

Redwood Creek Estuary Monitoring 2003 Annual Progress Report

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Introduction

This annual report summarizes Redwood National and State Parks' Fish and Wildlife Branch monitoring activities in the Redwood Creek estuary for calendar year 2003. Monitoring has occurred in the Redwood Creek estuary since 1980. The purpose of the estuary monitoring is to determine fish populations and growth, estuary water quality, water elevations, and document breaching incidents. In 2003, no berm elevations parallel to the shore were done. This report serves as the annual report for the parks' Division of Resource Management and Science.

Location

Redwood Creek estuary is located 2.5 miles west of Orick, California at the confluence of Redwood Creek with the Pacific Ocean (Figure 1). Redwood Creek is 108 km long and the basin is 720 km² in area. U.S. Army Corps of Engineers completed construction of 3.4 miles of flood control levees in 1968 on lower Redwood Creek. The levees bisect and terminate in the estuary. The estuary consists of the north and south sloughs, and the embayment. The south slough was the last meander of the river bypassed by the south levee.

Methods

Fish Monitoring

Population Estimates - The Peterson mark and recapture method (Youngs and Robson 1978) was used to estimate numbers of juvenile salmonid fish in the Redwood Creek embayment. Fish were seined with a 150-long, 15-foot wide, ¼ inch mesh beach seine net deployed off the bow of a 16-foot motor boat. A blue mark was applied to the upper or lower caudal fin, or anal fin of captured fish using a Panjet needleless injector and Alcian Blue dye. Captured fish were marked the first two days, allowed to mix the third day, and seined on the fourth day to determine the ratio of marked to unmarked fish. Population and 95 percent confidence interval (95% CI) estimates are rounded off to the nearest 10. Four population estimates were scheduled, but only three were successful during the summer/fall 2003.

Growth Estimates – Fish fork lengths (mm) were measured, to the nearest 1-mm, from 200 each of chinook salmon (*Oncorhynchus tshawytscha*) and steelhead trout (*O. mykiss*), and (wet) weight (g) measurements were taken from 30 juveniles of each species. Two electronic balances were used, a 200 g ± 0.01g capacity balance for smaller fish, and a 5,000 g ± 2g capacity for larger fish. Other salmonid species, coastal cutthroat trout (*O. clarki*) and coho salmon (*O. kisutch*), though not as numerous as chinook or steelhead, were also measured and weighed. Seven growth estimates were conducted, three in conjunction with the population estimates, and four separate days between and after a population estimate.

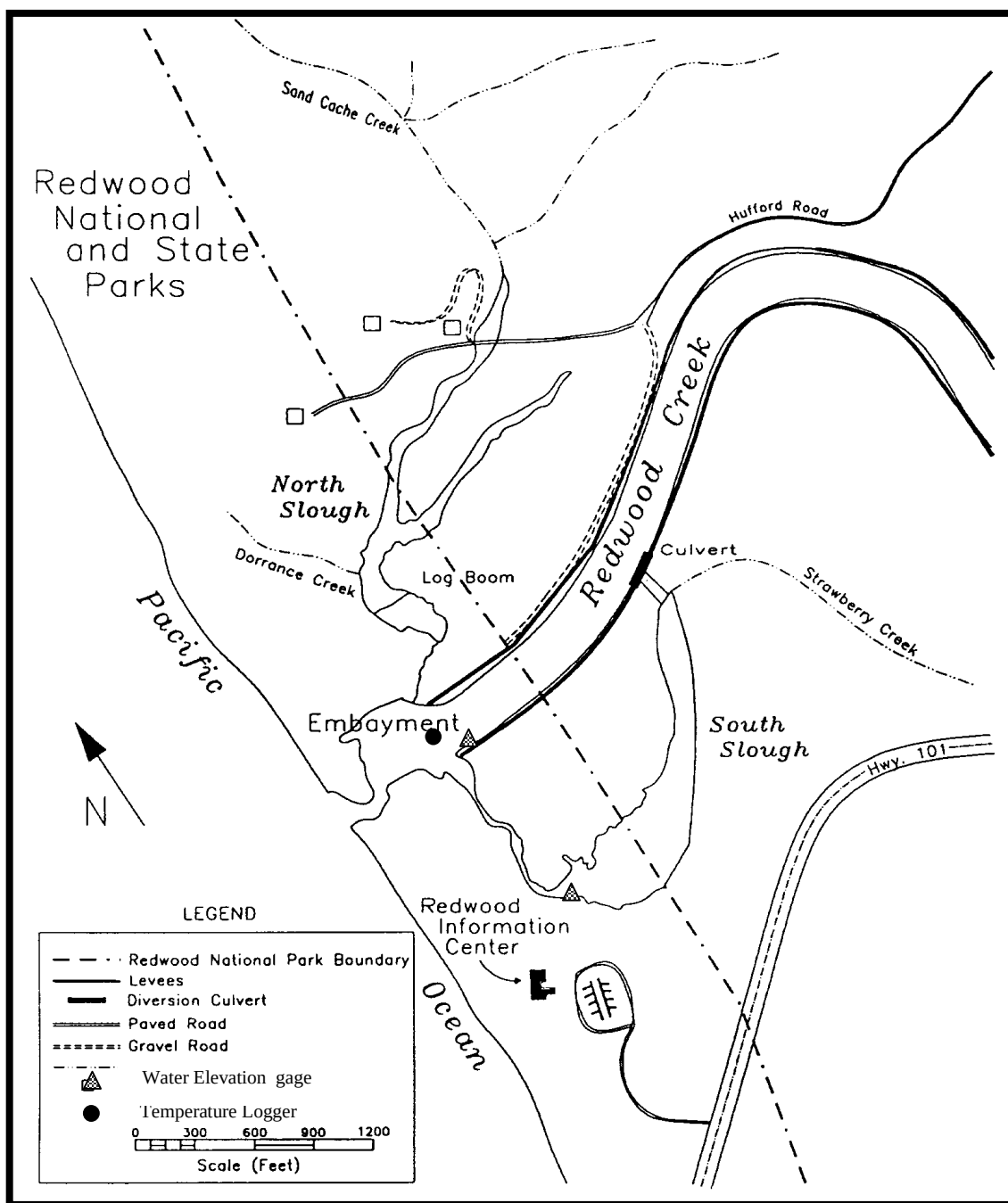


Figure 1. Map of the Redwood Creek Estuary, Humboldt County, California, including location of the embayment, north and south sloughs, and water elevation gages and temperature logger.

Condition Factor- Condition factor, a measure of fish ‘fatness’ was calculated for salmonid species measured and weighed. Because of the wide range of fish lengths, condition factor (K’) was calculated as: $K' = (100 \times \text{Weight}_{(g)}) / \text{Fork Length}_{(cm)}^b$ (Begenal and Tesch 1978). Slope (b) was calculated as: $\log_{10} \text{Weight}_{(g)} = \log_{10} a + b \log_{10} \text{Fork Length}_{(cm)}$.

Water Quality Monitoring

Water Temperature - Water temperature (°C) was measured hourly in the Redwood Creek embayment. An Onset TIDBIT™ temperature logger was located in the Redwood Creek channel between the ends of the north and south flood control levees. The probe floated about one foot off the bottom in the water column (Figure 1).

Tide and Stream Flow Data

Tide Data: Calendar year 2003 tide data for the mouth of Redwood Creek was compiled using software for Crescent City Harbor, California. It was corrected for the locality of the mouth of Redwood Creek [CC tide x 0.98] and transformed to feet Mean Sea Level (MSL) [tide – 3.65 = ft MSL] (Hubbard 1986).

Stream Flow Data: Hourly Redwood Creek flow data, cubic feet per second (cfs), at Orick for calendar year 2003 was downloaded from the California Department of Water Resources, Division of Flood Management website (<http://cdec.water.ca.gov>). Water Resources has not yet reviewed the preliminary flow data for accuracy and it is subject to change. The Orick gaging station (ORK) is located on Redwood Creek downstream of the confluence of Prairie Creek just north of Orick.

Estuary Water Levels

South slough water elevations (feet MSL) were recorded at 30-minute intervals by a continuous recording gage using a pressure transducer and ENMOS logger. The gage site is located at the end of the Redwood Information Center boardwalk trail (Figure 1). A seasonal gage site was installed at the end of the south levee to measure the water elevation in the estuary embayment. The south levee gage, a Global Water WL-14 Water Level Logger, measured embayment water levels every 12-minutes.

Estuary Cross Sections

Four of the five permanent cross-sections in the main embayment of the estuary perpendicular to flow were surveyed in 2003. Established in 1998, the northside cross section endpoints are 8 ft t-bar fence posts pounded into the sand, or partially buried monumented sea stacks located along the base of the hill. The permanent endpoints are surveyed and referenced to a BLM benchmark located at the park boundary fence separating the pasture from the parking area adjacent to the north levee. Each cross section was shot at a bearing of 170° using a Nikon Total Station. A diver with a rod and prism took points in the embayment at breaks in slope. Transects were measured to at least 11ft MSL in elevation.

Other Activities

Upper Redwood Creek Downstream Migrant Trapping - Steelhead marked at the upper trap were recaptured in the estuary.

North Slough Outlet Channel – Large woody debris was cleared from the North Slough channel to

allow water to flow unimpeded.

Moffatt and Nichol Engineers Setback Levees Modeling Report – Report was completed.

Humboldt County Levee Maintenance Army Corps Permit - Permit still in progress.

Estuary Poaching – NPS rangers reported poaching of adult salmon after the mouth opened.

2003 Results

Fish Monitoring

Presence – During the summer and fall of 2003, four salmonid species were seined in the Redwood Creek embayment; chinook and coho salmon, and steelhead and coastal cutthroat trout. In addition to the juvenile salmonids captured, three adult chinook and 9 adult coho salmon were captured. Seven other fish species were captured. One reptile, 37 bird, two mammal, and eight invertebrate species were observed. Of those, chinook, coho, and steelhead are federally listed as threatened and the brown pelican is listed as endangered. A complete list of all fish and other species captured or observed in and around the Redwood Creek estuary is presented in Table 1. No endangered tidewater gobies (*Eucyclogobius newberryi*) were seined in the estuary in 2003.

Population Estimates -Four population estimates were scheduled in the embayment the summer and fall of 2003. However, the first estimate the week of June 16 was scrapped when we had difficulty capturing fish because of the very shallow water depths in the embayment (see pictures in Appendix VI). In two days of seining, only 80 salmonids were captured. The remaining three population estimates were conducted the weeks of July 7, August 11, and September 22 (Table 2). The mouth was open during the week of July 7, the channel to the south with the mouth almost 2/3 the way to the visitor center. During the weeks of August 11 and September 22, and between, the mouth was closed. The number of fish marked, marked recaptures, total individuals captured in the ‘second sample’, and location of marks are presented in Appendix I.

In 2003, juvenile chinook estimates were low. The first juvenile chinook salmon estimate, the week of July 7 was 3,310 (95% Confidence Interval [CI] 2,720 to 3,910). During the week of August 11, because no marked chinook were recaptured the last day, the actual total number of chinook captured was 127. But based on the first two days, the estimate was 2,990 (95% CI 118 [actual] to 8,730). By the week of September 22, the population had decreased to 1,050 (95% CI 71 [actual] to 3,040). The CI was poor for the latter two estimates because only one marked chinook was recaptured.

For juvenile steelhead trout, the estimate the week of July 7 was 12,290 (95% CI 9,550 to 15,030). The population was 11,890 (95% CI 3,370 to 20,400) on August 11. The last steelhead estimate on September 22 decreased to 3,960 (95% CI 2,810 to 5,110).

No population estimates were possible for coho salmon as no marked fish were recaptured. Seven were captured the week of July 7, one the week of August 8, and two the week of September 22. Though not part of the population estimates, during the growth estimates, one coho was captured on August 27, 11 on October 23, and none captured on June 16 and 17, and July 22. The cutthroat trout population estimate for July 7 was 32 (95% CI 14 [actual] to 65). For August 11, the estimate was 23 (95% CI 12 [actual] to 44), and for September 22, the estimate was 75 (95% CI 19 [actual] to 200).

Table 1. List of salmonid and non-salmonid fish seined, birds, amphibians, reptiles, mammals, invertebrates, and others observed at and adjacent to the Redwood Creek estuary, Redwood National and State Parks, Humboldt County, California during the summer/fall 2003 fish sampling (X denotes presence).

Species	2003 Date (*Week of)						
	June 16*	July 7*	July 22	Aug 11*	Aug 27	Sept 22*	Oct 23
Salmonid Fish							
Coastal Cutthroat Trout		X	X	X	X	X	X
Steelhead Trout *	X	X	X	X	X	X	X
Chinook Salmon *	X	X	X	X	X	X	X
Coho Salmon *		X		X	X	X	X
Non-Salmonid Fish							
Three Spine Stickleback	X	X	X	X	X	X	X
Staghorn Sculpin	X	X	X	X	X	X	X
Prickly Sculpin	X		X	X		X	
Sucker		X		X	X	X	
Starry Flounder	X		X	X		X	X
Surf Smelt	X						
Shiner Surfperch	X	X					
Amphibians							
Western Toad				X		X	
Redlegged Frog						X	
Pacific Tree Frog						X	
Reptiles							
Garter Snake				X			
Birds							
Brown Pelican **	X	X	X	X	X	X	
Great Blue Heron						X	
Green Heron		X					
Double Crested Cormorant				X	X	X	X
Turkey Vulture	X	X	X	X		X	
Osprey	X	X	X	X		X	
American Kestrel						X	
Northern Harrier							X
Sharp Shinned Hawk						X	X
Red Shouldered Hawk				X		X	
Redtailed Hawk						X	
Peregrine Falcon					X		
Least Sandpiper		X					
Western Sandpiper			X				
Killdeer						X	
Scoter							X
Gulls (Western, Heerman, California, Mew, and Ringbilled)	X	X	X	X	X	X	X
Caspian Tern	X	X	X	X	X	X	
Violet Green Swallow	X	X	X		X		
Barn Swallow							

Species (Con't.)	2003 Date (Week of *)						
	June 16*	July 7*	July 22	Aug 11*	Aug 27	Sept 22*	Oct 23
Belted Kingfisher						X	X
Western Meadowlark						X	
Black Phoebe						X	
Morning Dove		X					
Robin		X					
California Quail		X					
Corvids (Crows and Ravens)	X	X		X		X	X
Redwinged Blackbird	X						
Canada Geese	X	X	X				
Snow Geese (formations)						X	
Black Brant							X
Merganser	X			X			X
Mammals							
Whale (offshore)		X					
Harbor Seal	X						
Invertebrates							
Jelly Fish	X						
<i>Corophium</i>	X			X		X	X
Sipunculidae (peanut worms - dead)	X						X
Insects							
West Coast Lady						X	
Orange Sulphur						X	
Cabbage White						X	
Limniphilidae caddisfly larvae	X						
Dragonfly (adults)						X	
Other							
Goodyear Blimp		X					
* = Federally listed as Threatened ** = Federally listed as Endangered							

Table 2. Population estimates and 95 percent confidence intervals for juvenile chinook and coho salmon, juvenile steelhead trout, and coastal cutthroat trout seined in the Redwood Creek estuary embayment, Humboldt County, California, summer/fall 2003. A population estimate was attempted the week of June 16, but low embayment water depths and poor fish catches suspended the estimate. Mouth of creek denotes if Redwood Creek mouth was open or closed to the Pacific Ocean during the estimate.

2003 DATE	Mouth of Creek (Open or Closed)	Chinook Salmon		Coho Salmon	
		Population Estimate	95% Confidence Interval	Population Estimate	95% Confidence Interval
07/07, 08, 10	OPEN	3,310	2,720 – 3,910	7 ^a	---
08/11, 12, 14	CLOSED	127 ^a	---	1 ^a	---
Estimate based on two days 8/11 & 12		2,990	118 ^b – 8,730		
09/22, 23, 25	CLOSED	1,050	71 ^b – 3,040	2 ^a	---
		Steelhead Trout		Cutthroat Trout	
07/07, 08, 10	OPEN	12,290	9,550 – 15,030	32	14 ^b - 65
08/11, 12, 14	CLOSED	11,890	3,370 – 20,400	23	12 ^b - 44
09/22, 23, 25	CLOSED	3,960	2,810 – 5,110	75	19 ^b - 200
a. Actual count of fish captured in seine net hauls. No marked fish were recaptured.					
b. Actual minimum count, calculated 95% lower confidence interval was below what was actually caught					

Growth Estimates – Seven growth estimates were conducted, three in conjunction with population estimates during the weeks of July 7, August 11, and September 22, and four growth estimates on June 16-17, July 22, August 27, and October 23 (Table 3). Though 200 length measurements each of chinook and steelhead was the goal, during several sample periods we did not capture that number of fish.

Chinook Salmon – From a sample of 659 juvenile chinook salmon fork lengths, mean fork length increased from 77 to 113mm, an increase of 36 mm between June and late August (Table 3 and Figure 2). After the mouth opened, fish averaged 101mm in late October. Between June and October, the minimum and maximum fork length was 59 and 128mm, respectively. On June 6-17, the minimum and maximum fork lengths were 59 and 91mm, and increased to 91 and 128mm the week of September 22. Mean weight increased from 5.4g to 15.3g, a 9.9g increase, between June and September. It decreased to 11.3g in late October. During the sample period, the minimum and maximum weight was 2.7 and 22.7g, respectively. The three adult chinook seined on October 23 when the mouth was open, ranged between 475 and 555mm.

Coho Salmon - Of the 22 juvenile coho salmon measured, fork lengths ranged from 70 to 158mm. Mean fork length was 90mm the week of July 8, 131mm for one fish on August 11 and 27, 119mm for two fish the week of September 23, and 101mm on October 23. Mean weight for samples greater than 2 ranged between 8.7 and 11.6g. During the sample period, the minimum and maximum weight was 4.0 and 43.8g. The nine adult coho seined on October 23 when the mouth was open, ranged between 415 and 630mm in length.

Steelhead Trout – From a sample of 1,184 juvenile steelhead trout fork lengths, mean fork length started at 130mm in mid-June, decreased to 81mm in early July, and increased to 138mm in late October. For the season, the minimum and maximum fork length was 51 and 223mm, respectively. Several age classes were present (Table 3 and Figure 3). Mean juvenile steelhead weight ranged from 5.1 to 31.6g, increasing later in the season. Minimum and maximum weight was 1.6 and 107.7g, respectively.

Cutthroat Trout - From a sample of 57 cutthroat trout fork lengths, mean fork length ranged between 227mm and 317mm. Minimum fork lengths ranged between 144 and 227mm, and maximum fork lengths ranged between 325 and 395mm. Mean weights ranged between 151.7 and 422.3g. Seasonal minimum weights ranged between 29.3 and 101.8g, and maximum weights ranged between 368 and 698g.

Condition Factor (K') – Fish condition factors are presented in Table 4. Species mean conditions factors of each date remained approximately the same throughout the season. Mean chinook K' ranged from 0.968 to 1.120, the seasonal mean for all chinook was 1.077. Mean coho K' ranged from 1.429 to 1.622, the seasonal mean for all coho was 1.542. Mean steelhead K' ranged from 1.067 to 1.209, the seasonal mean for all steelhead was 1.165. Mean cutthroat K' ranged from 0.749 to 0.981, the seasonal mean for all cutthroat was 0.838.

Table 3. Mean fork length (mm), mean weight (g), standard deviation, range, dates, and numbers sampled of juvenile chinook and coho salmon, and steelhead and coastal cutthroat trout seined in the Redwood Creek estuary embayment, Humboldt County, California, during summer and fall of 2003 from June 16 to October 23, 2003. Mouth denotes if Redwood Creek mouth was open or closed to the ocean.

Growth - Redwood Creek Estuary – Summer/Fall 2003									
2003 DATE	MOUTH	FORK LENGTH (mm)				WEIGHT (g)			
		No. Measured	Mean	Std. Dev	Range	No. Weighed	Mean	Std. Dev.	Range
JUVENILE CHINOOK SALMON									
06/16, 17	OPEN	40	77	6.6	59 - 91	29	5.4	1.5	3.2 – 8.9
07/07	OPEN	205	84	6.2	60 – 97	30	6.5	1.5	2.7 – 9.6
07/22	OPEN	207	93	6.2	76 – 112	30	9.6	1.9	5.6 – 12.8
08/11, 12, 14	CLOSED	125	99	8.4	72 – 115	30	10.6	3.0	4.6 – 15.7
08/27	CLOSED	2	113	12.7	104 - 122	2	14.0	1.2	13.1- 14.8
09/22, 23, 25	CLOSED	69	110	7.9	91 – 128	30	15.3	3.3	9.1 – 22.7
10/23	OPEN	11	101	6.1	90 – 114	11	11.3	1.7	8.3 – 15.3
JUVENILE COHO SALMON									
06/16, 17	OPEN	---	---	---	---	---	---	---	---
07/07, 08, 10	OPEN	7	90	17.8	70 – 108	7	8.7	4.3	4.0 - 13.8
07/22	OPEN	---	---	---	---	---	---	---	---
08/11	CLOSED	1	131	---	---	1	22.2	---	---
08/27	CLOSED	1	131	---	---	1	25.2	---	---
09/23, 25	CLOSED	2	119	55.2	80 – 158	2	24.9	26.8	5.9 – 43.8
10/23	OPEN	11	101	6.1	91 – 115	11	11.6	2.1	9.0 – 16.8

Growth – Redwood Creek Estuary – Summer/Fall 2003 (con't.)									
2003 DATE	MOUTH	FORK LENGTH (mm)				WEIGHT (g)			
		No. Measured	Mean	Std. Dev	Range	No. Weighed	Mean	Std. Dev	Range
JUVENILE STEELHEAD TROUT									
06/16, 17	OPEN	40	130	21.3	88 – 178	30	23.6	12.3	7.1 – 56.1
07/07, 10	OPEN	208	81	26.7	51 – 175	30	7.8	10.3	1.6 – 44.9
07/22	OPEN	212	87	21.9	61 – 172	30	5.1	2.4	2.4 – 15.2
08/11	CLOSED	206	100	30.6	57 – 193	30	15.4	13.7	4.1 – 51.3
08/27	CLOSED	108	128	33.3	70 – 189	30	24.5	17.9	5.2 – 60.8
09/22, 23	CLOSED	204	128	31.0	74 – 210	29	31.6	23.8	8.5 – 106.3
10/23	OPEN	206	138	29.9	82 – 223	30	29.9	22.6	7.9 – 107.7
CUTTHROAT TROUT									
06/16, 17	OPEN	---	---	---	---	---	---	---	---
07/07, 08, 10	OPEN	14	227	52.0	144 - 325	14	151.7	112.8	29.3 – 368
07/22	OPEN	4	263	61.2	209 – 339	4	251.1	183.8	101.8 – 482
08/11, 12, 14	CLOSED	12	275	73.7	150 – 392	12	285.6	209.2	36.4 – 688
08/27	CLOSED	7	317	43.3	227 – 356	7	422.3	148.0	130 – 574
09/22, 23, 25	CLOSED	19	306	53.1	227 – 395	16	404.3	168.1	144 – 698
10/23	OPEN	1	267	---	---	1	210	---	---
ADULT CHINOOK SALMON									
10/23	OPEN	3	508	41.8	475 – 555	2	2048	452.5	1728 – 2368
ADULT COHO SALMON									
10/23	OPEN	9	473	73.0	415 – 630	3	1199.3	347.6	1598 - 3598
Where number of length measurements is greater than the number of fish weighed, an electronic balance failure occurred.									

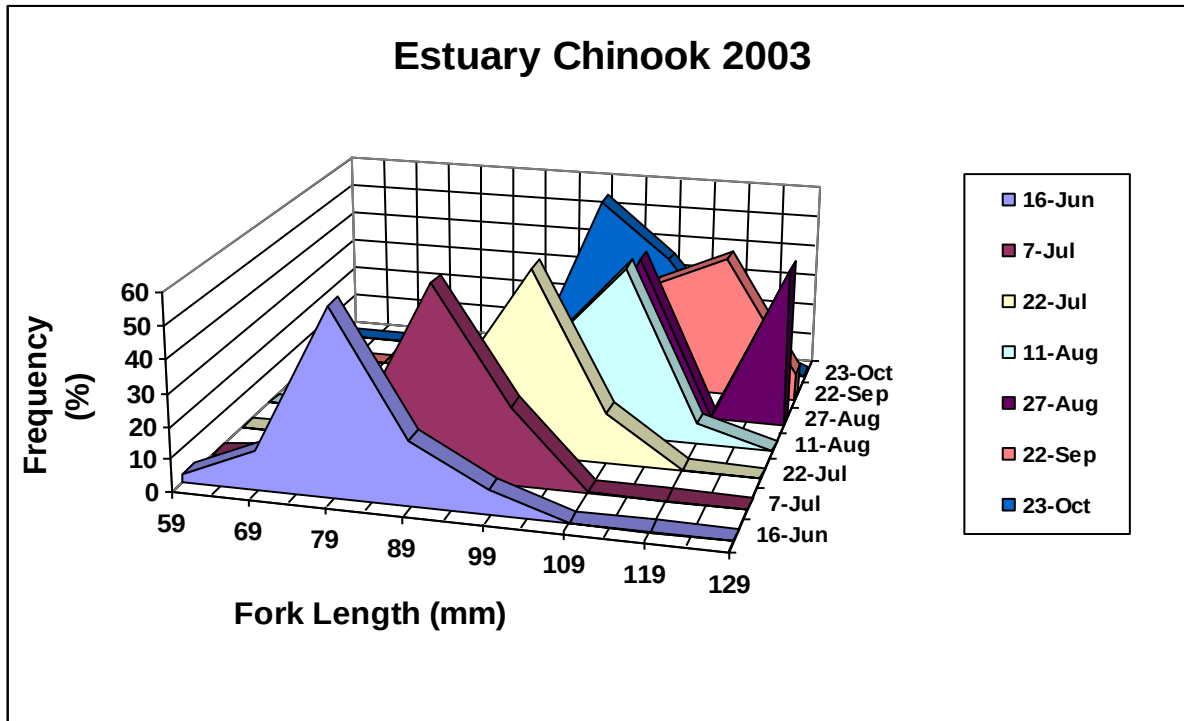


Figure 2. Fork length (mm) versus frequency (%) histogram of Redwood Creek estuary juvenile chinook sampled between June 16 and October 23, 2003. The fork length classes were 10-mm increments.

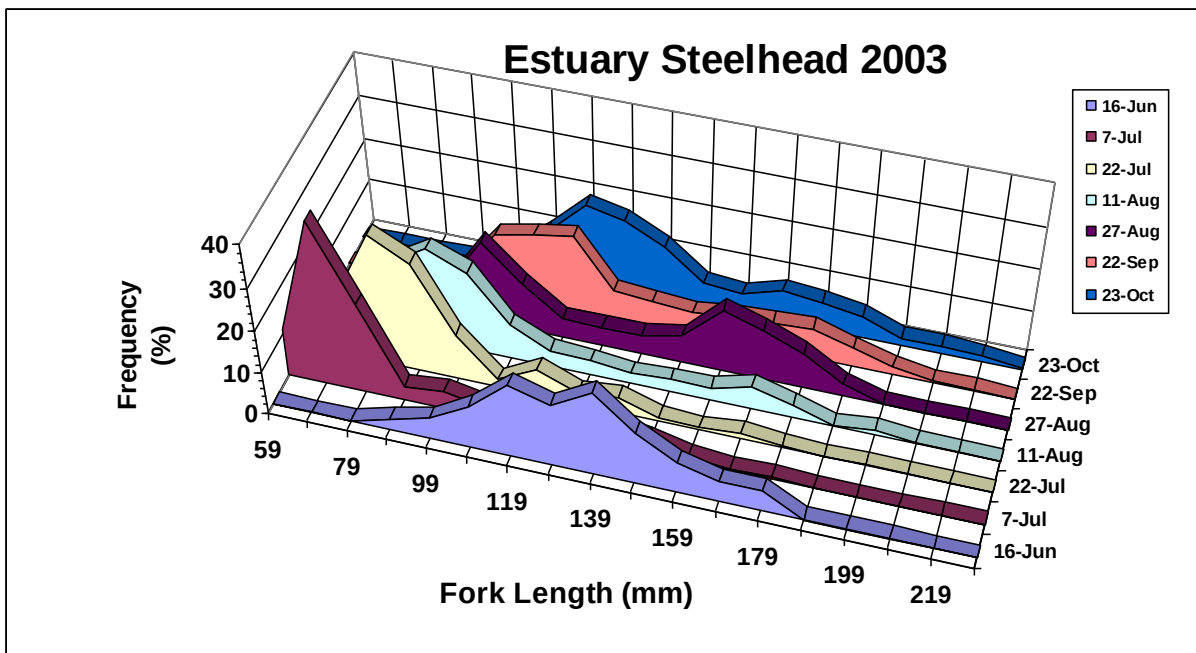


Figure 3. Fork length (mm) versus frequency (%) histogram of Redwood Creek estuary juvenile steelhead trout sampled between June 16 and October 23, 2003. The fork length classes were 10-mm increments. Several age classes are present.

Table 4. Mean condition factor (K'), sample size, standard deviation, minimum and maximum values of captured salmonids measured (fork length mm) and weighed (g) from the Redwood Creek embayment, Humboldt County, California, during the summer and fall of 2003. Condition factor is calculated as: $K' = 100W_{(g)}/FKL_{(cm)}^b$. Slope (b) was calculated as: $\log_{10} \text{Weight}_{(g)} = \log_{10} a + b \log_{10} \text{Fork Length}_{(cm)}$.

Condition Factor (K') - Redwood Creek Estuary 2003								
Date (week of)	6/16/2003	7/07/2003	7/22/2003	8/11/2003	8/27/2003	9/22/2003	10/23/2003	Summer/ Fall 2003
Chinook Salmon (b = 3.009)								
Mean	1.087	1.027	1.120	1.057	0.968	1.097	1.083	1.077
Count	29	30	30	30	2	30	11	162
Standard Deviation	0.086	0.064	0.055	0.0434	0.243	0.084	0.063	0.077
Minimum	0.818	0.955	1.027	0.959	0.797	0.929	0.975	0.797
Maximum	1.234	1.292	1.304	1.142	1.140	1.370	1.186	1.37
Coho Salmon (b = 2.856)								
Mean	---	1.517	---	1.429	1.622	1.602	1.550	1.542
Count	0	7	0	1	1	2	11	22
Standard Deviation	---	0.080	---	---	---	0.069	0.053	0.080
Minimum	---	1.434	---	1.429	1.622	1.554	1.488	1.429
Maximum	---	1.672	---	1.429	1.622	1.651	1.643	1.672
Steelhead Trout (b = 2.959)								
Mean	1.166	1.067	1.185	1.168	1.201	1.209	1.160	1.165
Count	30	30	30	30	30	29	30	209
Standard Deviation	0.195	0.229	0.075	0.048	0.116	0.078	0.052	0.137
Minimum	0.434	0.319	1.067	1.082	0.781	1.003	1.070	0.319
Maximum	1.375	1.423	1.367	1.258	1.402	1.350	1.322	1.421
Cutthroat Trout (b = 3.118)								
Mean	---	0.758	0.802	0.764	0.833	0.981	0.749	0.838
Count	0	14	4	12	7	16	1	54
Standard Deviation	---	0.070	0.087	0.077	0.069	0.589	---	0.333
Minimum	---	0.634	0.702	0.612	0.752	0.613	0.749	0.612
Maximum	---	0.875	0.910	0.891	0.921	2.759	0.749	2.759

Water Quality Monitoring

Water Temperature - In summer/fall 2003, water temperature (°C) was the only water quality parameter monitored in the Redwood Creek estuary. The TidBit temperature logger recorded water temperature every 1-hour from June 30 through October 30, 2003 (Figure 4). The maximum and minimum water temperatures were 22.1°C (on August 15 at 6pm) and 10.8°C (on October 11 at 12 noon, October 12 2am to 9am, and October 13 3am to 7am), respectively. The minimum water temperatures were associated with high tides when the mouth was open. The average water temperature for the period of was 16.8 °C. Maximum diurnal range was 6.2°C on June 30. The maximum weekly average temperature (MWAT) was 20.2°C.

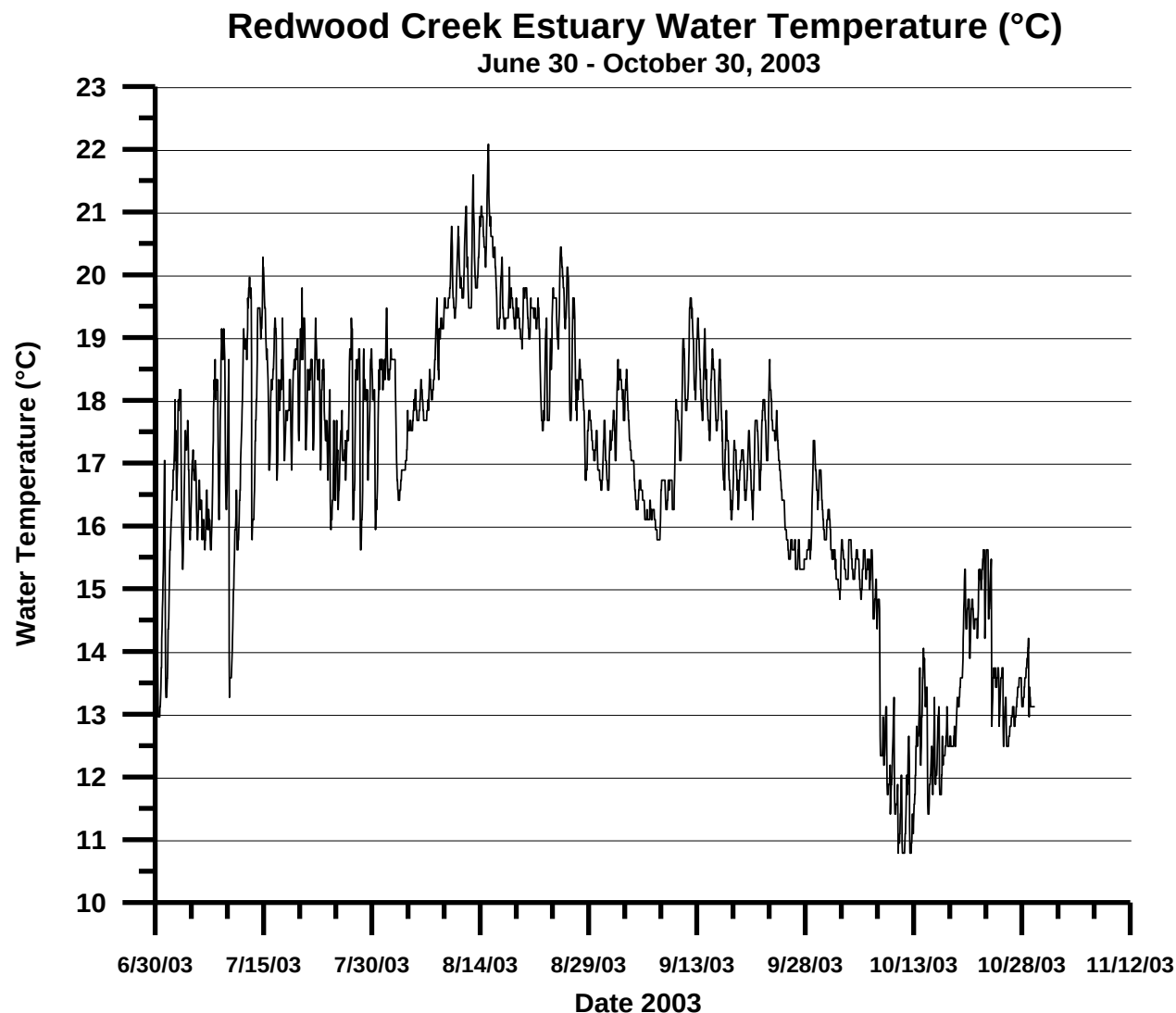


Figure 4. Redwood Creek estuary water temperatures (°C) measured by an Onset Tidbit temperature logger located in the embayment between the ends of the north and south flood control levees. The temperature logger, located one foot from the bottom, recorded water temperature every 1-hour from June 30 to October 30, 2003.

Tide and Stream Flow

Tides at the Mouth of Redwood Creek - The maximum and minimum calculated tide at the mouth was 5.07 ft MSL and -6.00 ft MSL, respectively, a range of 11.07 feet. Tidal data is included in Figure 5.

Stream Flow - Calendar year 2003 stream flow data, January 1 through December 31, is presented in Appendix II. The maximum flow was 17,100 cfs on December 13, 2003. The gage measured a minimum flow of 7 cfs during the last week of October. The flow data is provisional and subject to revision.

Estuary Water Level

South Slough and South Levee/Embayment Water Level Gaging

South slough water elevations (feet MSL) were recorded for the period January 1 to December 31, 2003 (Figure 5). The temporary south levee gage was installed on June 19 and removed on December 15. Due to data downloading problems and battery life, data was recorded from July 22 to September 11, September 18 to November 8, and November 17 to December 15, 2003.

The embayment site at the end of the south levee could measure lower embayment water elevations than the gage in the south slough. The lowest water levels in the south slough are limited by the invert of the south slough culvert gates and/or sand deposited in the south slough outlet channel. Based on south slough water elevation gaging data, with the south slough culverts open, the lowest south slough water elevation was limited to 2.7 ft MSL. With the culverts closed, the lowest south slough elevations was limited to 5 ft MSL prior to opening the culverts and after the closing the culverts. The culvert opening (invert) is lower than the natural south slough channel thalweg. The lowest embayment water elevation measured, 1.0 ft MSL, was 1.7 ft lower than that measured in the south slough (Figure 6).

Closure, Breaching and Estuary Response

Based on field notes, estuary photos, and recording water level gages in the south slough and embayment, the Redwood Creek estuary closed and breached twice during the summer and fall of 2003 (Figures 5 and 6). The estuary mouth closed on July 24, remained closed for 63.3 days, until opening on October 9. The mouth closed again on October 30, remained closed for 14.6 days, until opening on November 14, 2003. The estuary was closed for a total of 77.9 days.

July 24 Closure and October 9 Breach

The estuary first closed on July 24 at 4.8 ft MSL. On July 10th, the channel was to the south, two-thirds the distance to the visitor center, and on the 22nd, the channel was still to the south. The water elevation peaked at 7.1 ft MSL on August 7 and proceeded to decline, with a secondary peak at 6.3 ft MSL on September 12. It declined to about 4.6 ft MSL then spiked to 6.1 ft MSL and breached on October 9 at 1 am. The embayment water level bottomed out at 1.0 ft MSL, at 10:24 pm, a drop of 5.1 ft in 19.5 hours. There were no preceding flow or rain events. The Orick gage was reading 9-10 cfs that day and only 0.04 inches of precipitation had fallen the previous day. During a period of high seas, large ocean waves had washed over the berm causing the estuary to fill up, top over, and breach. The tide was 2.0 ft MSL at the time of the breach, decreasing from a high of 2.7 ft MSL at 11:30 pm that night.

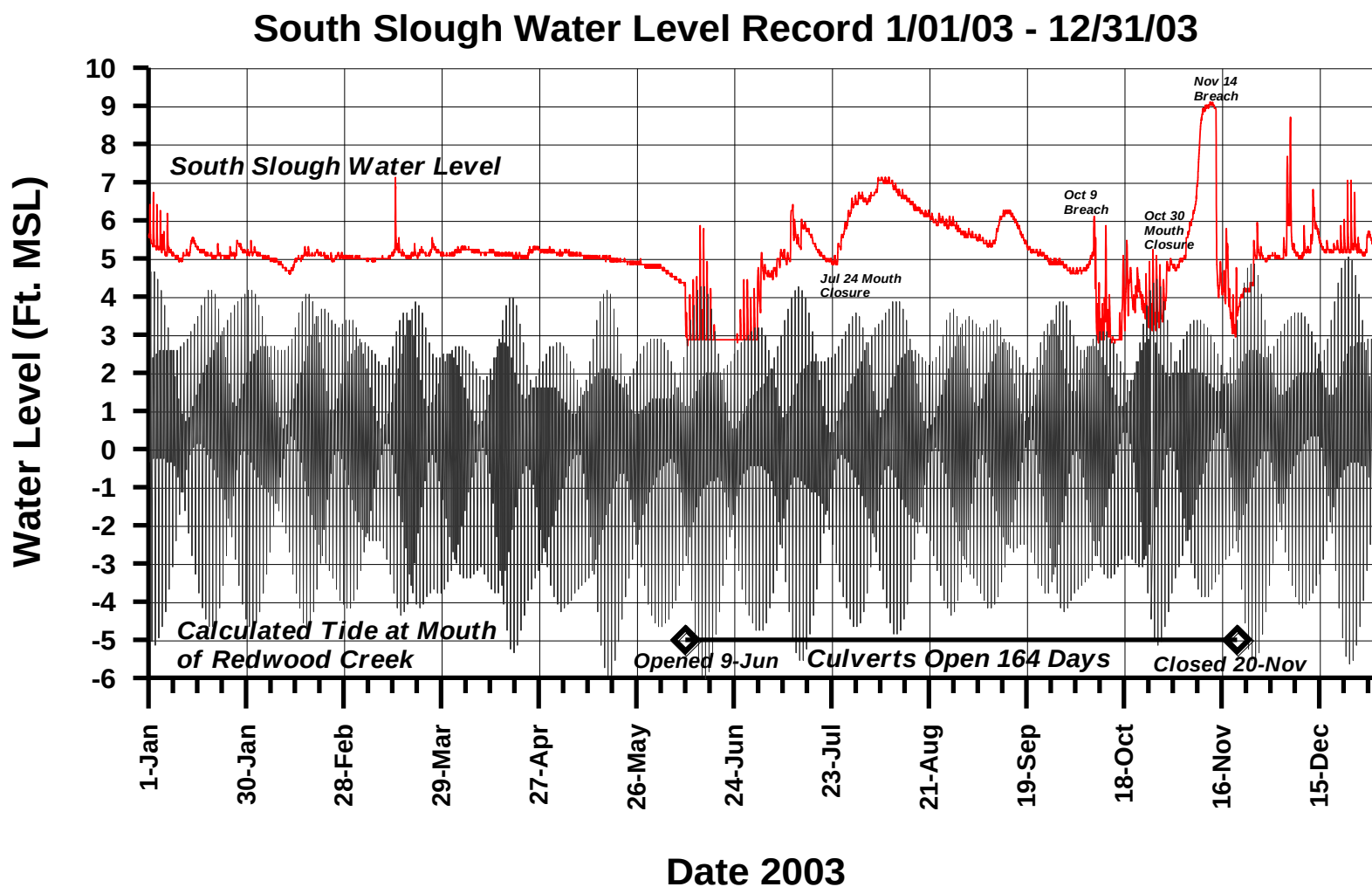


Figure 5. South slough water elevations (feet Mean Sea Level [MSL]) of the Redwood Creek estuary, Humboldt County for the period January 1 to December 31, 2003. Estimated ocean tidal elevations are corrected for the coastal locality at the mouth of Redwood Creek and adjusted to feet MSL

2003 South Slough Water / South Levee Embayment Water Level Record

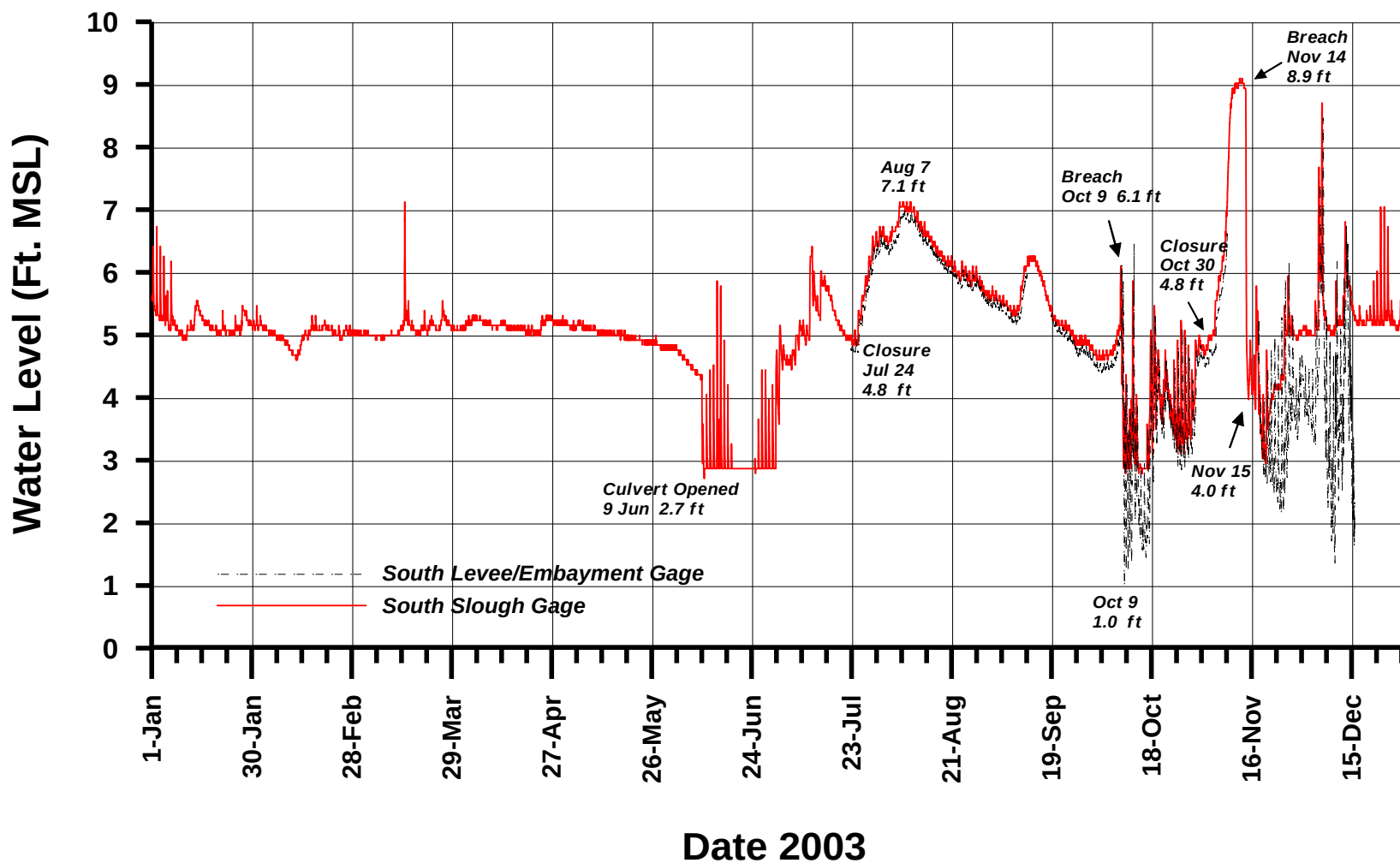


Figure 6. Water level elevations (ft. Mean Sea Level [MSL]) recorded in the south slough and at the end of the south levee of the embayment, Redwood Creek estuary, Humboldt County, California for calendar year 2003.

The tide decreased to -2.8 ft MSL at 6:10 am the morning of the breach. The estuary remained open another 21.5 days before closing on October 30.

October 30 Closure and November 14 Breach

The estuary closed on October 30 at 4.8 ft MSL and peaked at 9.1 ft on November 13, the highest recorded estuary water elevation for 2003. An unsuccessful illegal breach was attempted on November 12 (see next section). The estuary began to breach November 14 around 8 am at 8.9 ft MSL and initially bottomed out at 4.0 ft MSL the next morning, November 15 at 5 am., a 4.9 ft decrease in water elevation. The tide on November 14 at 8 am was 0.5 ft MSL, the high low tide. The Orick gage was reading 24 cfs when the breach occurred, but the gage had read 103 cfs on the 9th, and read 181 cfs on November 15 at 11 am. Between November 2 and 9, 2.84 inches of rain had fallen. This breach was caused by a river flow event filling up the estuary and causing it to top over the berm. The estuary remained open the rest of the year.

Illegal Breach Attempt

On November 12, a park employee alerted us to an illegal breaching attempt of the sand berm. Park fishery biologists responded along with a law enforcement ranger. No one was there when we arrived. The shovel dug channel, was already filled in with sand from wave overwash (Figure 7). The side cast sand mounds were shoveled into the remnant channel (Figure 8).



Figure 7. Remnant channel of an illegal estuary breaching attempt on November 12, 2003



Figure 8. Remnant channel from illegal breach attempt filled with the side cast sand and smoothed out. Note that the estuary water level on November 12 is above the tidal elevation and almost overtopping the berm. The estuary breached two days later on November 14, 2003.

South Slough Culvert Gates

The culvert gates are opened to increase circulation between the south slough and the embayment after the last storms of spring. On February 24, the culvert gates were checked after it was observed there was no surface water connection between the south slough and the embayment. The culvert gates under which water was flowing were completely closed by hand the next day by an additional half inch. Water stopped flowing through the culverts and water started flowing between the slough and embayment. A small rock weir in the middle culvert was also dismantled.

The three south slough culvert gates were opened on June 9. Water flowed out the culverts from the south slough into the embayment. The south slough water elevation dropped 1.42 ft, from 4.36 to 2.95 ft MSL in six hours. The gates were closed on November 20, 2003 to prevent sedimentation in the south slough from large flow events. The gates were open for 164 days (Figure 5).

Estuary Cross Sections

Four of the five permanent parallel cross-sections in the embayment, E-2 through E-5, were surveyed on July 23, 2003. Starting beyond the end of the levees with E-2 and ending to the west at E-5, the sea stack adjacent to the berm, the surveys extended south from the northside hill through the embayment to the sand dunes. Estuary cross sections, 1998 through 2003, are presented in Appendix III. The lowest substrate bottom elevation (i.e. deepest point MSL), at E-2 -2.59 ft MSL, at E-3 -3.25 ft MSL, at E-4 -2.79 ft MSL, and at E-5 -3.25 ft MSL. Based on the cross sectional data, at its

greatest closed mouth water elevation of 9.1 ft MSL, water depth at the deepest point surveyed in the embayment would be 12.35 ft deep. At its lowest closed mouth water elevation of 4.6 ft MSL, water depth at the deepest point surveyed would be 7.85 ft deep. At its lowest open mouth water elevation of 1.0 ft MSL, water depth at the deepest point surveyed would be 4.25 ft deep.

The net change (scour or fill) and total scour and total fill compared to the 2002 surveyed cross sections were as follows: E-2 +89.7 ft² (total scour -621.3 ft², total fill +711.0 ft²); E-3 +8.5 ft² (total scour -731.2 ft², total fill +769.7 ft²); E-4 -1,743.8 ft² (total scour -1,858.1 ft², total fill +114.4 ft²); and E-5 -2,635.8 ft² (total scour -2,635.8, total fill +0.0 ft²).

Other Activities

Redwood Creek Downstream Migrant Trapping

Mike Sparkman, of California Department of Fish and Game (CDFG) ran the downstream rotary migrant trap in Redwood Valley again in 2003. It ran from March 25 to August 9, 2003. The 0+ chinook population estimate calculated from 649 captured juveniles was 987 (95% CI 900 – 1,074) (Sparkman 2004). This is down from the 2000-2002 0+ chinook estimates that ranged from 378,063 to 518,189 juveniles migrating past the trap.

For the first time, a rotary migrant trap was located on lower Redwood Creek trap upstream of the Prairie Creek confluence. The trap was funded for \$25,000 by the CDFG Steelhead Report Card fund. It was run by US Fish and Wildlife Service – Arcata Office and the data is currently being analyzed by their fishery biologists.

Steelhead, 1+ and 2+, were marked with photonic dye at the upper trap by the USFWS crew. A total of 956 steelhead were marked with a variety of colors and fins between May 13 and July 22 (Appendix IV). Of a possible 11 marked steelhead that were recovered in the estuary, seven were probably marked at the upper trap (Appendix V). Data from all three monitoring projects, the estuary, upper and lower trap will be analyzed together.

North Slough Channel

A letter authorizing the removal of only woody debris blocking the drainage of the north slough was issued by the Corps in May 2002 (copy of letter in Anderson 2003) to Tom McNamara, adjacent landowner, for 5 years. He rented an excavator the first week of January and cleared a channel of LWD to allow water to again flow from the north slough unimpeded by driftwood dams. Mr. McNamara did additional work later in Spring using his backhoe (Figures 9, 10, and 11).

Moffatt and Nichol Engineers Setback Levees Modeling Report

The report, *Hydraulic analysis of alternative levee configurations for lower Redwood Creek, Humboldt County, California* was completed in April 2003 (Moffatt and Nichol Engineers 2003). The report determined current levee conditions and modeled six alternative levee configurations for lower Redwood Creek below the town of Orick at different flow occurrences 2-, 10-, 50-, 100-year and SPF flows. (Standard project flood defined as >200 year flood flow). Five of the six alternatives were different variations and widths of setback levees. A LIDAR survey was presented for the area. The modeling simulated inundation depths and extent of flooding, and sedimentation for each of the alternatives and existing levee condition.



Figure 9. North Slough outlet channel on March 31, 2003 after clearance of the channel of woody debris by adjacent landowner (looking north). Wood was moved to the banks of the channel to allow water to flow unimpeded. (RNSP)



Figure 10. Upper North slough outlet channel on May 1, 2003 looking north (RNSP).



Figure 11. North Slough outlet channel on May 1, 2003, looking south (RNSP).

The report was presented by Dr. Dilip Trivedi, the principle investigator, from Moffatt and Nichol Engineers to an interagency meeting in Arcata on June 10. Agencies present were the park, US Fish and Wildlife Service, NOAA-National Marine Fisheries Service, US Army Corps of Engineers, National Weather Service, California Coastal Conservancy, and Humboldt County. On the evening of October 1, a community meeting was held in Orick at the Orick Community Hall. Humboldt County Public Works and the Coastal Conservancy presented the alternatives in a meeting moderated by Humboldt County Supervisor Jill Geist. A second community meeting was held on December 2. Not all were in agreement with the alternatives presented. Some wanted the levees to remain the same and the causes of the diminished flood capacity, accumulated gravel and vegetation, removed to 1968 maintenance manual standards.

Humboldt County Levee Maintenance Army Corps Permit Application

The park partnered with Humboldt County's five year levee maintenance permit application to include excavation of the channels at the north and south slough necks to improve connectivity and slough drainage. The park provided language for possible affected species, excavation calculations, digitized aerials, and drawings of the proposed work needed for the permit application. The county would include the four foot deep channels in the permit and if and when approved, the park will do the work with its own equipment. The permit application was still undergoing consultation in 2003.

Estuary Poaching

From Redwood National and State Parks Management Team Notes:

November 23, 2003 – Ranger responded to a report of illegal fishing at the Mouth of Redwood Creek. Rangers contacted several juveniles within the area who all claimed to be out taking a walk and not fishing. Rangers discovered lying on the jetty/rocks freshly caught salmon and a number of fishing poles and gear. All individuals contacted by Rangers denied ownership or knowledge of the

poles/gear and salmon. All the fishing gear, including poles, gaff and tackle box with tackle along with two King Salmon were processed and stored as evidence.

The two fish, chinook salmon, were approximately 10lbs, 2' 3" in length, and 35lbs, 3' 3" in length. The fish were given to the Yurok Tribal food bank in Crescent City. A witness indicated that the suspects had been out there before, fishing and netting salmon.

Other

David Anderson gave an estuary restoration briefing at the estuary for the Pacific West regional director, Jon Jarvis, on May 15.

Additional 2003 estuary photos are in Appendix VI.

2003 Summary/Discussion

- Mean lengths and weights of chinook and steelhead increased during the summer. Fish that remained in the estuary to grow were larger than those that emigrated to the ocean prior to the July 24 closure. The remaining fish mean lengths were greater than 100mm. The larger size would confer an increased survival in the ocean (Reimers 1973).
- Estuary chinook populations were low in the beginning of the summer, 3,310 in July. The low numbers reflect overall low numbers trapped at the upper Redwood Creek downstream migrant trap and reflects a very poor chinook cohort for 2003. An estimated 987 0+ chinook passed by the upper trap in 2003 versus a range of 378,063 to 518,184 for years 2000 to 2002 (Sparkman 2004). It is thought that high flows in December 2002 may have scoured redds and/or negatively influenced egg survival.
 - The estuary chinook population decreased 68% from 3,310 in July to 1,050 in September.
 - The estuary steelhead population decreased 68% from 12,290 in July to 3,960 in September.
 - Though the number of juvenile chinook was low in the beginning of the summer, the final September population estimate for chinook remaining in the closed estuary (1,050) is similar to previous years. This suggests there is a carrying capacity for the estuary and conditions do not support large numbers of rearing juvenile chinook through the entire summer/fall season.
- Very few coho salmon juveniles reared in the estuary during the period of June 16 to October 23, 2003. We processed 22 coho juveniles out of a total of 6,354 juvenile salmonids counted, a percentage of 0.35%. This is similar to previous years (Anderson 1995).
- Water temperatures in the embayment were warm. The maximum temperature recorded was 22.1°C. The average water temperature for the period June 30 to October 30 was 16.8°C.

- The estuary closed late in 2003, and closed and breached twice. The estuary mouth closed on July 24, remained closed for 63.3 days, until opening on October 9. The first breach was the result of wave overwash filling the estuary. The mouth closed again on October 30, remained closed for 14.6 days, until opening on November 14, 2003. The second breach was the result of a rain caused flow event. The estuary was closed for a total of 77.9 days.
- An illegal breach using shovels was unsuccessfully attempted on November 12. Wave overwash filled most of the excavated channel with sand.
- Despite a coordination meeting among the three monitoring projects, particularly about dye colors and fish fin marking locations, the USFWS marking crew at the upper trap used blue and purple dye on fin locations of steelhead trout used by the estuary monitoring project. The steelhead, however were rarely picked up in the estuary and their effect on estuary population estimates is assumed to be negligible.

References

- Anderson, D.G. 1995. Biological supplement to Redwood National and State Parks U.S. Army Corps of Engineers Application: Coho salmon utilization of the Redwood Creek estuary. Research and Resources Management Division, Redwood National and State Parks, Orick, California. 13 pp.
- Anderson, D.G. 1999. 1998 Redwood Creek Estuary annual monitoring report. Fish and Wildlife Branch, Redwood National and State Parks, Orick, California. 47pp.
- Anderson, D.G. 2000. 1999 Redwood Creek Estuary annual monitoring report. Fish and Wildlife Branch, Redwood National and State Parks, Orick, California. 44pp.
- Anderson, D.G. 2001. 2000 Redwood Creek Estuary annual monitoring report. Fish and Wildlife Branch, Redwood National and State Parks, Orick, California. 45pp.
- Anderson, D.G. 2002. 2001 Redwood Creek Estuary annual monitoring report. Fish and Wildlife Branch, Redwood National and State Parks, Orick, California. 51pp.
- Anderson, D.G. 2003. 2002 Redwood Creek Estuary annual monitoring report. Fish and Wildlife Branch, Redwood National and State Parks, Orick, California. 54pp.
- Bagenal, T.B. and F.W. Tesch. 1978. Age and Growth. Pp. 101-136. In: Methods of assessment of fish production in fresh waters. Third Edition. T. Bagenal (ed.) Blackwell Scientific Publications, London. 365 pp.
- Hubbard, J.R. 1986. Memo: Time and height corrections for the entrance of Redwood Creek. NOAA – Tidal Datum Quality Assurance Section, Sea and Lake Level Branch. 2 pp.

- Moffat and Nichol Engineers. 2003. Hydraulic analysis of alternative levee configurations for lower Redwood Creek, Humboldt County, California. Prepared for Department of Public Works, County of Humboldt, Eureka, California by Moffat and Nichol Engineers, Walnut Creek, California, 94596. Funding provided by California Coastal Conservancy.
- Reimers, P.E. 1973. The length and residence of juvenile fall chinook salmon in Sixes River, Oregon. Research Reports of the Fish Commission of Oregon 4(2).
- Sparkman, M.D. 2004. Upper Redwood Creek juvenile salmonid downstream migration study, 2000-2003. CDFG AFRAMP Annual Report 2a5: 83pp.
- Youngs, W.D., and D.S. Robson. 1978. Estimation of population number and mortality rates. Pp. 137 - 164. In: Methods of assessment of fish production in fresh waters. Third Edition. T. Bagenal (ed.) Blackwell Scientific Publications, London. 365 pp.

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[03/2004]

Appendix I. Number of salmonid fish marked, marked recaptures, and total individuals captured in the second sample from the RNSP Redwood Creek estuary mark and recapture population estimates during the summer/fall of 2003. Fish fins, top and bottom caudal, and anal fins were marked with a Panjet needleless injector using Alcian Blue dye. Mark appearance ranged from a blue dot to a pigment streak along the fin rays. Formulas used to calculate population estimate and its 95% Confidence Interval.

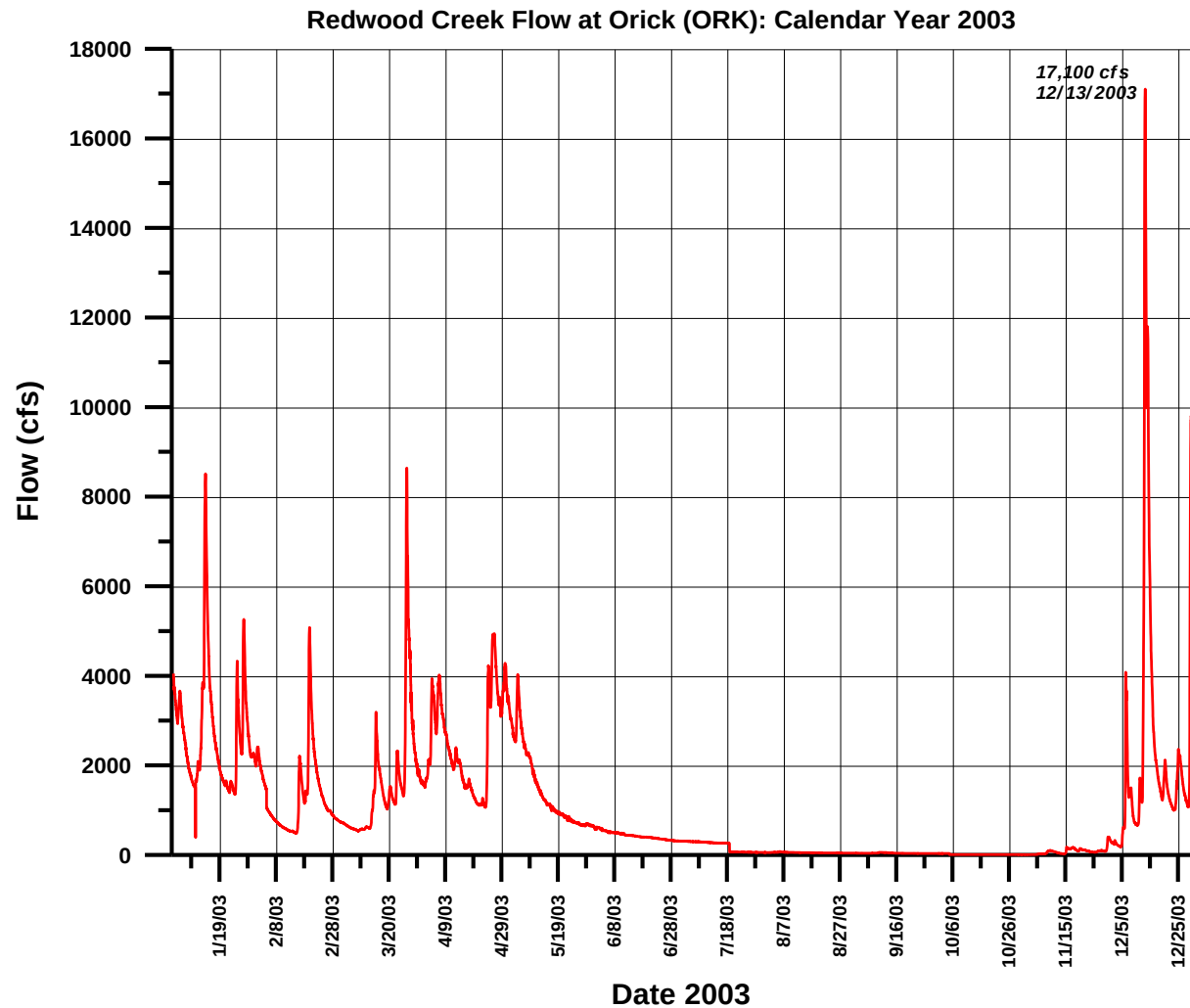
2003 Date		Number of Fish Marked ^a Marked Fish Recaptured ^b Total Fish Captured in Second Sample ^c				Panjet Fin Marks	
		Chinook	Coho	Steelhead	Cutthroat		
July 7 & 8	a	759	4	709	7	Top Caudal – All Fish	
July 10	b	82	0	66	2		
	c	358	3	1,144	9		
Aug 11 & 12	a	117	1	640	9	Bottom Caudal – All Fish	
Aug 14	b	0	0	7	2		
	c	5	0	130	5		
Aug 11	a	83					
Aug 12	b	1					
	c	36					
Sept 22 & 23	a	25	1	317	5	Blue Anal – All Fish	
Sept 25	b	1	0	37	1		
	c	42	1	462	15		

$$\text{Population Estimate (N)} = \frac{(\text{No. of fish marked}) \times (\text{total no. captured in second sample})}{(\text{No. of marked fish recaptured in second sample})}$$

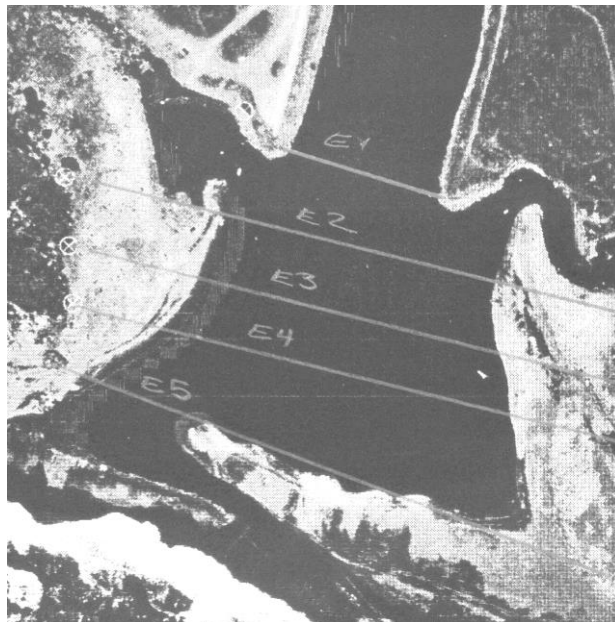
$$95\% \text{ CI} = \pm 1.96 \times \sqrt{\frac{(N^2) \times (N - \text{no. marked}) \times (N - \text{no. in second sample})}{(N - 1) (\text{No. marked}) \times (\text{no. in second sample})}}$$

-

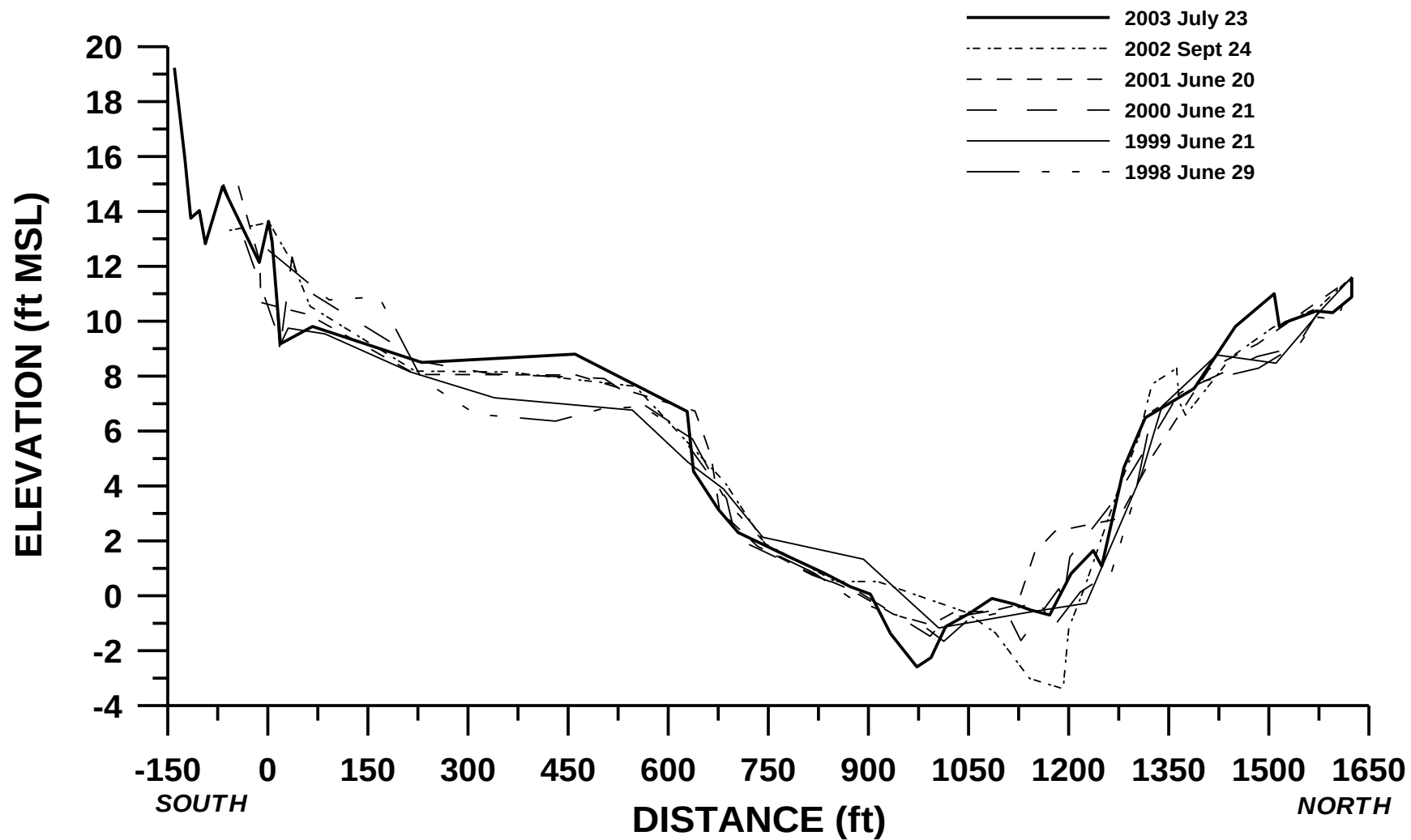
Appendix II. Hourly Redwood Creek flow data for calendar year 2001, January 1 through December 31, 2003. Data is from the California Department of Water Resources Orick (ORK) gaging station located on Redwood Creek downstream of the confluence of Prairie Creek and north of Orick, California.



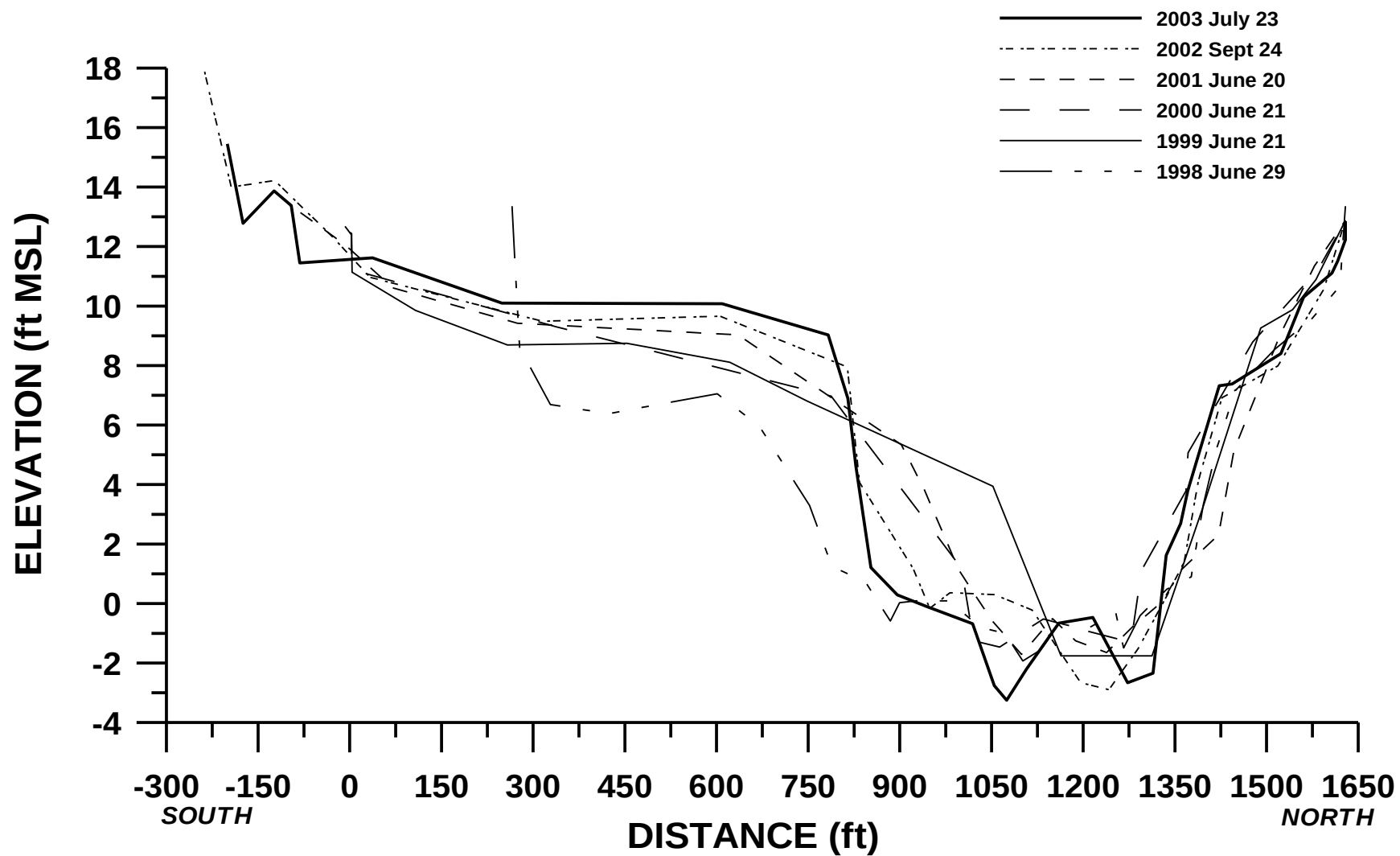
Appendix III. Four of the five permanent cross-sections (E-2 through E-5) surveyed on July 23, 2003 in the Redwood Creek estuary embayment perpendicular to the flow. Established in June of 1998, each cross section was shot at a bearing of 170° from the north endpoints through the embayment to the sand dunes on the south. The five parallel cross sections start between the ends of the levees with E-1 and end to the west with E-5 at the sea stack adjacent to the beach. Graphed with cross sections from 1998, 1999, 2000, 2001, and 2002 surveys (Anderson 1999, 2000, 2001, 2002, and 2003).



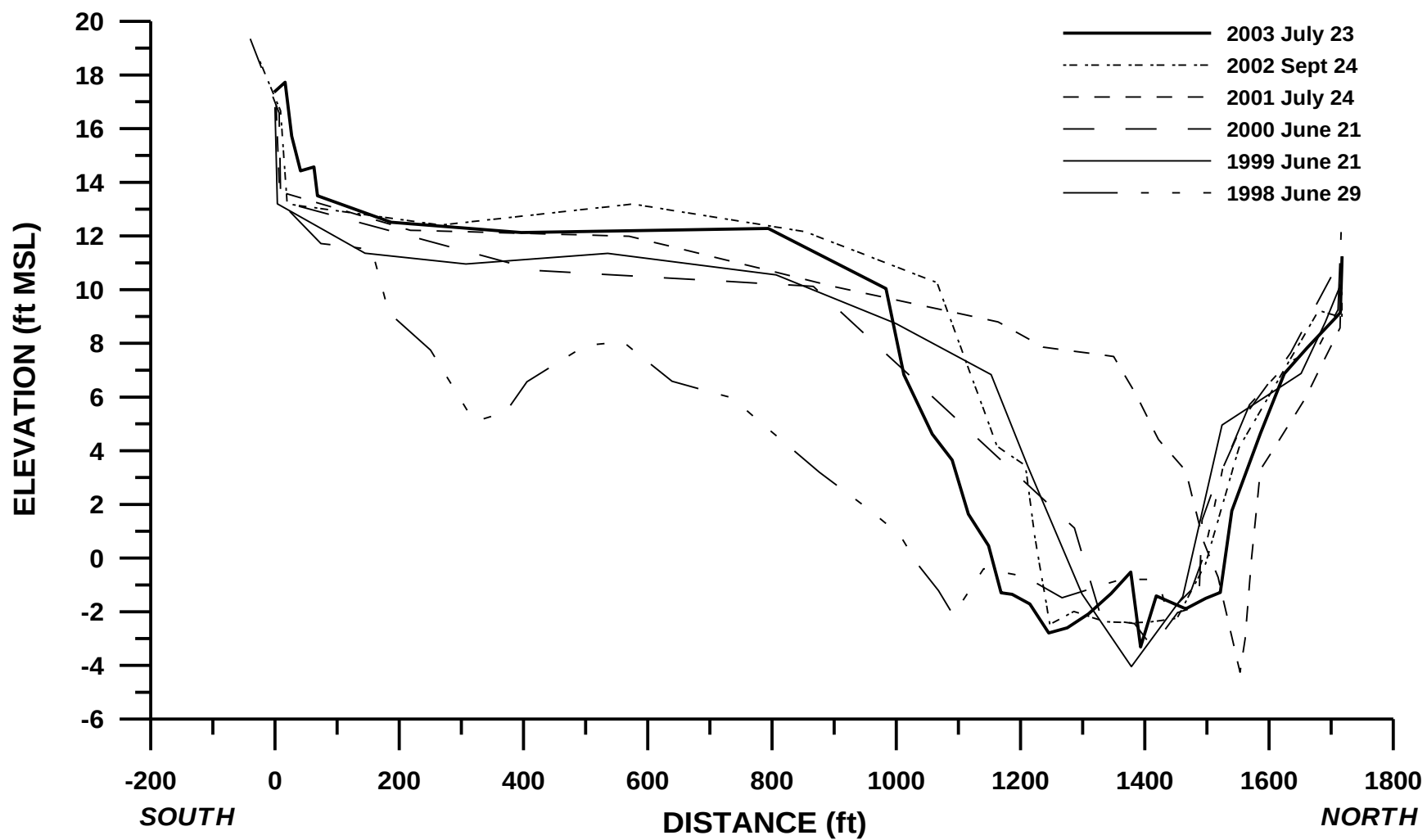
ESTUARY CROSS SECTION E-2



ESTUARY CROSS SECTION E-3

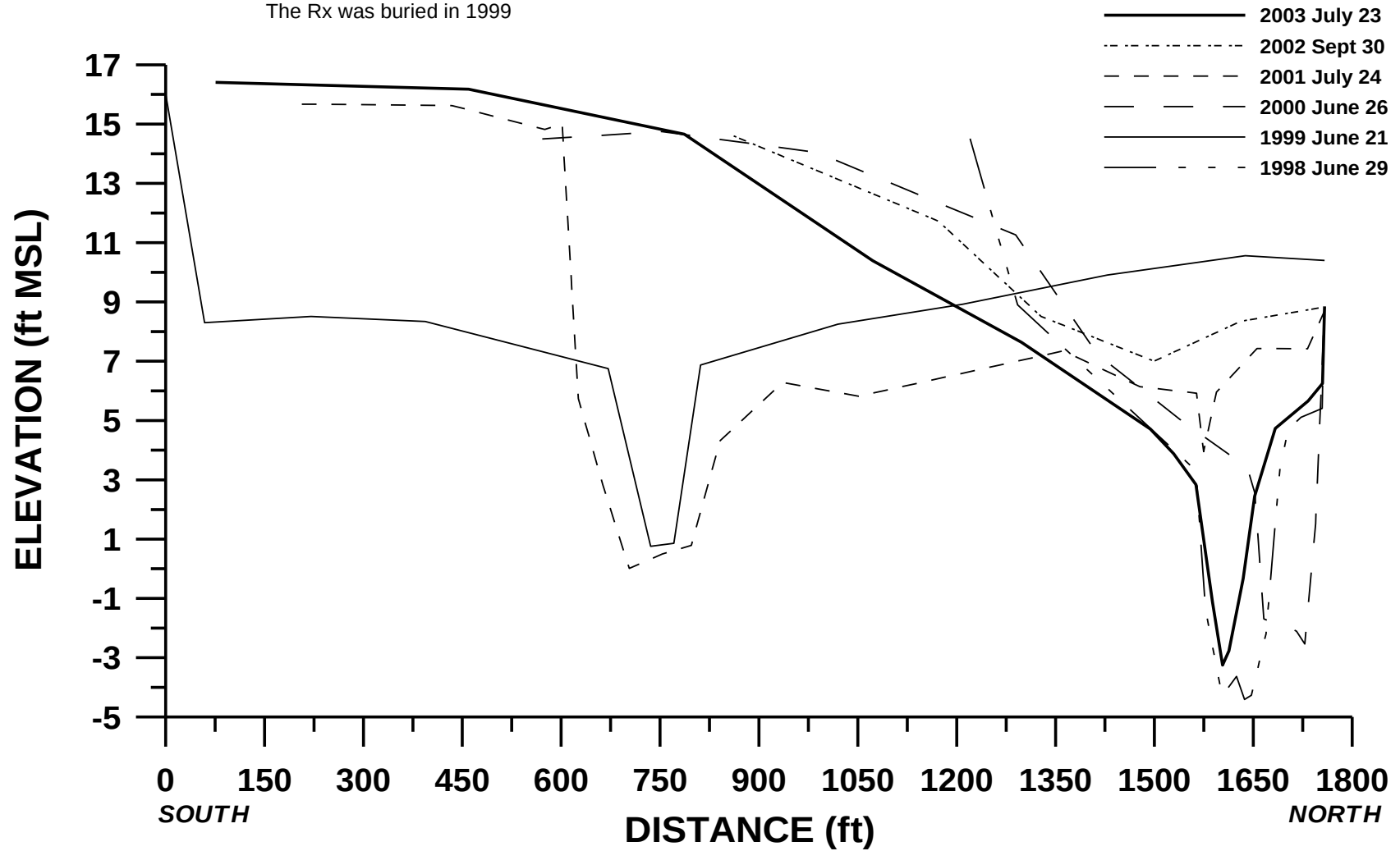


ESTUARY CROSS SECTION E-4



ESTUARY CROSS SECTION E-5

The Rx was buried in 1999



Appendix IV. List of 1+ and 2+ steelhead fish marked with photonic dye in Redwood Creek at the CDFG upper downstream migration trap in Redwood Valley during 2003.
(From B. Pinnix –USFWS Arcata).

List of Fish Marked with Photonic Dye in Redwood Creek
(All fish listed are steelhead 1+ or 2+)

5/13/03 Blue Upper Caudal (this is a light blue) 194 fish marked (1+)
 5/21/03 Pink Upper Caudal (a bright fluorescent pink) 277 marked (1+ and 2+)
 5/27/03 Purple Anal Fin (this is a light purple/violet color) 119 marked (1+ and 2+)
 6/03/03 Blue Anal Fin (again, light blue, marked at base of fin, usually shows up as a streak rather than a dot) 106 marked (1+ and 2+)
 6/10/03 Pink Anal Fin 80 marked (1+ and 2+)
 6/17/03 No fish marked (gun not working)
 6/24/03 Purple Upper Caudal 39 fish marked (1+ and 2+)
 7/1/03 Pink Upper Caudal (this should have been lower caudal, but a mistake was made) 36 fish marked (1+ only)
 7/8/03 Yellow Anal 52 Fish Marked (1+ only)
 7/15/03 Pink Lower Caudal 27 Fish Marked (1+ and 2+)
 7/22/03 Purple Anal (a darker purple than the above mark--true purple, not violet) 26 fish marked (1+ and 2+)

Appendix V. Number by date and fork length of marked steelhead from the upper CDFG down migrant trap seined in the Redwood Creek estuary during the summer/fall 2003 and total number of steelhead (all age classes) seined that day. (Note: to factor out the young-of-the-year fish from the total number of steelhead examined, percentage of age classes greater than 0+ would have to be determined from fork length frequency histograms for that day or week).

2003 Sample Dates	Steelhead Marks Observed	No.	Fork Length (mm)	No. marked/ Total examined
6/16/2003	None	0	---	0 / 30
6/17/2003	None	0	---	0 / 40
7/07/2003	None	0	---	0 / 227
7/08/2003	Pink upper caudal Purple upper caudal	1 1	92mm	2 / 452
7/10/2003	Pink upper caudal Blue anal Pink anal	1 1 1	114mm 117mm 144mm	3 / 1,144
7/22/2003	Middle caudal red?	1	---	1 / 786
8/11/2003	Yellow anal	1	124mm	1 / 479
8/12/2003	None	0	---	0 / 207
8/14/2003	None	0	---	0 / 130
8/27/2003	None	0	---	0 / 108
9/22/2003	Blue anal	1	160mm	1 / 175
9/23/2003	None	0	---	0 / 175
9/25/2003	Middle caudal blue?	2	---	2 / 462
10/23/2003	Orange left pelvic	1	159mm	1 / 206

Appendix VI. Selected photos of the Redwood Creek estuary in 2003.



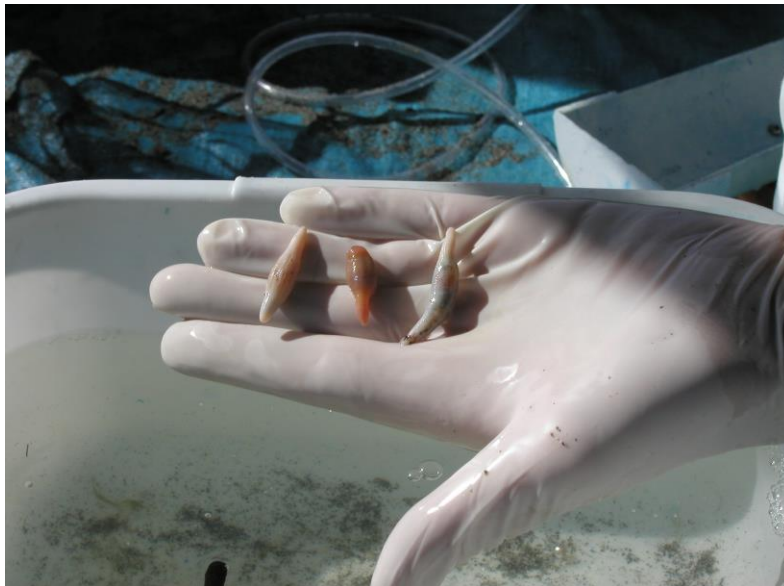
Aerial photo of Redwood Creek estuary and Orick Valley on May 19, 2003. (From the Marbled Murrelet Project, HSU/NPS).



Seine netting off the south levee in the Redwood Creek estuary, September 23, 2003 (RNSP).



Redwood Creek estuary and Orick Valley on December 3, 2003 (From Michael Sparkman-California Department of Fish and Game).



Peanut worms (Sipunculidae) seined from the Redwood Creek estuary on October 23, 2003 (RNSP).



Redwood Creek estuary with open mouth at low tide on June 19, 2003. A large mid-embayment gravel bar was exposed at low tide and water depths elsewhere in the estuary were very shallow (RNSP).



Redwood Creek estuary between the lower levees on June 19, 2003 (looking west). A large expanse of the gravel bar was exposed (RNSP).

2003 Acknowledgements

David Anderson, RNSP fishery biologist, led estuary monitoring in the field, analyzed data, and wrote the annual report. Others assisted, and/or contributed to the various estuary monitoring activities (e.g., seining, helping install or remove monitoring equipment, or surveying).

Estuary Biological Monitoring (seining)

Fish and Wildlife Branch: David Anderson, Baker Holden, Terry Hines, Ben Littlefield, Katie Moriarty, Beverly Shaw, Jeanne Mayer, Kyle Max, and Kristin Schmidt

Resource Management Labor Support Crew: Glen Fickbohm, Keith Richey, and Tim Tanno

Roads and Trails: Maureen Thompson, Chuck Webster, Tim Martinez, Jared Denatly, Lucas Hildebrand, and Austin Dalbo

Volunteer In the Park: Eveline Rodriguez, Vinnie Basso, and Steve Ecrement

CDFG: Mike Sparkman, Damon Zeller, Mike Gilmore, and Harrison Gauss

USGS-BRD: Chris Currens

HSU California Cooperative Fish Research Unit: Andrew

Fish Descriptive Statistics

Fish and Wildlife Branch: David Anderson

Estuary Water Level Monitoring

Geological Services: Carrie Jones (South Slough Data Collection and synthesis, gage maintenance).

Fish and Wildlife Branch: David Anderson (South Levee Data Collection and synthesis)

Installation or Removal of South Levee Water Elevation Recording Gage

Fish and Wildlife Branch: David Anderson, Terry Hines, Katie Moriarty

Estuary Survey of Berm and Embayment Cross Sections

Geological Services Branch: Vicki Ozaki and Carrie Jones

Fish and Wildlife Branch: David Anderson

Water Temperature Monitoring

Fish and Wildlife Branch: David Anderson, Kyle Max, Howard Sakai

Culverts Opening or Closing

Fish and Wildlife Branch: David Anderson, Terry Hines

Seine Net Repair

Fish and Wildlife Branch: Jeanne Mayer, Ben Littlefield, Beverly Shaw, Katie Moriarty