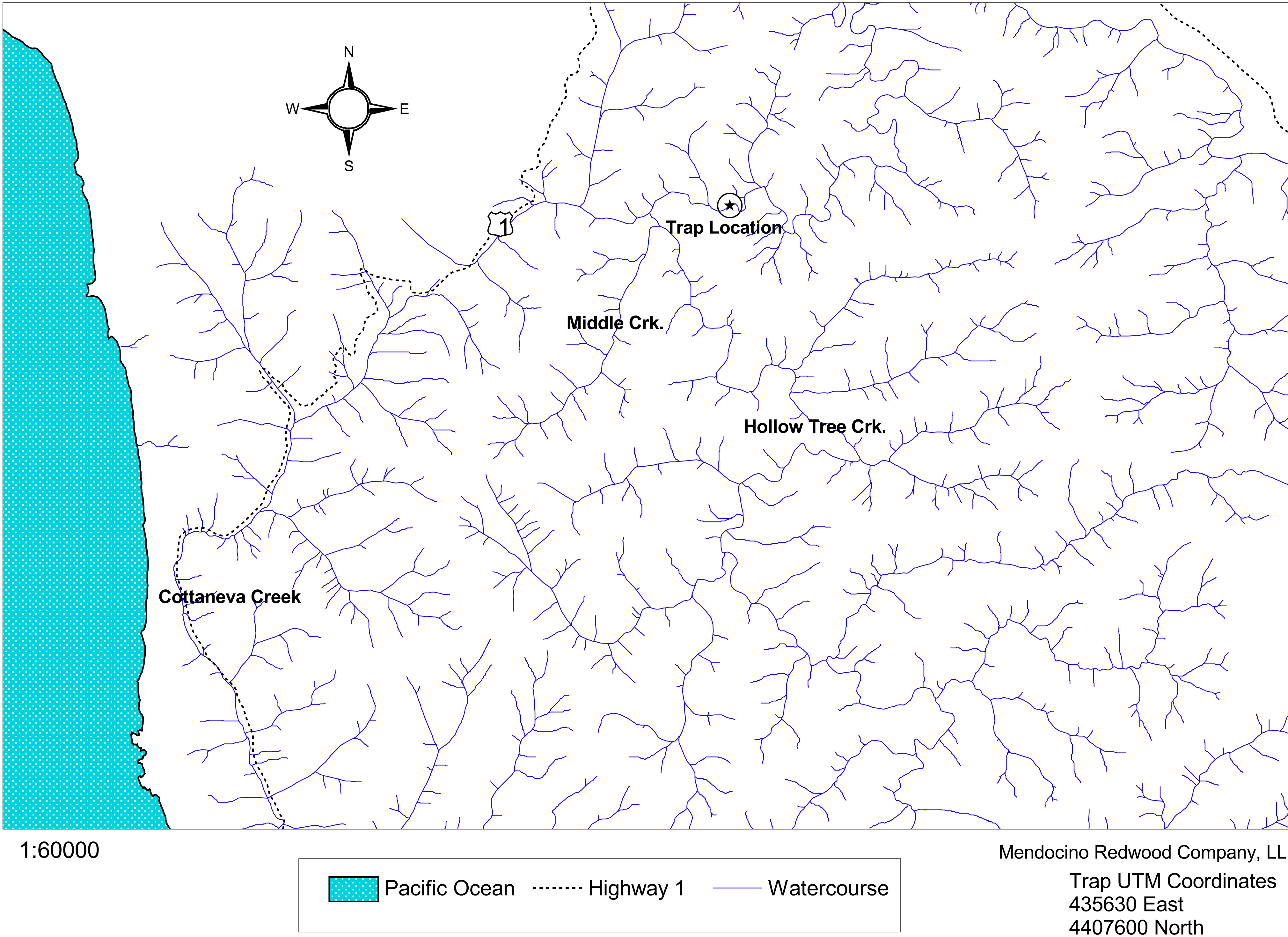


Figure 20. Monthly rainfall at Miranda, California.



Mendocino Redwood Company, LLC

Trap UTM Coordinates
435630 East
4407600 North

Figure 21. Location of out-migrant trap operated in Hollow Tree Creek, Mendocino County California.

References

Bjorkstedt, E.P. 2000. DARR (Darroch analysis with rank-reduction): A method for analysis of stratified mark-recapture data from small populations, with application to estimating abundance of smolts from out-migrant trap data. U.S. Dep. Commer., NOAA, NMFS, SWFSC, Admin. Rep., Santa Cruz, SC-00-02. 28p.*

California Department of Water Resources 2002. Rain gauge measurements taken at Sylvandale (Miranda) California, http://cdec.water.ca.gov.

Darroch J.N. 1961. The two sample capture recapture census when tagging and sampling are stratified. Biometrika 48: 241-260.

Mendocino Redwood Company 2002. Aquatic Species Distribution on Mendocino Redwood Company Forestlands. Mendocino Redwood Company, LLC, P.O. Box 489, Fort Bragg California 95437.

* The use of DARR does not constitute NMFS certification of the data or results.

Cottaneva Creek

Juvenile Salmonid Out-migrant Trapping Update (2002)

Introduction

The anadromous salmonid species found within Cottaneva Creek are steelhead trout (*Oncorhynchus mykiss*) and coho salmon (*O. kisutch*). The National Marine Fisheries Service has listed these fish runs as threatened under the Endangered Species Act. Steelhead were listed on 7 June 2000 and coho were listed on 31 Oct. 1996. Between 1876 and the early 1950's, a sawmill operated at the mouth of Cottaneva Creek; construction of the sawmill filled in a portion of the north side of the cove through which Cottaneva Creek flows. Since then, logging and associated road construction has been the predominant activity in the basin. Mendocino Redwood Company (MRC) is assessing the status of salmonids within Cottaneva Creek. This is being achieved through juvenile salmonid distribution surveys (MRC 2002) and out-migrant trapping. Out-migrant trapping produces data regarding the outmigration timing, community structure, and abundance of salmonids. Repeating out-migrant trapping in the future may identify temporal trends in salmonid abundance. This information will aid MRC in focusing restoration efforts and developing timber management strategies.

Study Area

Cottaneva Creek is a fourth order coastal stream in Mendocino County, California. The drainage area of Cottaneva Creek is 10,579 acres. MRC owns 75% of this area; the remainder is predominantly timberland owned by other private landowners. The basin's elevation ranges from 0-1,973 ft. above sea level. Mean annual precipitation is approximately 50 inches/year. The topography is steep, and rocks are highly sheered. Cottaneva Creek flows in a westerly direction. The trap was located approximately .5 miles upstream of the Pacific Ocean (Fig. 18).

Methods

A pipe trap (Fig. 1 and 2) was fished in Cottaneva Creek during the spring of 2000 and 2001. The trap consisted of a full-channel weir with a 1-m opening on the left bank to allow for passage of adult fish. At the apex of the weir, water flowed into a 20-cm diameter section of PVC pipe. Fish were concentrated into this 20-m long pipe and transported into a live box. A Mcbain ramp was used to dissipate the high pressure of the water before it entered the live box, thus reducing potential injury to the fish. To minimize predation of young of the year (YOY) by larger fish, a fry box was placed in the live box. The fry box was constructed of 7-mm mesh screen framed with wood.

Fish were removed from the live box every morning and anesthetized with CO_2 by placing the fish in a five-gallon bucket containing approximately 4-gal. of water and 2 dissolved Alka-Seltzer™ tablets. The species and fork length (to the nearest mm) of each fish was recorded. Steelhead were classified as YOY, presmolt (parr), or smolt based upon coloration. YOY were distinguishable by their relatively small size compared to presmolts. Presmolts had pronounced parr marks and were larger than YOY. Finally, fish silver in color with blackened fin tips and no parr marks were identified as smolts. Coho were identified as YOY or smolts based upon size. All parr and smolts were assumed to be one year of age or older (age 1+). Age 1+ fish are referred to as “out-migrants”. However, it is uncertain what percentage of these fish actually entered the ocean. Within each species, up to thirty parr and thirty smolts were given a fin clip. Types of fin clips were rotated in a 4-week cycle. After being handled, the fish were placed in a 5-gal. bucket containing approximately 4-gal. of aerated water to recover. Marked fish were released in random locations, 75-100 ft. above the trap. Assuming that fish emigrated past or into the trap within 3 weeks, this methodology allowed for fish to have a discreet mark every week. Recapture data was used to estimate trap efficiency using Darroch Analysis with Rank-Reduction (DARR) (Bjorkstedt, 2000).

Flows were taken daily in a riffle directly upstream of the trap using a Swoffer™ Model 2100 flow meter. This was achieved by dividing the stream’s width into either 1 or 2 foot cells, recording the velocity and area of the water in each of these cells, and summing the volume of water traveling through the cells. Temperature was recorded daily with a hand-held thermometer and with a temperature probe (Hobo™**)** placed in a riffle directly downstream of the trap. The probe recorded the water temperature every 2 hours continuously over the trapping period.

Figure 1. Full channel weir funneling water and fish into PVC pipe.

Figure 2. Water leaving pipe and entering live box.

Data Analysis

To calculate the total abundance of out-migrants (± 1 standard deviation), captures and recaptures were totaled by week and analyzed using DARR (Bjorkstedt 2000). DARR is a software application that analyzes mark-recapture data using a modified form of Darroch analysis (Darroch 1961). Assumptions associated with this analysis are listed below. The relationship between physical parameters and the number of out-migrants was analyzed using Pearson correlation.

Assumptions

To increase the accuracy of our out-migrant abundance estimates the following assumptions have to be met (adapted from Bjorkstedt 2000):

1. Marked and unmarked fish were well mixed;
2. All individuals exposed to capture at a given time had equal probability of being captured;
3. Marked individuals were unambiguously identified;
4. Marked individuals experienced negligible (or known) mortality;
5. Marks were retained for the duration of the experiment (In this case, until they migrated past or through trap);
6. Marked fish resumed migration in a minimum of 3 weeks.

Year 1 Results: 1 April – 6 June, 2000

The trap was fished continuously from 1 April-6 June 2000 except for the dates of 17-18 April and 19 May. On these days the trap was not fished due to high flows (17-18 April) or technical problems (19 May).

Steelhead

A total of 397 age 1+ steelhead were captured throughout the trapping period. The total migration during trapping is estimated at 2214 ± 608 individuals (Fig. 3). It appears that steelhead migrated before and after trap installation, resulting in a negatively bias population estimate. Estimated trap efficiency ranged from 15-19% (mean = 18%) throughout the trapping period.

A total of 217 YOY were captured (Fig. 4). The YOY migration began during week 4 (24 April - 28 April) and continued throughout the study.

Steelhead lengths ranged from 22-183 mm. (mean = 72 mm.). YOY lengths ranged from 22-60 mm. (mean = 30 mm) and age 1+ steelhead lengths ranged from 62-183 mm. (mean = 95 mm) (Fig. 5, Table 1).

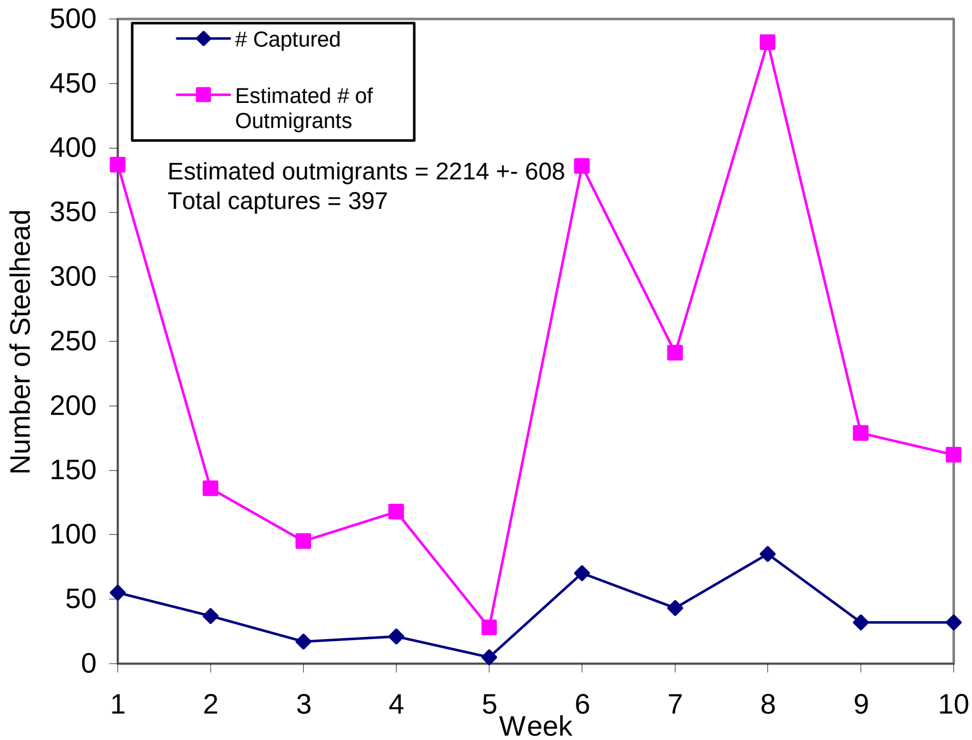


Figure 3. Number of age 1+ steelhead captured and estimated number of age 1+ steelhead out-migrants in Cottaneva Creek, 1 April - 6 June 2000.

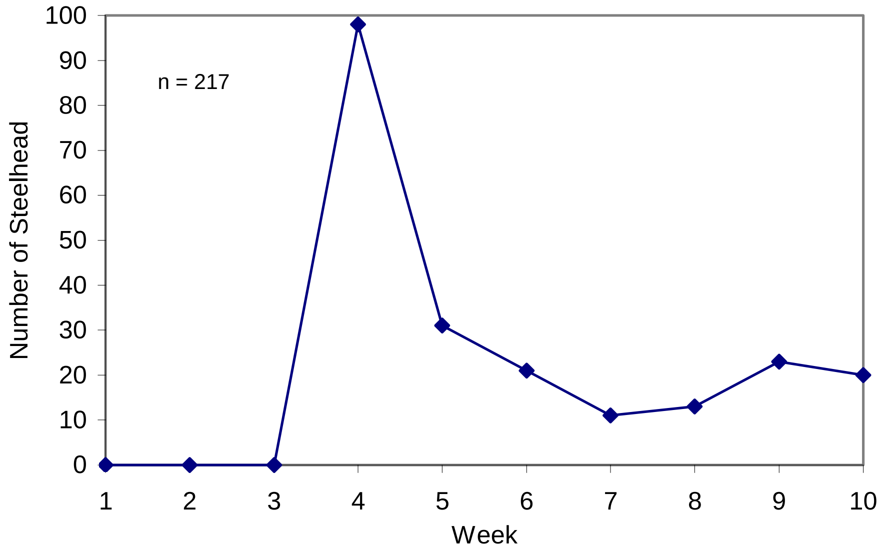


Figure 4. Number of steelhead YOY captured in Cottaneva Creek, 1 April - 6 June 2000.

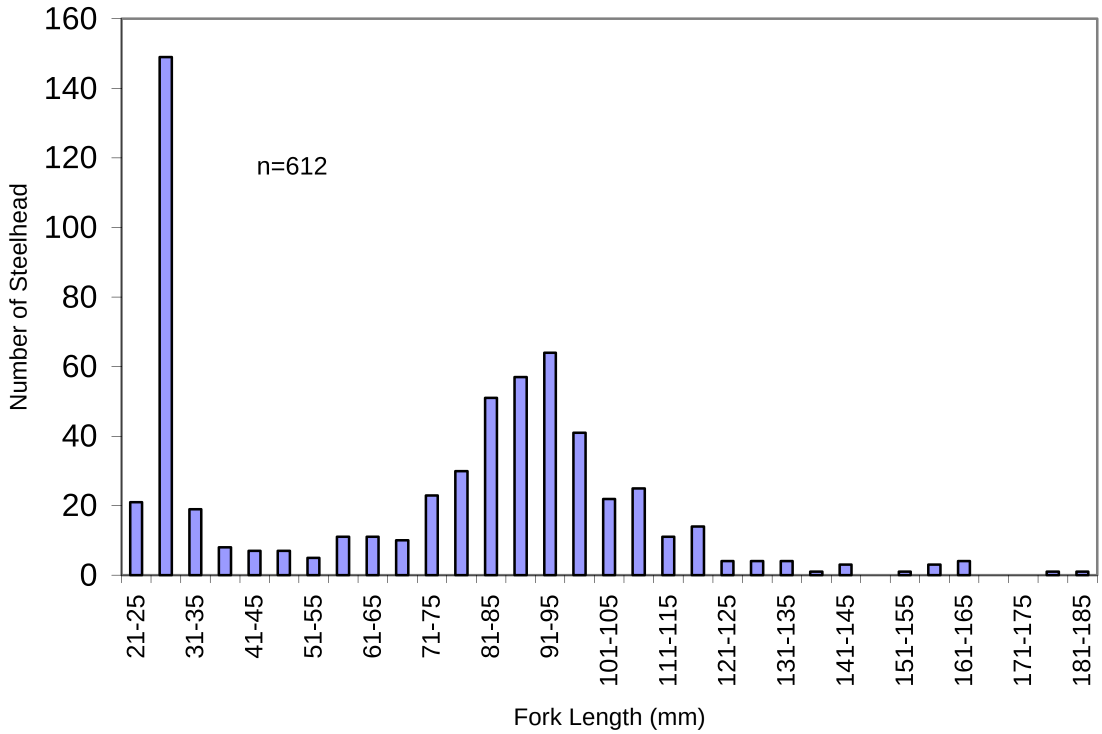


Figure 5. Length frequency of steelhead captured in Cottaneva Creek, 1 April-6 June, 2000.

Table 1. Weekly lengths (by 5 mm size classes) of steelhead captured in Cottaneva Creek, 1 April-6 June, 2000.

	Dates										
Fork Lenght (mm)	4/1-4/7	4/8-4/14	4/15-4/21	4/22-4/28	4/29-5/5	5/6-5/12	5/13-5/19	5/20-5/26	5/27-6/2	6/3-6/6	Total
21-25				14	3	4					21
26-30				77	26	15	10	9	6	6	149
31-35	1			5	1	2	1	3	5	1	19
36-40				1				1	3	3	8
41-45									3	4	7
46-50								1	2	4	7
51-55				1			1		2	1	5
56-60				1			1	2	3	4	11
61-65		1	1	1		1		1	2	4	11
66-70	3	1	1					1	2	2	10
71-75	4	4	1	6	1	4	1	1	1		23
76-80	10	4		1	1	4	5	3	2		30
81-85	4	6	7		1	12	3	9	3	6	51
86-90	11	7	5	2	1	12	5	10	2	2	57
91-95	8	2		3		14	7	19	7	4	64
96-100	1	3		2		9	7	14	3	2	41
101-105		1		2		3	4	7	4	1	22
106-110	2	3	1	1		3	4	8	1	2	25
111-115	1			1	1	2	2	2	2		11
116-120	2		1			3	1	3	2	2	14
121-125	1							1		2	4
126-130						2	1	1			4
131-135	1						1	1		1	4
136-140								1			1
141-145				1		1				1	3
146-150											0
151-155		1									1
156-160	1	2									3
161-165	3	1									4
166-170											0
171-175											0
176-180		1									1
181-185	1										1
Total	54	37	17	119	35	91	54	98	55	52	N=612

Coho

A total of 122 smolts were captured. The migration peaked during week 2 (8 April - 14 April). The number of smolt migrants during trapping was estimated at 2870 ± 1639 (Fig. 6). Trap efficiency ranged from 3-25% (mean = 7%) throughout the trapping period. A portion of the migration appears to have been missed, consequently negatively biasing the estimate of the total annual migrants. Only 28 YOY were captured (Fig. 7). The length frequency of coho was clearly bimodal, composed of YOY and smolts (Fig. 8, Table 2). YOY fork lengths ranged from 23-46 mm (mean = 31 mm), and smolt fork lengths ranged from 81-122 mm (mean = 102 mm).

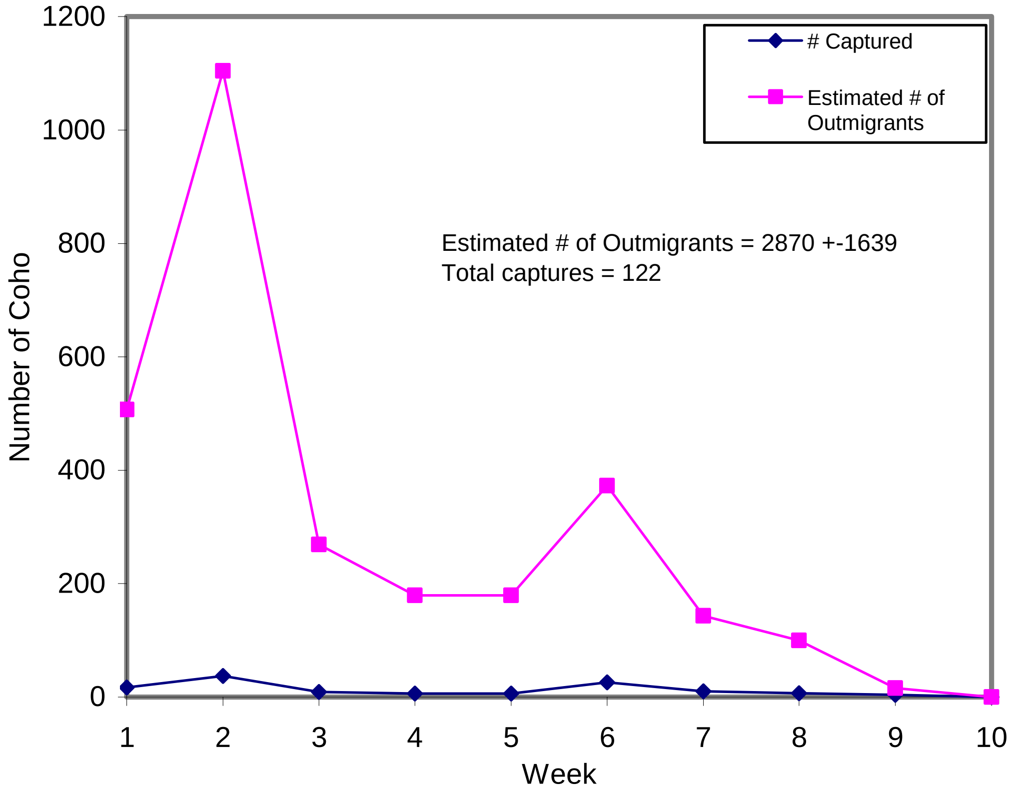


Figure 6. Number of coho smolt captured and estimated number of coho smolt out-migrants in Cottaneva Creek, 1 April - 6 June 2000.

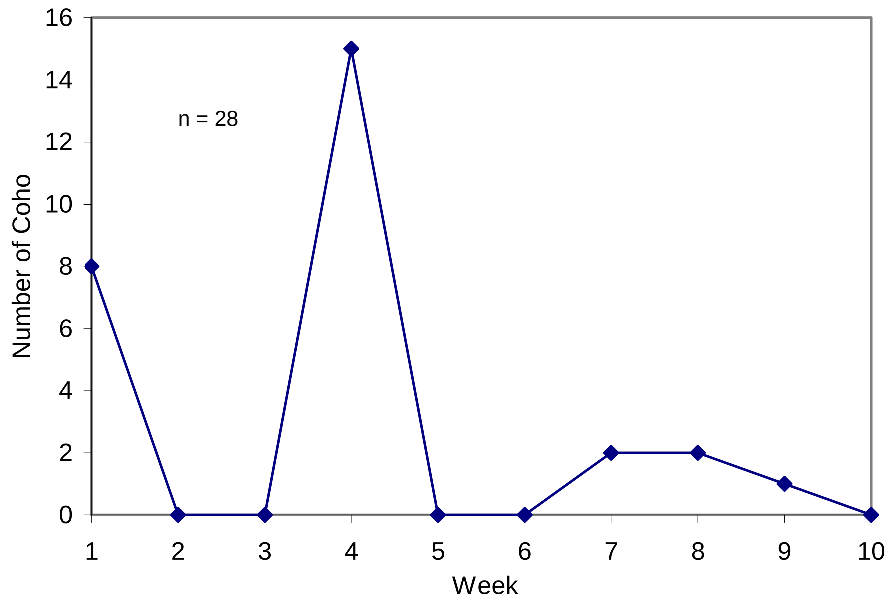


Figure 7. Number of coho YOY captured in Cottaneva Creek, 1 April - 6 June 2000.

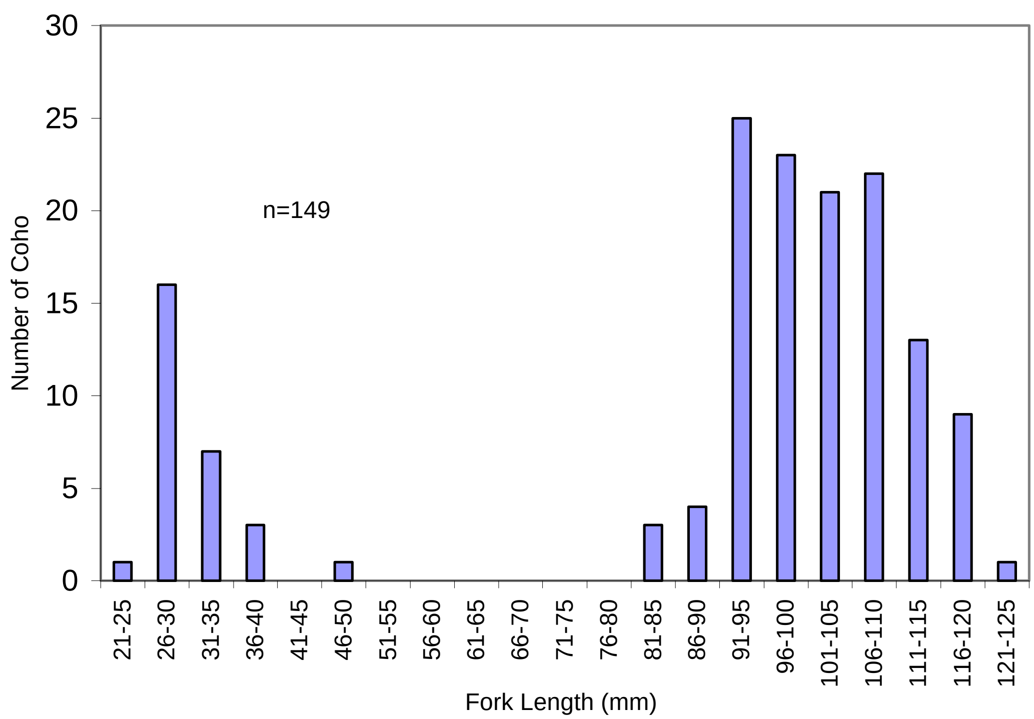


Figure 8. Length frequency of coho captured in Cottaneva Creek, 1 April - 6 June 2000.

Table 2. Weekly lengths (by 5 mm size classes) of coho captured in Cottaneva Creek, 1 April-6 June, 2000.

	Dates									
Fork Length (mm)	4/1-4/7	4/8-4/14	4/15-4/21	4/22-4/28	4/29-5/5	5/6-5/12	5/13-5/19	5/20-5/26	5/27-6/2	Total
21-25									1	1
26-30				13			2	1		16
31-35	5			2						7
36-40	3									3
41-45										0
46-50								1		1
51-55										0
56-60										0
61-65										0
66-70										0
71-75										0
76-80										0
81-85		2	1							3
86-90	1		2		1					4
91-95	6	9	3		1	4		2		25
96-100	3	6		3		7	1	2	1	23
101-105	2	10		2	1	3	2		1	21
106-110	3	6	3		2	6	2			22
111-115	1	2		1		4	1	2	2	13
116-120	1	1			1	2	3	1		9
121-125							1			1
Total	25	36	9	21	6	26	12	9	5	n=149

MORTALITIES AND NON-SALMONID SPECIES

In addition to salmonids, prickly sculpin (*Cottus asper*), coastrange sculpin (*C. aleuticus*) and three-spine sticklebacks (*Gasterosteus aculeatus*) were captured. Mortalities were recorded daily (Table 3).

Table 3. Total organisms captured and total trap-related mortalities at Cottaneva Creek, 1 April – 6 Jun 2000.

SPECIES	# Captured	# of Mortalities	% Mortalities
Coho Salmon *(O. kisutch)* Young of the Year	28	0	0%
Coho Salmon Smolts	122	1	1%
Steelhead Trout (*O. mykiss*) Young of the Year	217	7	3%
Steelhead Trout (Age 1+)	397	6	2%
Coastrange Sculpin (*Cottus aleuticus*)	523	0	0%
Prickly Sculpin (*C. asper*)	879	3	0.3%
Three Spine Stickleback (*Gasterosteus aculeatus*)	52	3	6%

Physical Parameters

Throughout the study, stream temperature ranged from 10.3-12.7 °C. (mean = 11.2 °C) and stream discharge ranged from 7-50 CFS (mean = 11 CFS). Fig. 9 shows weekly averages of stream temperature and discharge. Statistical relationships were analyzed between the migration rate of out-migrants and stream temperature / stream discharge, no significant correlations were found.

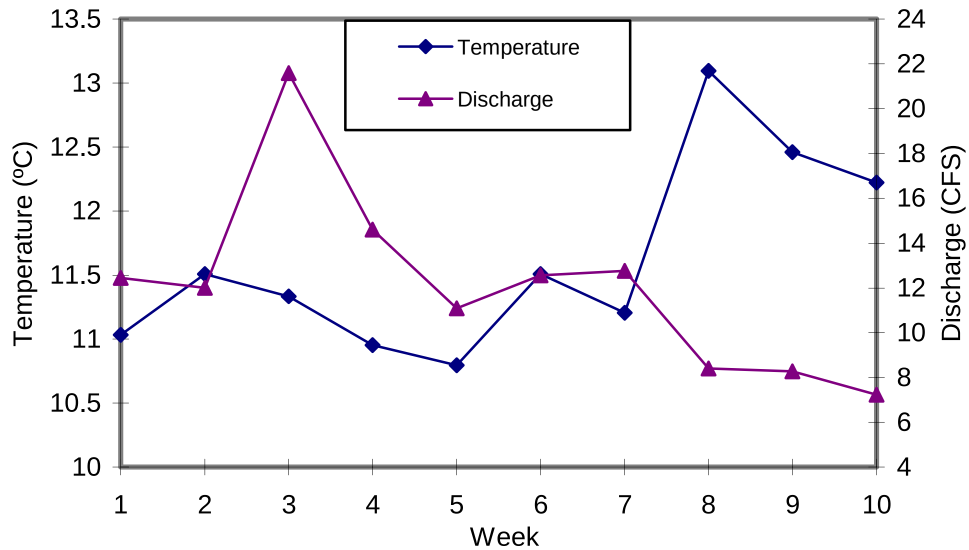


Figure 9. Mean weekly water temperature and discharge of Cottaneva Creek during out-migrant trapping, 1 April - 6 June 2000.

Year 2 Results: 3 March – 21 June 2001

Steelhead

A total of 918 age 1+ steelhead were captured throughout the trapping period. The total annual migration is estimated at 11127 ± 1782 individuals (Fig. 10). Estimated trap efficiency ranged from 4%-75% (mean = 22%) throughout the trapping period. The peak of the migration occurred during the eighth week (20 April-26 April) of trapping. A total of 732 YOY were captured (Fig. 11). The YOY migration began during week 8 (20 April - 26 April) and continued throughout the study.

Steelhead lengths ranged from 24-203 mm (mean = 108 mm). YOY lengths ranged from 24-61 mm (mean = 32 mm), and age 1+ steelhead lengths ranged from 45-203 mm (mean = 108 mm) (Fig. 12, Table 4).

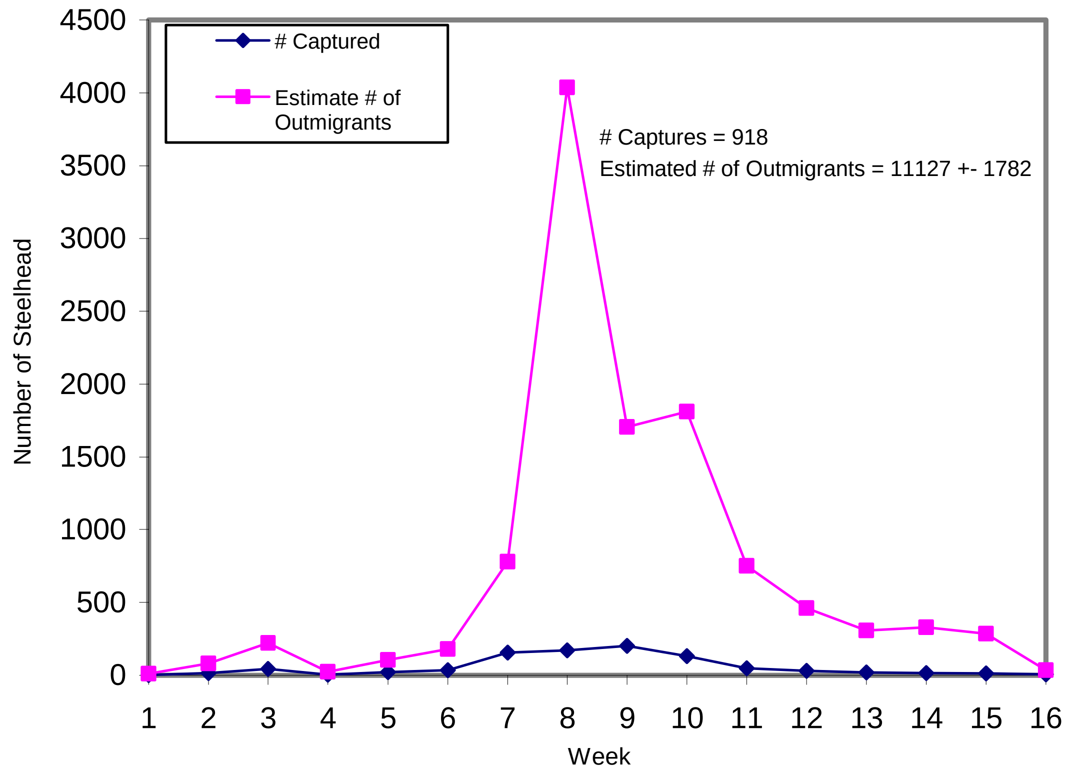


Figure 10. Number of age 1+ steelhead captures and estimated number of age 1+ steelhead out-migrants in Cottaneva Creek, 3 March - 21 June 2001.

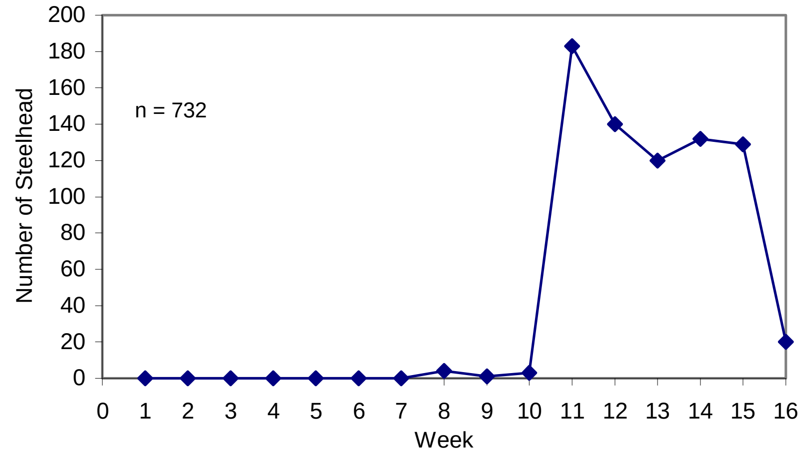


Figure 11. Number of steelhead YOY captured in Cottaneva Creek,
3 March - 21 June 2001.

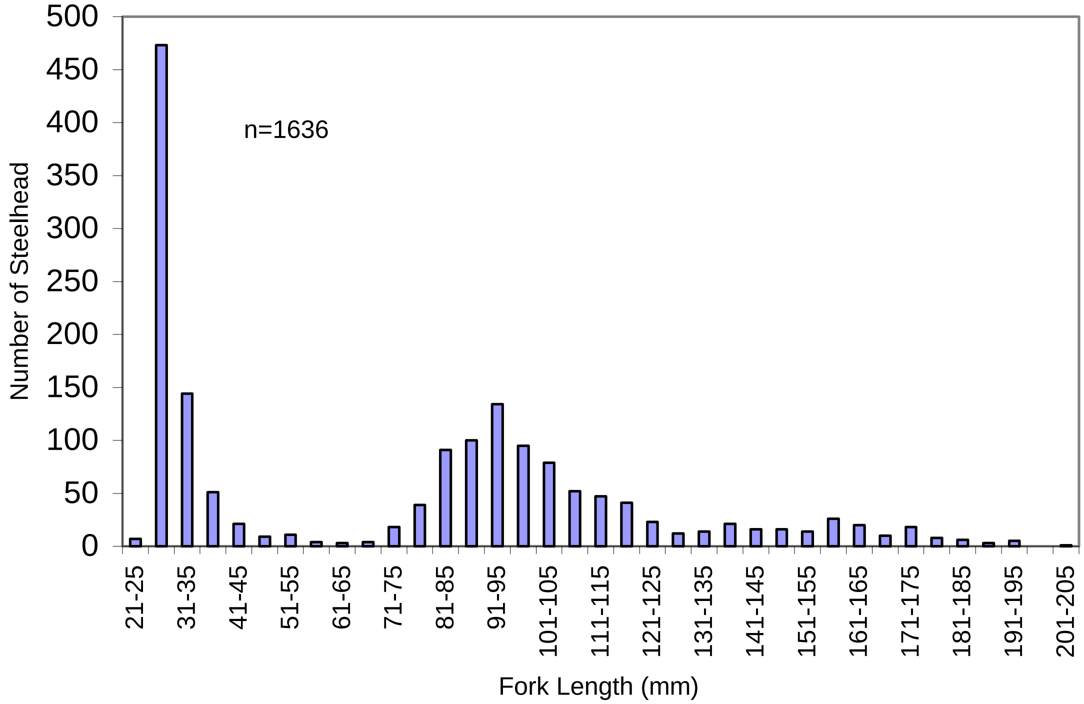


Figure 12. Length frequency of steelhead captured in Cottaneva Creek,
3 March-21 June, 2001.

Table 4. Weekly lengths (by 5 mm size classes) of steelhead captured in Cottaneva Creek, 3 March-21 June, 2001.

	Dates																
Fork Length (mm)	3/3-3/8	3/9-3/15	3/16-3/22	3/23-3/29	3/30-4/5	4/6-4/12	4/13-4/19	4/20-4/26	4/27-5/3	5/4-5/10	5/11-5/17	5/18-5/24	5/25-5/31	6/1-6/7	6/8-6/14	6/15-6/21	Total
21-25												1	6				7
26-30								1		2	141	113	55	99	61	1	473
31-35								3	1	1	31	25	34	18	27	4	144
36-40												1	14	7	23	6	51
41-45		1											8	2	8	2	21
46-50														2	5	2	9
51-55														4	5	2	11
56-60		2														2	4
61-65	1		1													1	3
66-70			2					1	1								4
71-75		1	1		1			3	8		2	1		1			18
76-80	1		3	2	1		2	8	9	8		3	2				39
81-85			4	1			18	18	29	8	7	2	1		2	1	91
86-90		1	3			2	17	21	23	16	8	6	2	1			100
91-95			1			6	23	22	39	22	10	3	2	3	2	1	134
96-100					4	1	14	25	14	19	7	3	4		3	1	95
101-105				1		3	10	20	15	14	5	1	2	4	2	2	79
106-110		1		1		1	11	14	4	7	2	8	2	1			52
111-115			2		2		6	11	9	6	1	2	3	3	1	1	47
116-120		1				1	10	7	8	7	3		1	1	1	1	41
121-125			1		1		3	1	6	6	2	1			2		23
126-130		1	1		1			2	3	4							12
131-135		1	1				4	1	3	2			1	1			14
136-140		1				2	5	2	9	2							21
141-145			1			1	6	5	2		1						16
146-150		2	4			2	6			1	1						16
151-155			2		1	2	3	2	3	1							14
156-160		1	2		3	6	2	4	6	2							26
161-165		1	2		4	2	4		6	1							20
166-170			1			3	2	2	1	1							10
171-175			3		1	2	5	1	3	3							18
176-180			3		1	1	1	1		1							8
181-185			2		1		3										6
186-190		1	1						1								3
191-195		1	2			1		1									5
196-200																	0
201-205			1														1
Total	2	16	44	5	21	36	155	176	203	134	221	170	137	147	142	27	n=1636

Coho

A total of 232 smolts were captured. The number of smolt migrants during trapping was estimated at 1313 ± 360 individuals (Fig 13). The migration peaked during week 10 (4 May – 10 May). Trap efficiency ranged from 12-55% (mean = 16%) throughout the trapping period. Only 1 YOY was captured. It was captured on 16 May and had a fork length of 42 mm. Coho smolt lengths ranged from 82-133 mm. (mean = 106 mm.) (Fig. 14 , Table 5).

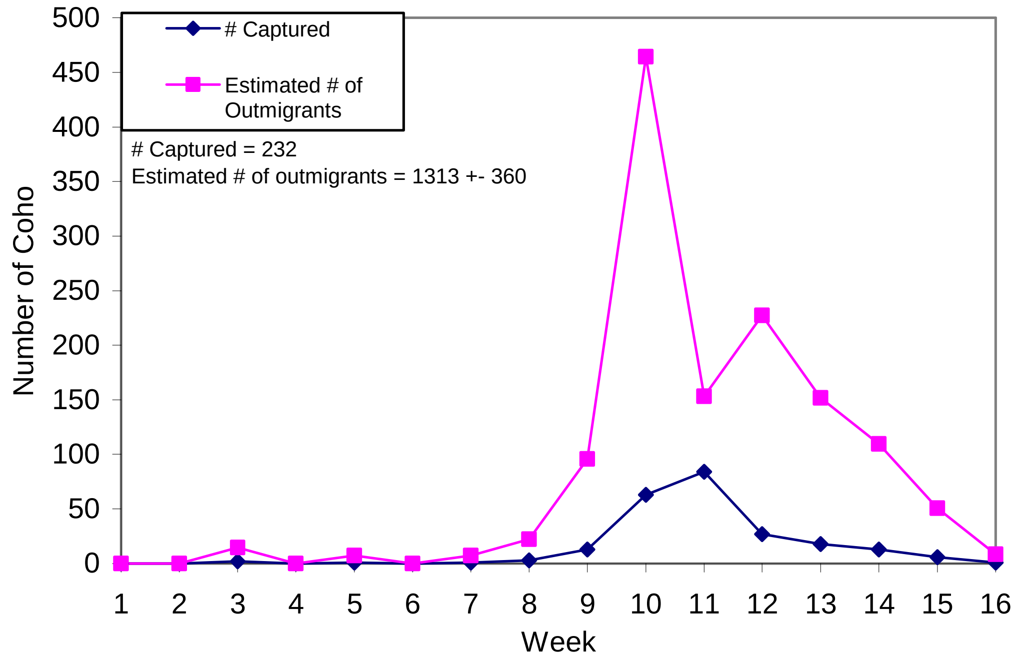


Figure 13. Number of coho smolts captured and estimated number of coho smolt out-migrants in Cottaneva Creek, 3 March - 21 June 2001.

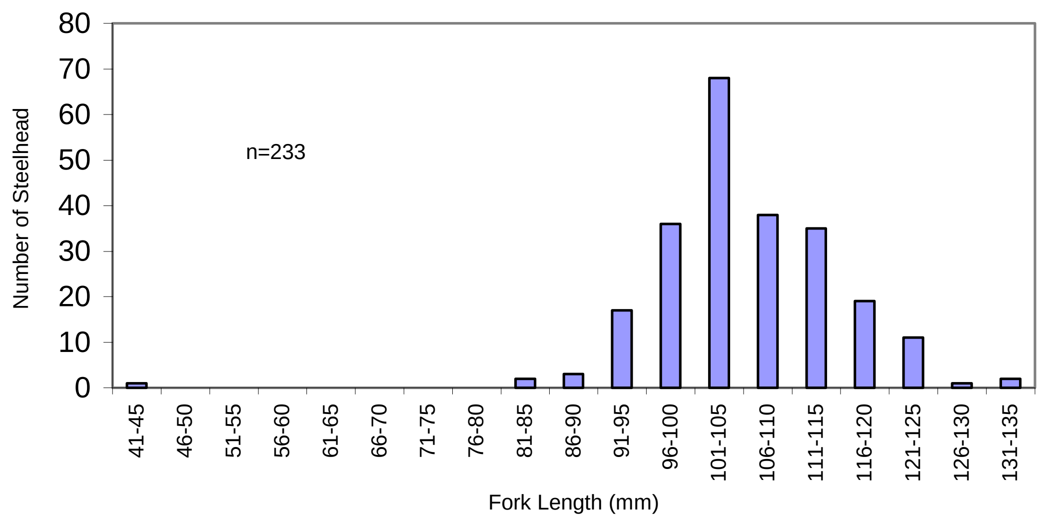


Figure 14. Length frequency of coho captured in Cottaneva Creek, 3 March - 21 June 2001.

Table 5. Weekly lengths (by 5 mm size classes) of coho captured in Cottaneva Creek, 3 March-21 June, 2001.

	Dates																
Fork Length (mm)	3/3-3/8	3/9-3/15	3/16-3/22	3/23-3/29	3/30-4/5	4/6-4/12	4/13-4/19	4/20-4/26	4/27-5/3	5/4-5/10	5/11-5/17	5/18-5/24	5/25-5/31	6/1-6/7	6/8-6/14	6/15-6/21	Total
41-45											1						1
46-50																	0
51-55																	0
56-60																	0
61-65																	0
66-70																	0
71-75																	0
76-80																	0
81-85			1									1					2
86-90			1		1						1						3
91-95							1		1	1	5	4	2	2	1		17
96-100									1	7	8	9	2	4	4	1	36
101-105								1	4	16	29	8	6	3	1		68
106-110										7	21	2	5	3			38
111-115								1	4	14	11	3	2				35
116-120									1	10	6		1	1			19
121-125								1	2	7	1						11
126-130										1							1
131-135											2						2
Total	0	0	2	0	1	0	1	3	13	63	85	27	18	13	6	1	n=233

MORTALITIES AND NON-SALMONID SPECIES

In addition to salmonids, prickly sculpin (*Cottus asper*), coastrange sculpin (*C. aleuticus*), three-spine sticklebacks (*Gasterosteus aculeatus*), and pacific giant salamanders (*Dicamptodon tenebrosus*) were captured. Mortalities were recorded daily (Table 6).

Table 6. Total organisms captured and total trap-related mortalities at Cottaneva Creek, 3 March – 21 June, 2001.

Species	# Captured	# of Mortalities	% Mortalities
Coho Salmon (*Oncorhynchus kisutch*) Young of the Year	1	0	0%
Coho Salmon Smolts	232	1	0.4%
Steelhead Trout (*O. mykiss*) Young of the Year	732	23	3%
Stealhead Age 1+	918	11	1%
Steelhead Adults	2	0	0%
Coastrange Sculpin (*Cottus aleuticus*)	323	1	0.3%
Prickly Sculpin (*C. asper*)	1546	8	1%
Three Spine Stickleback (*Gasterosteus aculeatus*)	20	5	25%
Pacific Giant Salamander (*Dicamptodon tenebrosus*)	2	0	0%

Physical Parameters

Throughout the study, stream temperature ranged from 7.0-15.2 °C. (mean = 10.9 °C) and stream discharge ranged from 7-49 CFS (mean = 8 CFS). Stream dissolved oxygen ranged from 8.1 – 11.2 mg./l. (mean = 9.9 mg./l.) and stream pH ranged from 6.6-7.4 (mean = 7.1). The weekly number of estimated coho smolt out-migrants was positively correlated with the weekly mean stream temperature (r=.50, p=.02, n=16) (Figs. 15-17). This may be explained by Baggerman's (1960) suggestion that salmonid emigration is stimulated by a combination of decreasing flow, increasing water temperature, and increasing photoperiod.

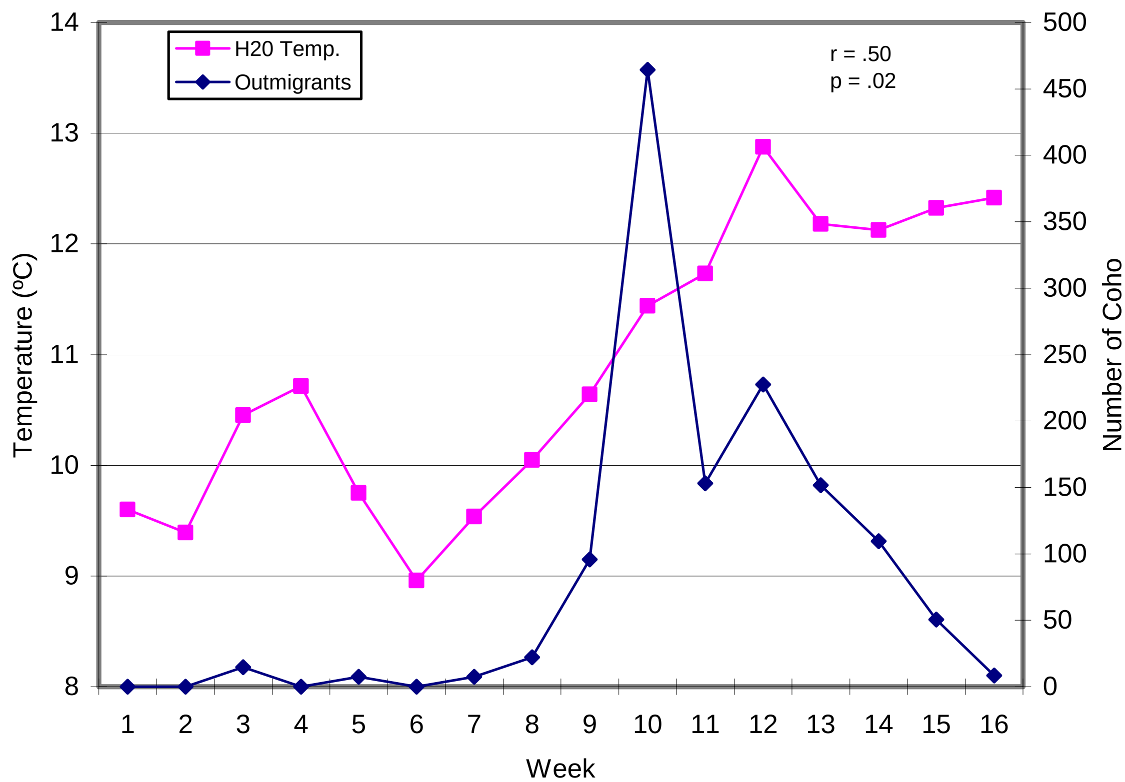


Figure 15. Mean weekly stream temperature and estimated number of coho smolt out-migants in Cottaneva Creek, 3 March - 21 June 2001.

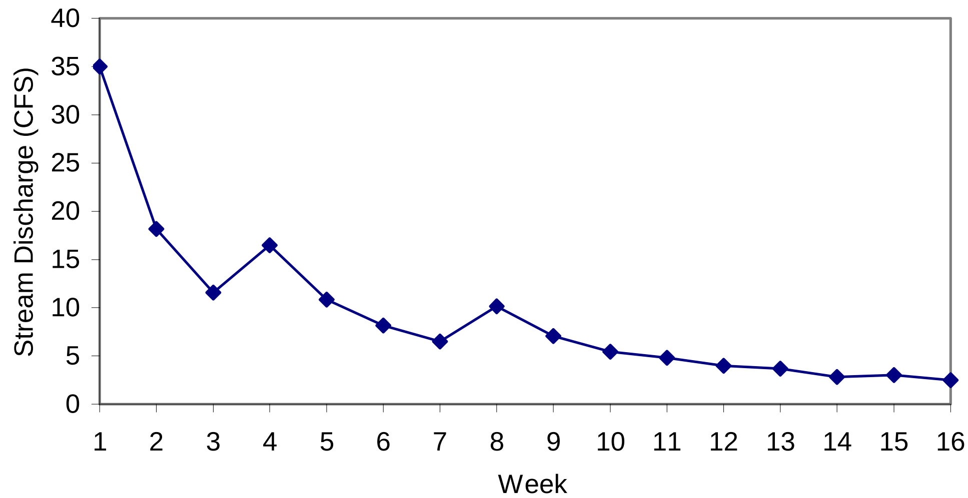


Figure 16. Mean weekly stream discharge of Cottaneva Creek, 3 March - 21 June 2001.

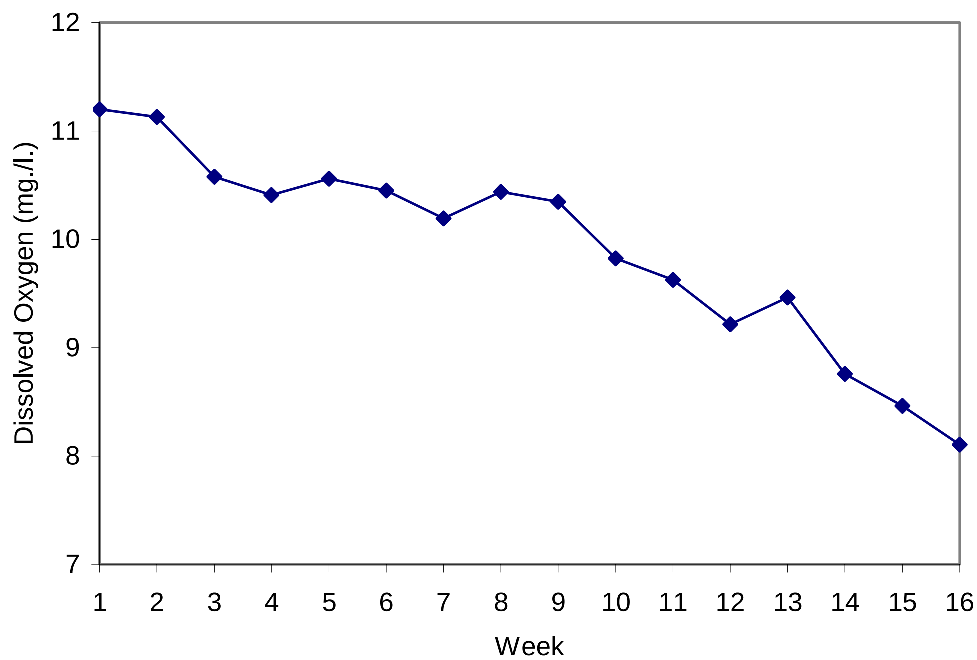
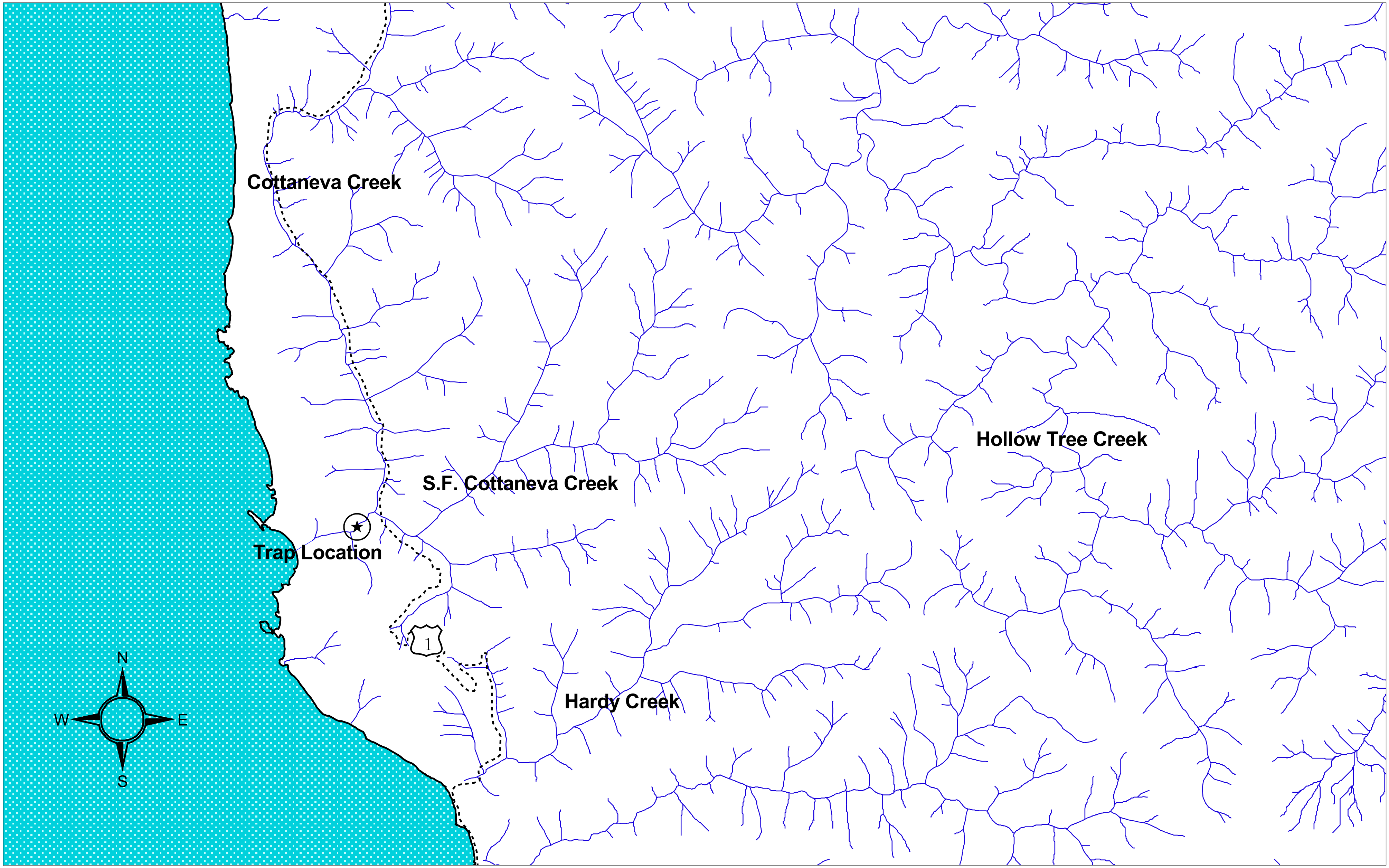


Figure 17. Mean weekly dissolved oxygen of Cottaneva Creek, 3 March - 21 June 2001.

Discussion

In depth analysis of the data is being delayed until the third year of data is collected (after the summer of 2002). However, it is important to note the importance of installing the traps as early as possible. It is evident that a large proportion of the salmonid out-migration was missed during the first year of trapping (Figs. 3, 6). The second year of trapping appears to have sampled a majority of the out-migration (Figs. 10,13).



1:60000

Mendocino Redwood Company, LLC

Highway 1 | Pacific Ocean | Watercourse

Trap UTM Coordinates
429800 East
4398750 North

Figure 18. Location of out-migrant trap in Cottaneva Creek, Mendocino County California.

References

Baggerman, B. 1960. Salinity preference, thyroid activity and seaward migration of four species of Pacific salmon (*Oncorhynchus*). Journal of the Fisheries Research Board of Canada 17:295-322.

Bjorkstedt, E.P. 2000. DARR (Darroch analysis with rank-reduction): A method for analysis of stratified mark-recapture data from small populations, with application to estimating abundance of smolts from out-migrant trap data. U.S. Dep. Commer., NOAA, NMFS, SWFSC, Admin. Rep., Santa Cruz, SC-00-02. 28 pp.*

Darroch J.N. 1961. The two sample capture recapture census when tagging and sampling are stratified. Biometrika 48: 241-260.

Mendocino Redwood Company 2002. Aquatic Species Distribution on Mendocino Redwood Company Forestlands. Mendocino Redwood Company, LLC, P.O. Box 285, Fort Bragg California 95437.

* The use of DARR does not constitute NMFS certification of the data or results.