Redwood

National Park

National Park Service
US Department of the Interior

2013 Redwood Creek Estuary Monitoring

Fish and Wildlife Branch
June 2016

Cover: (Summer/Fall 2013 RNP Photos) clockwise from top left
Captured Chinook and coho salmon in live cart
Gulls roosting on the Redwood Creek estuary sand berm
Southward flowing outlet channel of Redwood Creek mouth.
Processing (marking, measuring, scanning, weighing) captured fish.
Coastal Cutthroat Trout seined from Redwood Creek Estuary
Seining Crew.

Back Cover
Redwood Creek mouth open to the ocean after breaching the morning of September 23, 2013.

Table of Contents

2013 Estuary Monitoring Summary vii
Introduction 1
Location 1
Methods 1
Fish Monitoring 1
Population Estimates 1
Growth Estimates 2
Condition Factor (K') 3
PIT Tagged Fish 3
FishTrapping in Kuchel Visitor Center Wetland Channels 3
Physical Monitoring 4
Water Temperature 4
Embayment Water Level Gaging 4
Tide, Ocean Waves, Stream Flow, and Precipitation 4
Estuary Cross-sections 4
2013 Results 5
Fish Monitoring 5
Sampling Dates 5
Fish Presence 5
Other Species 5
Population Estimates 8
Chinook Salmon 8
Coho Salmon 8
Steelhead Trout 8
Coastal Cutthroat Trout 8
Growth Estimates 10
Chinook Salmon 10
Coho Salmon 12

Steelhead Trout 12
Coastal Cutthroat Trout 12
Condition Factor (K') 14
PIT Tagged Fish 14
KVC Wetland Fish Trapping 14
Physical Monitoring 17
Water Temperature 17
Tides at the Mouth of Redwood Creek 18
Stream Flow 18
Ocean Wave Height 19
Illegal Breach Attempt 19
Embayment Water Level Gaging 20
Closure, Breaching and Estuary Response 20
June 8 Closure and June 9 Breach 20
June 25 Closure and June 27 Breach 23
July 4 Closure and July 8 Breach 23
July 18 Closure and September 23 Breach 23
Estuary Cross-sections 25
Estuary Volume 25
South Slough Culvert Gates 25
CDFW Redwood and Prairie Creek Downstream Migrant Trapping 25
Population Abundance 25
Growth 26
References 28
Acknowledgements 29
Appendix I. Number of salmonid fish marked, marked recaptures, total individuals captured in the second sample, and total number of seines from the RNP Redwood Creek estuary mark and recapture population estimates during the Summer of 2013. Fish fin locations: top, middle, and bottom caudal, and anal fin marked with a Panjet needleless injector using Alcian Blue dye. Formulas used to calculate population estimate and its 95% confidence interval. 30

Appendix II. Tides (ft. MSL) calculated at the mouth of Redwood Creek for calendar year 2013 31

Appendix III. Redwood Creek flow (cfs) at Orick for calendar year 2013. 32

Appendix IV. Ocean wave heights (ft) measured hourly at St. Georges Buoy 46027 located 8 nm NW of Crescent City, California for 2013. 33

Appendix V. Five permanent cross-sections (E-1 through E-5) surveyed June 5, 2013 in the Redwood Creek estuary embayment perpendicular to the channel. Established in 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 at the west with E-5 at the sea stack adjacent to the beach. 5

Appendix VI. Calculated volume (ft^3) of the Redwood Creek embayment at water elevations of –3 to 11 ft MSL based on the five cross sections E-1 through E-5 surveyed on June 5, 2013 (left). Volume of embayment is defined as the area west of the ends of the north and south levee and not including the north or south outlet channels or sloughs. Embayment water elevation versus volume (right). 40

Appendix VII. Photographs of 2013 Redwood Creek Estuary Monitoring. 41

List of Figures

Figure 1. Redwood Creek Estuary, Humboldt County, California, including the embayment, north and south sloughs, levees, south levee gated culverts, and southward flowing outlet channel to ocean (Google Earth June 6, 2013). 2

Figure 2. Fish trapping locations in the wetlands adjacent to the Kuchel Visitor Center (left) and South Slough (top) (Google Earth June 6, 2013) 3

Figure 3. Fork length (mm) versus frequency (%) histogram of Redwood Creek estuary juvenile chinook salmon seined June 3 through September 19, 2013. Fork length intervals were 10-mm increments. 10

Figure 4. Fork length (mm) histogram of Redwood Creek estuary juvenile coho salmon captured June 3, 4, 6, and August 22, 2013. 12

Figure 5. Fork length (mm) versus frequency (%) histogram of Redwood Creek estuary juvenile steelhead seined June 3 through September 19, 2013. Fork length intervals were 10-mm increments 13

Figure 6. Fork length (mm) versus frequency (%) of Redwood Creek estuary coastal cutthroat trout seined June 4 through September 19, 2013. Fork length intervals are 10-mm increments. 13

Figure 7. Boardwalk channel with beaver dam in KVC wetland (RNP photo September 24, 2013). 14

Figure 8. Redwood Creek estuary water temperatures (°C) measured by an Onset Tidbit temperature logger located in the embayment beyond the ends of the north and south levees. The temperature logger, located one foot above the bottom, recorded water temperature every hour from June 1 to October 28, 2013. 17

Figure 9. Redwood Creek flow (cfs) at Orick for May 30 to November 26, 2013 18

Figure 10. Illegal estuary breach attempt August 19, 2013; looking toward the estuary (left); looking toward the ocean (right). Person in ditch is on their knees. (RNP photo) 19

Figure 11. Ditch filled in from sides on August 19 (left) and results of wave overwash filling in more of the ditch with sand overnight on August 20, 2013. (RNP photo) 20

Figure 12. Water level elevations (ft Mean Sea Level [MSL]) recorded in the Redwood Creek estuary, Humboldt County, California for May 30 to November 18, 2013. 21

Figure 13. Redwood Creek estuary water levels and tides at the mouth of Redwood Creek May 30 to November 18, 2013. 22

Figure 14. Ocean wave heights (ft) measured hourly at Buoy 4627 located 8 nm NW of Crescent City, California and the wave heights at Redwood Creek closure and breaching occurrences for May 30 to November 26, 2013. 23

Figure 15. Mouth of Redwood Creek closed to the ocean, the end of the outlet channel filled in with sand from wave overwash, July 23, 2013 (RNP photo). 24

List of Tables

Table 1. List of salmonid and non-salmonid fish seined, birds, amphibians, mammals, invertebrates, and others observed at and adjacent to the Redwood Creek estuary, Redwood National and State Parks, Humboldt County, California during the summer 2013 fish sampling (Shading denotes presence). 6

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 2013.

Mouth of creek denotes if Redwood Creek mouth was open or closed to the Pacific Ocean during the estimate. 9

Table 3. Mean fork length (mm), mean weight (g), standard deviation, range, dates, and numbers sampled of juvenile chinook and coho salmon; and steelhead, coastal cutthroat seined in the Redwood Creek estuary embayment, Humboldt County, California, during summer of 2013 from June 03 to September 19. Mouth denotes if Redwood Creek mouth was open or closed to the ocean. 11

Table 4. Mean condition factor (K'), sample size, standard deviation, minimum and maximum values of captured salmonids measured (fork length cm) and weighed (g) from the Redwood Creek embayment, Humboldt County, California, during the Summer of 2013. Condition factor is calculated as: $K' = 100W_{(g)} / FKL_{(cm)}^{b}$. Slope (b) was calculated as: $\log_{10}$ Weight $_{(g)} = \log_{10} a + b \log_{10}$ Fork Length $_{(cm)}$. 15

Table 5. CDFW PIT tagged fish recaptured in the Redwood Creek estuary in 2013. 16

Table 6. Estimated population, peak monthly migration and percentage of population, and peak week of juvenile salmon and steelhead, and cutthroat trout migration from CDFW downstream migrant rotary screw trapping on Lower Redwood Creek and the at the mouth of Prairie Creek, 2013. 26

Table 7. Seasonal mean fork length (mm) and weights (g) from downstream salmonids measured at the CDFW downstream migrant rotary screw traps at lower Redwood Creek and mouth of Prairie Creek (From Sparkman, et al. 2014a and 2014b). 27

2013 Estuary Monitoring Summary

The Redwood Creek estuary was monitored in summer/fall 2013. Four combined salmonid population and growth estimates were conducted the weeks of June 3, July 8, August 19, and September 16. Embayment water elevations were monitored from May 30 to November 18. Water temperature (°C) was measured hourly in the embayment from June 1 through October 28. Estuary cross sections were surveyed on June 5.

- Four salmonid species were captured during estuary seining: chinook and coho salmon, and steelhead and coastal cutthroat trout. Eight other fish, three amphibians, 67 bird species, and eight invertebrates were captured or observed in the estuary.

- Estimated estuary juvenile chinook and steelhead populations peaked in July and decreased through the summer.
    - There was a 97% decrease decrease in estimated chinook abundance between July and September, from 106,650 to 2,920.
    - Between July and September, estimated steelhead abundance decreased 84%, from 11,580 to 1,890. Only 54 steelhead were caught in June.
    - 141 Coho smolts were caught in June and one in August. None were captured in July and September.
    - At total of 23 coastal cutthroat were captured in June, July, and September.

- Mean fork length of chinook and cutthroat increased during the summer. Fish that remained in the estuary were larger than those that emigrated to the ocean prior to the July 18th closure.
    - Mean chinook fork length increased from 60 to 85 mm, a 25 mm increase between the weeks of June 3 and September 16.
    - Mean cutthroat fork length increased from 241 to 321 mm between the weeks of June 3 and September 16.
    - Mean coho fork length the week of June 3 was 109 mm and the one fish caught on August 22 was 115 mm.
    - Mean steelhead fork length did not follow an increased growth trend with time, the smallest mean in August at 108 mm and the largest in July at 125 mm.

- Water temperatures were warm. The maximum and minimum temperatures measured between June 1 and October 28 were 21.6°C and 9.6°C, the average water temperature was 16.6°C.
    - August (18.4°C mean) and September (17.8°C mean) were the warmest months of the summer.
    - Water temperature was equal or greater than 18.0°C 42 percent of the time for July and August.
    - Maximum weekly average temperature (MWAT) was 19.6°C and maximum weekly maximum temperature (MWMT) was 20.3°C for July and August.

- The Redwood Creek estuary closed and breached four times during the summer. It remained closed for a total of 71.6 days.
    - It first closed on June 8 and breached on June 9, and was closed for 0.6 days.
    - It closed a second time on June 25 and breached on June 27, closed for 1.2 days.
    - It closed a third time on July 4 and breached on July 8, closed for 3.3 days.
    - It closed on July 18 and breached on September 23 and was closed for 66.5 days.
        - The berm breached at a height of 7.2 ft at 6:45 am, a combination of stream flow and wave overwash causing the estuary to fill with water.
        - The average water elevation during the 66.5 day closure was 5.2 ft MSL.

- An illegal estuary breach attempt was discovered the morning of August 19, but was unsuccessful. Mean water elevation at the time was 5.0 ft MSL, an elevation where adjacent roads or fields are not inundated.

Redwood Creek estuary embayment water elevation gage near end of south levee, November 18, 2013 (RNP photo).

Processing captured seined fish – marking, measuring, weighing, and scanning in the 'coho cabana' at the Redwood Creek estuary on July 9, 2013 (RNP photo).

2013 Redwood Creek Estuary Monitoring

Introduction

This report summarizes 2013 Redwood National Park Fish and Wildlife Branch biological and physical monitoring activities in the Redwood Creek estuary. Monitoring has occurred in the Redwood Creek estuary since 1980. The purpose of the estuary monitoring is to estimate fish population numbers and growth; record estuary water quality and water elevations; document breaching incidents; and determine cross section changes.

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 watershed is 720 km^2 in area. The 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 historically the last meander of Redwood Creek. It was cut off by the south levee. Gated culverts through the south levee now connect the slough and creek when the gates are open.

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 estuary embayment. Fish were seined with a 150-foot long, 16-foot wide, quarter inch knotless mesh beach seine net deployed off the bow of a 16-foot boat powered by a 15 hp outboard motor. Seining occurred downstream of the south levee culverts in the embayment along the sand banks and berm and north and south levee rip rap. A blue mark was applied to the upper, middle, or lower caudal fin or anal fin of MS-222 anesthetized fish using a Panjet needleless injector and Alcian Blue dye. Mark appearance ranged from a blue dot to a pigment streak along a fin ray. 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 conducted, one each in June, July, August, and September during summer 2013.

Growth Estimates – Fish fork lengths were measured to the nearest 1 mm. Though not always possible, 200 fork lengths each of chinook salmon (*Oncorhynchus tshawytscha*) and steelhead trout (*O. mykiss*), and wet weight (g) from 30 juveniles of each species were measured. Two electronic balances were used, a 200 g ± 0.01g capacity balance for smaller fish, and a 5,000 g ± 2g capacity balance for larger fish. Fish weights were rounded off to the nearest 0.1g for the smaller capacity balance. Other salmonid species, coastal cutthroat trout (*O. clarki*) and coho salmon (*O. kisutch*), though not as numerous, were measured and weighed. Non-salmonids were also measured (total length). Four growth estimates were conducted in conjunction with the population estimates.

Figure 1. Redwood Creek Estuary, Humboldt County, California, including the embayment, north and south sloughs, levees, south levee gated culverts, and southward flowing outlet channel to ocean (Google Earth June 6, 2013).

Condition Factor (K')- 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: $K' = (100 \times \text{Weight}_{(g)})/\text{Fork Length}_{(cm)}^{b}$ (Bagenal and Tesch 1978). Slope (b) was calculated as: $\log_{10} \text{Weight}_{(g)} = \log_{10} a + b \log_{10} \text{Fork Length}_{(cm)}$.

PIT Tagged Fish – Some fish trapped at the two California Department of Fish and Wildlife (CDFW) downstream migrant traps on mainstem Redwood Creek (River mile 4.2 and 33) are tagged with passive integrated transponders (PIT) tags. Each tag has an individual unique number and is implanted in the body cavity of the fish. During the processing of estuary seined fish, a PIT tag reader is used to scan every fish.

Fish Trapping in Kuchel Visitor Center Wetland Channels – Two slough channels draining into the South Slough in the vicinity of the Kuchel Visitor Center (KVC) were trapped with roe baited minnow traps (Figure 2). Traps were placed in the channel where it was not covered with vegetation and were soaked for approximately 3.5 to 4 hours before retrieving them. One channel termed the 'boardwalk channel' is near the wood boardwalk and observation deck (UTM 408799E 4571290N). The second, termed the 'east channel' was east of the line of trees (UTM 408863E 4571198N).

Figure 2. Fish trapping locations in the wetlands adjacent to the Kuchel Visitor Center (left) and South Slough (top) (Google Earth June 6, 2013)

Physical Monitoring

Water Temperature - In Summer/Fall 2013, water temperature (°C) was measured hourly in the Redwood Creek embayment with an Onset TIDBIT temperature logger (S/N 1154748). It was located in the Redwood Creek channel beyond the ends of the north and south flood control levees (UTM 408793E 4571704N NAD83). The logger, anchored to a large cinder block, was suspended in the water column about one foot off the bottom.

Embayment Water Level Gaging – Estuaries are dynamic, with interactions between ocean, coastal, stream, and floodplain processes that influence estuary volume, creek mouth location, opening and closing of the mouth, and flooding in the lower valley. Redwood Creek embayment water elevation, feet Mean Sea Level (ft MSL), was determined using a ventless U20 Onset water level data logger (SN 9673046) that recorded water depth every 15 minutes inside a perforated steel pipe driven into the channel thalweg near the end of the south levee. The estuary data logger is a temporary gaging station installed when the creek mouth is open and retrieved after the estuary breaches and before large flow events can bury the pipe. A second water level data logger located 1.6 miles away at RNP South Operations Center, measured atmospheric barometric pressure for corrections to the water depth data. Conversion from water depth to water elevation feet MSL is done using surveyed water level elevations when the estuary cross sections are surveyed.

The embayment gage site at the end of the south levee measures lower embayment water elevations than in the south slough. The lowest water levels in the south slough are limited by the invert of the south slough culvert gates and sand deposited in the south slough outlet channel.

Tide, Ocean Waves, Stream Flow, and Precipitation – Tide at the mouth of Redwood Creek is determined using verified tide data downloaded from the Crescent City gage located in the harbor (http://tidesandcurrents.noaa.gov/) and corrected for the Redwood Creek ocean location (Hubbard, J.R., 1986). Hourly ocean wave height (ft) was determined using downloaded data from St. Georges NOAA buoy 46027 located 8 nm NW of Crescent City (http://www.wrh.noaa.gov/eka/marine/buoys.php). Redwood Creek stream flow (cfs) for the calendar year was downloaded from the California Department of Water Resources (DWR) California Data Exchange Center (http://cdec.water.ca.gov/queryTools.html). The DWR/USGS operated Orick (ORK) station is located in lower Redwood Creek, 3.7 miles upstream of the mouth of Redwood Creek at the northern end of the town of Orick. A tipping bucket measures precipitation (inches) at the station.

Estuary Cross-sections - Five permanent cross-sections, E-1 through E-5, located in the estuary embayment perpendicular to the channel are surveyed during the summer. 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 on the beach. Established in 1998, the cross-sections are shot with a Nikon Total Station and prism rod at a bearing of 170° from the north endpoints through the embayment to the back dunes to the south. The elevations are converted to feet MSL using a BLM reference monument located adjacent to the north levee at the park boundary.

2013 Results

Fish Monitoring

Sampling Dates – The Redwood Creek estuary embayment was sampled four weeks during the summer of 2013 for population and growth estimates. Sample dates were June 3, 4, and 6; July 8, 9, and 11; August 19, 20, and 22; and September 16, 17, and 19, 2013. A planned growth estimate for October was cancelled when the mouth breached in late September.

Seines and Fish Handled - The total number of estuary seine hauls in 2013 was 55. The numbers of salmonid fish processed during estuary monitoring were 7,115 juvenile chinook (74 incidental mortalities, 1.04%), 1,079 steelhead (3 incidental mortality, 0.28%), 145 coho smolts (0 incidental mortality), and 23 coastal cutthroat (0 incidental mortality) for a total of 8,362 fish and 77 incidental mortalities (0.92%). Authorization for handling threatened fish was under Redwood National Park's 4(d) NOAA/CDFW permit #17558 and CDFW Scientific Collecting Permit #SC-10028.

Fish Presence – During the summer of 2013 four salmonid species were seined in the Redwood Creek embayment; chinook and coho salmon, and steelhead and coastal cutthroat trout (Table 1). Juvenile chinook and steelhead were present on all sample dates between June 3 and September 19. Coho salmon were captured on all three days in June and one on August 22. Coastal cutthroat were captured in June, July, and September.

In addition to the juvenile salmonids and adult cutthroat captured, eight additional fish species were captured; Staghorn Sculpin **(***Leptocottus armatus*), Prickly Sculpin (*Cottus asper*), Coastrange Sculpin (*Cottus aleuticus*), Threespine Stickleback (*Gasterosteus aculeatus*), Sacramento Sucker (*Catostomus occidentalis*), Starry Flounder (*Platichthys sellatus*), Shiner Surfperch (*Cymatogaster aggregata*) and Surfsmelt (*Hypomesus pretiosus*). Surfsmelt presence, a marine species, was due to the mouth of the creek being open to the ocean.

Of the fish captured, chinook (California Coastal Chinook Salmon ESU), coho (Southern Oregon/Northern California Coast Coho ESU), and steelhead (Northern California Steelhead DPS) are federally listed as threatened. No endangered tidewater goby (*Eucyclogobius newberryi*) were captured during estuary seining in 2013. They are no longer present and are considered extirpated.

Other Species - Other non-fish species were caught: *Corophium*, *Gnorimosphaeroma*, Dungeness crab (*Metacarcinus magister* formerly *Cancer magister*), Gammarus amphipods, Mysid shrimp, invasive New Zealand Mud Snails (*Potamopyrgus antipodarum*), Limniphilid stonecase caddisfly nymphs, and an unidentified snail; Red-legged frogs and Western Toads; and Rough-skinned newt.

In addition, 67 bird species were identified in and adjacent to the Redwood Creek estuary. Several of those are fish predators including Bald Eagle, Belted Kingfisher, Brown Pelican, California Gull, Caspian Tern, Common Merganser, Double-crested Cormorant, Elegant Tern, Great Blue Heron, Great Egret, Heermann's Gull, Osprey, Western Grebe, and Western Gull. The gulls, terns, and pelicans were mostly seen roosting on the sand spit separating the estuary from the ocean. Harbor seals were also observed inside the estuary in June.

Table 1. List of salmonid and non-salmonid fish seined, birds, amphibians, mammals, invertebrates, and others observed at and adjacent to the Redwood Creek estuary, Redwood National and State Parks, Humboldt County, California during the summer 2013 fish sampling (Shading denotes presence).

Species		2013 Date (Week of)			
Common Name	Scientific Name	June 3	July 8	Aug 19	Sept 16
Salmonid Fish					
Chinook Salmon *	*Oncorhynchus tshawytscha*	■	■	■	■
Coastal Cutthroat Trout	*Oncorhynchus clarki*	■	■		■
Coho Salmon *	*Oncorhynchus kisutch*	■		■	
Steelhead Trout *	*Oncorhynchus mykiss*	■	■	■	■
Other Fish					
Coast Range Sculpin	*Cottus aleuticus*			■	■
Prickly Sculpin	*Cottus asper*	■		■	■
Sacramento Sucker	*Catostomus occidentalis*			■	
Shiner Surf Perch	*Cymatogaster aggregata*		■		
Staghorn Sculpin	*Leptocottus armatus*	■	■	■	■
Starry Flounder	*Platichthys stellatus*			■	■
Surf Smelt	*Hypomesus pretiosus*		■	■	
Three Spine Stickleback	*Gasterosteus aculeatus*	■	■	■	■
Amphibians					
Northern Red-legged Frog (Adult)	*Rana aurora*			■	
Rough-skinned Newt	*Taricha granulosa*			■	
Western Toad (Adult)	*Bufo boreas*			■	
Birds					
Aleutian Crackling Goose	*Branta hutchinsii leucopareia*			■	
American Crow	*Corvus brachyrhynchos*	■	■	■	■
American Goldfinch	*Carduelis tristis*	■	■	■	■
American Pipit	*Anthus rubescens*				■
American Robin	*Turdus migratorius*		■		
Bald Eagle	*Haliaeetus leucocephalus*			■	
Band-tailed Pigeon	*Patagioenas fasciata*		■		
Barn Swallow	*Hirundo rustica*	■	■	■	■
Belted Kingfisher	*Ceryle alcyon*			■	■
Black Brant	*Branta bernicla nigricans*	■			
Black-headed Grosbeak	*Pheucticus melanocephalus*		■		
Black Oystercatcher	*Haematopus bachmani*	■			
Black Phoebe	*Sayornis nigricans*			■	■
Black-capped Chickadee	*Poecile atricapillus*		■	■	■
Brown Pelican	*Pelecanus occidentalis*	■	■	■	■
Brown-headed Cowbird	*Molothrus ater*	■	■		
California Gull	*Larus californicus*	■	■	■	■
Canada Goose	*Branta canadensis*		■	■	■
Caspian Tern	*Sterna caspia*	■	■	■	■
Chestnut-backed Chickadee	*Poecile rufescens*		■	■	■

Species		2013 Date (Week of)			
Common Name	Scientific Name	June 3	July 8	Aug 19	Sept 16
Cliff Swallow	*Petrochelidon pyrrhonota*				
Common Merganser	*Mergus merganser*				
Common Raven	*Corvus corax*				
Common Yellowthroat	*Geothlypis trichas*				
Coopers Hawk	*Accipiter cooperii*				
Double-crested Cormorant	*Phalacrocorax auritus*				
Downy Woodpecker	*Picoides pubescens*				
Elegant Tern	*Sterna elegans*				
Fox Sparrow	*Passerella iliaca*				
Golden-crowned Kinglet	*Regulus satrapa*				
Great Blue Heron	*Ardea herodias*				
Great Egret	*Ardea alba*				
Greater Yellowlegs	*Tringa melanoleuca*				
Heermann's Gull	*Larus heermanni*				
Killdeer	*Charadrius vociferus*				
Least Sandpiper	*Calidris minutilla*				
Mallard	*Anas platyrhynchos*				
Northern Flicker	*Colaptes auratus*				
Northern Harrier	*Circus cyaneus*				
Northern Rough-winged Swallow	*Stelgidopteryx serripennis*				
Orange-crowned Warbler	*Vermivora celata*				
Osprey	*Pandion haliaetus*				
Peregrine Falcon	*Falco peregrinus*				
Pacific (Winter) Wren	*Troglodytes pacificus*				
Purple Finch	*Carpodacus purpureus*				
Red-shouldered Hawk	*Buteo lineatus*				
Red-throated Loon	*Gavia stellata*				
Semipalmated Plover	*Charadrius semipalmatus*				
Short-billed Dowitcher	*Limnodromus griseus*				
Song Sparrow	*Melospiza melodia*				
Spotted Sandpiper	*Actitis macularius*				
Stellers Jay	*Cyanocitta stelleri*				
Surf Scoter	*Melanitta perspicillata*				
Swainsons Thrush	*Catharus ustulatus*				
Tree Swallow	*Tachycineta bicolor*				
Turkey Vulture	*Cathartes aura*				
Unidentified Ducks	*Anatidae*				
Unidentified Gull	*Larus sp*				
Unidentified Hummingbird	*Trochilidae sp*				
Unidentified Sandpiper	Scolopacidae				
Unidentified Sparrow	*Passer sp*				
Unidentified Swallow	*Hirundidae sp*				
Vauxs Swift	*Chaetura vauxi*				
Violet-green Swallow	*Tachycineta thalassina*				
Western Grebe	*Aechmophorus occidentalis*				
Western Gull	*Larus occidentalis*				

Species		2013 Date (Week of)			
Common Name	Scientific Name	June 3	July 8	Aug 19	Sept 16
Western Sandpiper	*Calidris mauri*				
White-crowned Sparrow	*Zonotrichia leucophrys*				
Wilsons Warbler	*Wilsonia pusilla*				
Wood Duck	*Aix sponsa*				
Wrentit	*Chamaea fasciata*				
Mammals					
Harbor Seal	*Phoca vitulina*				
Invertebrates					
Amphipod	*Corophium sp.*				
Caddisfly (larvae)	Limniphilidae				
Isopod	*Gnorimosphaeroma sp.*				
Dungeness Crab	*Metacarcinus magister*				
Mysid Shrimp	*Neomysis mercedes*				
New Zealand Mud Snail	*Potamopyrgus antipodarum*				
Scud	*Gammarus*				
Unidentified Snail	*Mollusca*				
Plants					
Pink Sand Verbena	*Abronia umbellata*				
* = Federally listed as Threatened					

Population Estimates - Four population estimates were conducted during the weeks of June 3, July 8, August 19, and September 16 (Table 2). The mouth was open during the June and July population estimates and closed during the August and September estimates. The number of fish marked, marked recaptures, total individuals captured in the 'second sample', number of seines, and fins marked are presented in Appendix I.

Chinook Salmon - The first juvenile chinook salmon estimate, the week of June 3 was 63,390. The estimate for the week of July 8 was 106,650; for the week of August 18 the estimate was much lower, 5,820; and for the week of September 15 population estimate was 2,920. There was a 97 percent decrease in population between July and September.

Coho Salmon – A population estimate for June 3 was not possible as no marked fish were recaptured. The actual number of coho captured in all 11 seine net hauls was 141. No estimate for the week of August 22 was possible as only one coho salmon was seined. None were captured in June or September.

Steelhead Trout - The first estimate the week of June 3 was not possible as no marked fish were recaptured and not many steelhead were seined, 57 from 11 seines over three days. The estimate for the week of July 8 was 11,580; for the week of August 19, the estimate decreased to 1,460, and for the week of September 16, the population estimate was 1,890. Between July and September the population decreased 84 percent.

Coastal Cutthroat Trout - No coastal cutthroat trout were captured during the week of August 19. In the other three estimates, no marked fish were recaptured. Four, nine, and 10 cutthroat were seined in June, July, and September, respectively. A total of 23 cutthroat were caught during the 2013 season.

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 2013. Mouth of creek denotes if Redwood Creek mouth was open or closed to the Pacific Ocean during the estimate.

2013 DATE	**Mouth of Creek (Open or Closed)**	**Chinook Salmon**		**Coho Salmon**	
		Population Estimate	95% Confidence Interval	Population Estimate	95% Confidence Interval
06/3, 4, 6	OPEN	63,390	±15,150 (48,240 – 78,530)	141[a]	---
07/8, 9, 11	OPEN	106,650	± 55,230 (51,420 – 161,880)	None caught	---
08/19, 20, 22	CLOSED	5,820	± 4,160 (1,660 - 9,990)	1[a]	---
09/16, 17, 19	CLOSED	2,920	± 5,620 (120[b] – 8,550)	None caught	---
		Steelhead Trout		**Cutthroat Trout**	
06/3, 4, 6	OPEN	57[a]	---	4[a]	---
07/8, 9, 11	OPEN	11,580	± 12,790 (546[b] – 24,380	9[a]	---
08/19, 20, 22	CLOSED	1,460	± 1,090 (370 – 2,550	None caught	---
09/16, 17, 19	CLOSED	1,890	± 1,150 (740 – 3,030)	10[a]	---

a. Actual number 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 – Four growth estimates were conducted in conjunction with the four population estimates during the weeks of June 3, July 8, August 19 and September 16 (Table 3). The absence of fish made it difficult to attain the 200 length measurements for steelhead in June and August, and chinook in September.

Chinook Salmon – A total of 740 juvenile chinook salmon were measured. Mean fork length increased from 60 to 85 mm, a 25 mm increase between the weeks of June 3 and September 16 (Table 3 and Figure 3). The smallest fish were measured in June at 44 mm. The largest fish measured was 106 mm in July, though a 101 mm fish was measured in September. The difference in the minimum and maximum fork lengths measured each sample period ranged between 53 and 31 mm.

Of a total of 123 chinook weighed, mean weight increased from 2.6 g to 6.8 g between the weeks of June 3 and September 16, an increase of 4.2 g. During the sample period the minimum and maximum chinook weights were 0.8 g and 13.1 g, respectively.

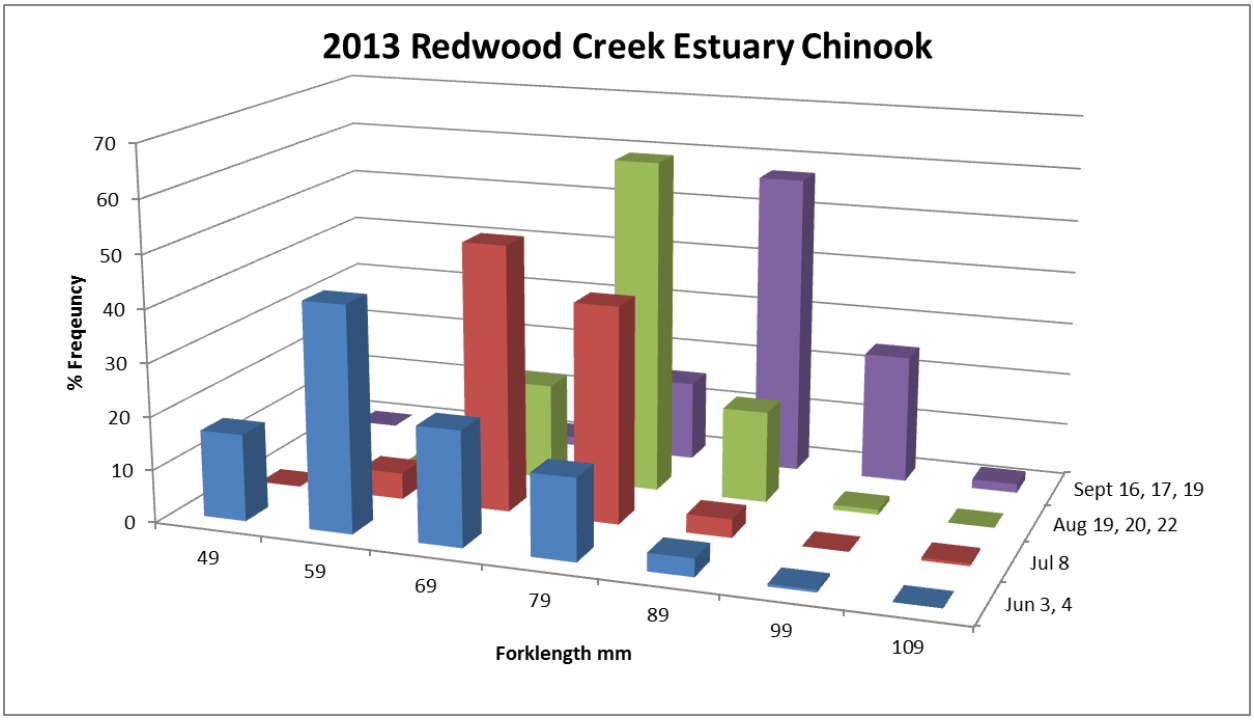


Figure 3. Fork length (mm) versus frequency (%) histogram of Redwood Creek estuary juvenile chinook salmon seined June 3 through September 19, 2013. Fork length intervals were 10-mm increments.

Table 3. Mean fork length (mm), mean weight (g), standard deviation, range, dates, and numbers sampled of juvenile chinook and coho salmon; and steelhead, coastal cutthroat seined in the Redwood Creek estuary embayment, Humboldt County, California, during summer of 2013 from June 03 to September 19. Mouth denotes if Redwood Creek mouth was open or closed to the ocean.

Growth - Redwood Creek Estuary – Summer/Fall 2013									
2013 DATE	**MOUTH**	**FORK LENGTH (mm)**				**WEIGHT (g)**			
		No. Measured	Mean	Std. Dev	Range	No. Weighed	Mean	Std. Dev.	Range
JUVENILE CHINOOK SALMON									
06/3, 4	OPEN	207	60	10.0	44 - 91	32	2.6	1.4	0.8 – 5.1
07/8	OPEN	201	69	6.8	53 – 106	30	4.3	2.0	2.0 – 13.1
08/ 19, 20, 22	CLOSED	213	75	5.7	59- 90	31	4.5	0.8	3.0 – 7.1
09/ 16, 17, 19	CLOSED	119	85	6.7	67 - 101	30	6.8	1.9	3.6 – 11.6
JUVENILE COHO SALMON									
06/ 3, 4, 6	OPEN	141	109	8.8	82 - 131	140	14.6	3.8	6.0 – 28.0
07/8, 9, 11	OPEN	None caught	---	---	---	---	---	---	---
08/22	CLOSED	1	115	---	---	1	15.8	----	----
09/16, 17, 19	CLOSED	None caught	---	----	----	----	----	----	---
JUVENILE STEELHEAD TROUT									
06/3, 4, 6	OPEN	58	115	17.9	47 - 152	31	19.5	8.3	1.0 – 36.4
07/8	OPEN	205	125	18.6	64 - 191	30	22.4	8.5	5.2 – 44.5
08/19, 20, 22	CLOSED	191	108	32.2	56 - 191	30	11.1	10.5	2.2 – 45.5
09/16, 17, 19	CLOSED	213	122	31.4	66 - 203	30	21.3	17.7	4.7 – 74.6
CUTTHROAT TROUT									
06/4	OPEN	4	241	66.4	172 - 310	4	161.1	120.8	50.8 - 300
07/8, 9, 11	OPEN	9	273	48.3	206 - 336	9	248.6	135.7	90.0 - 454
08/19, 20, 22	CLOSED	None caught	---	---	---	---	---	---	---
09/17, 19	CLOSED	10	321	41.8	262 - 376	10	411.6	175.3	192 - 666

Coho Salmon - Of the 142 juvenile coho measured, fork lengths ranged from 82 to 131 mm (Table 3 and Figure 4). This would indicate only smolts were captured, no 0+ fish. Mean fork length the week of June 3 was 109 mm and the one fish caught in August was 115 mm. Mean weight in June was 14.6 g and the one fish caught in July was 15.8 g. Coho weight ranged from 6.0 g to 28.0 g.

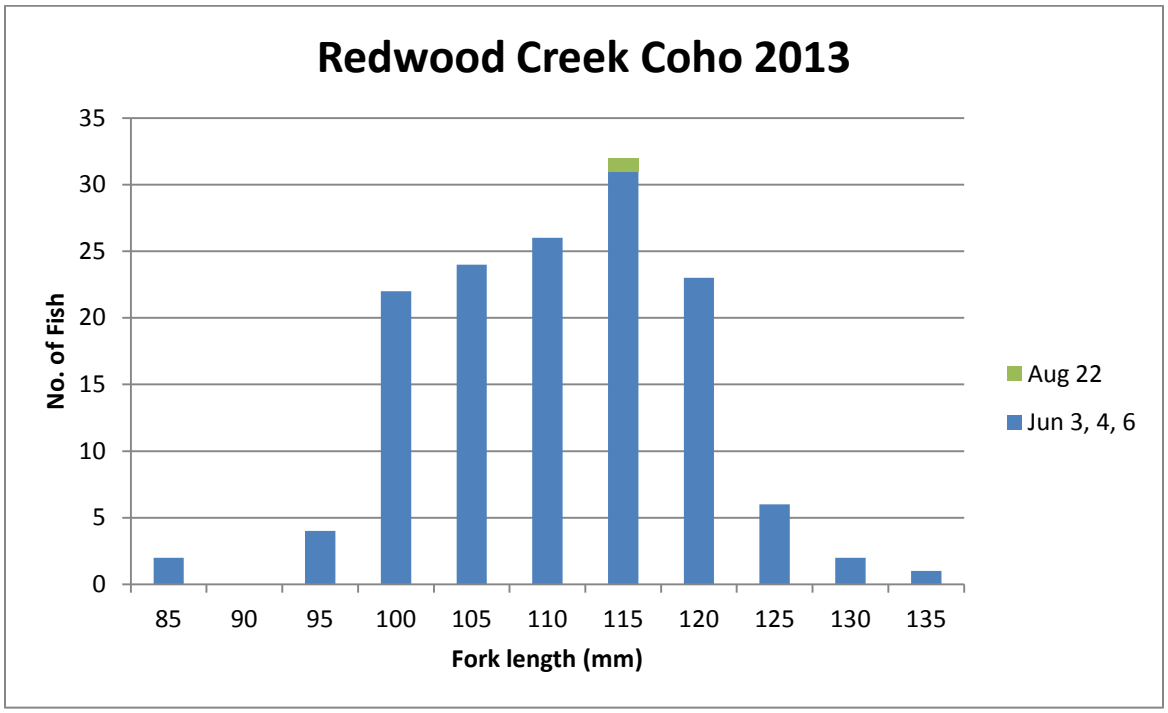


Figure 4. Fork length (mm) histogram of Redwood Creek estuary juvenile coho salmon captured June 3, 4, 6, and August 22, 2013.

Steelhead Trout - A total of 667 juvenile steelhead were measured. Mean fork length did not follow an increased growth trend with time, the smallest being in August at 108 mm and the largest in July at 125 mm (Table 3 and Figure 5). This most likely reflected the percentage of different age classes seined each sampling week, but generally the range of measured lengths increased over time. For the season, the smallest fish measured was 47 mm, the largest 203 mm. The same pattern occurred for mean juvenile weight. Mean weight ranged from 11.1 g to 22.4 g. The minimum and maximum weight measured during the sample season was 1.0 g and 74.6 g, respectively.

Coastal Cutthroat Trout - A total of 23 coastal cutthroat trout were captured. Mean cutthroat fork length increased from 241 to 321 mm between the weeks of June and September (Table 3). The smallest cutthroat measured was 172 mm, the largest 376 mm. Several age classes were present (Figure 6). Mean weight was 120.8 g in June, 248.6 g in July, and 411.6 g in September. Weight ranged between 50.8 g and 666 g (1.5 lb.).

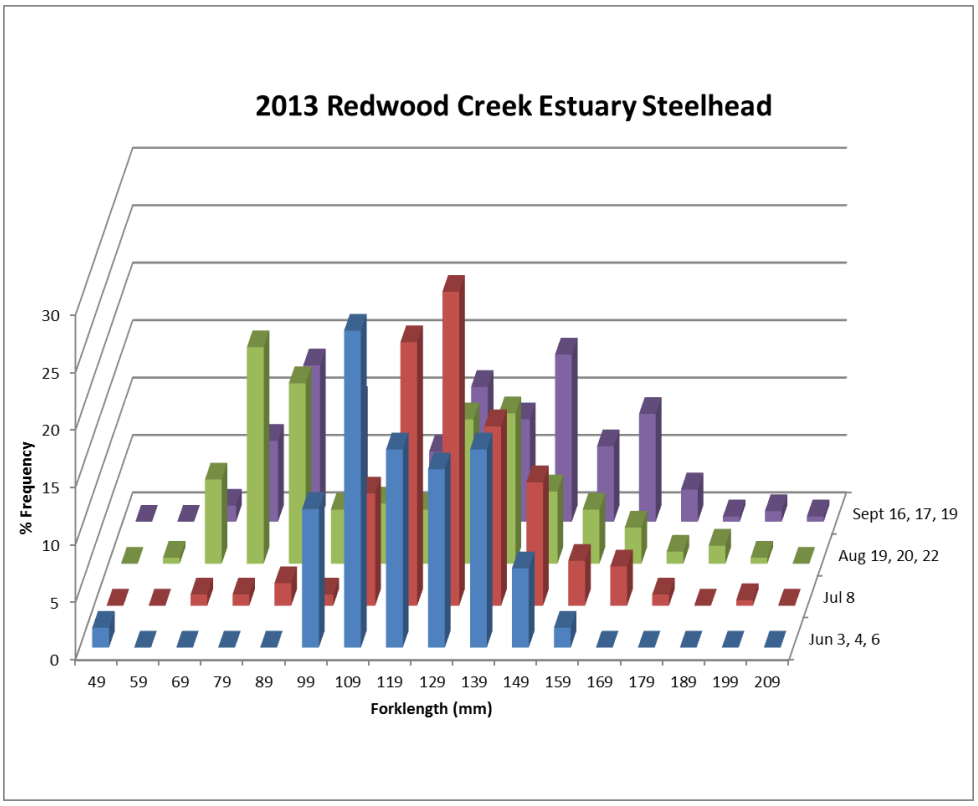


Figure 5. Fork length (mm) versus frequency (%) histogram of Redwood Creek estuary juvenile steelhead seined June 3 through September 19, 2013. Fork length intervals were 10-mm increments.

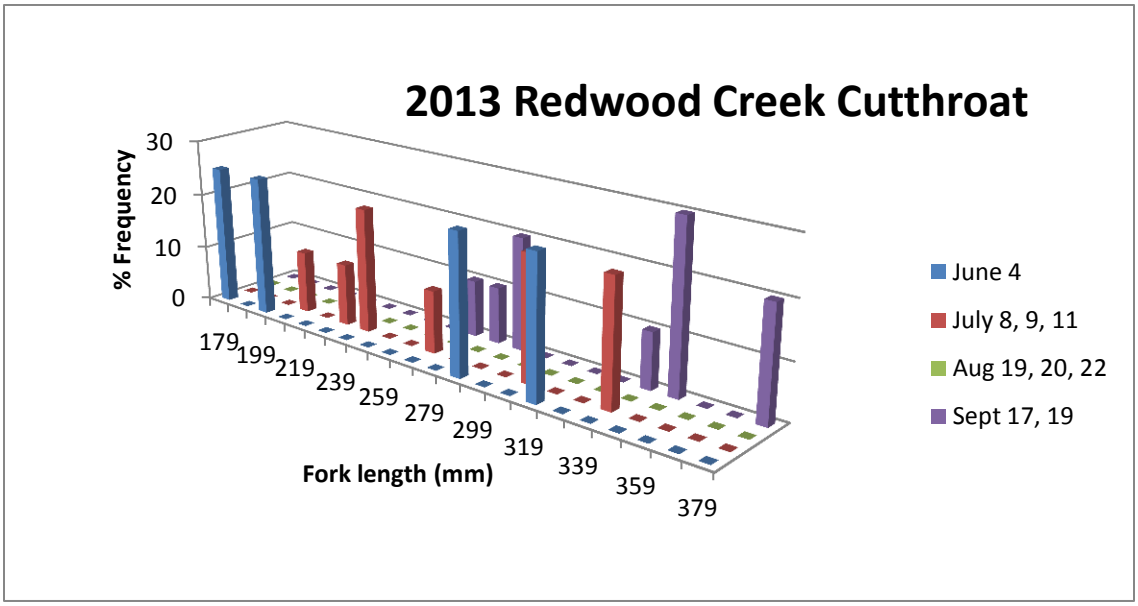


Figure 6. Fork length (mm) versus frequency (%) of Redwood Creek estuary coastal cutthroat trout seined June 4 through September 19, 2013. Fork length intervals are 10-mm increments.

Condition Factor (K') – Fish condition factors are presented in Table 4. Species mean condition factors at each sample date remained approximately the same throughout the season. Mean chinook K' for the four sample dates ranged from 1.0297 to 1.0461, but individual K' ranged between 0.7963 and 1.8193. The seasonal mean for all chinook was 1.0362. The seasonal mean for all 141 coho was 0.9427. Mean steelhead K' for the four sample dates ranged from 1.0668 to 1.1321, but individual K' ranged between 0.8486 and 1.2903. The seasonal mean for all steelhead was 1.1016. Mean cutthroat K' for the three sample dates where cutthroat were captured ranged from 0.3844 to 0.4162, but individual K' ranged between 0.3607 and 0.4807. The seasonal mean for all 23 cutthroat was 0.4117.

PIT Tagged Fish – In 2013, five CDFW PIT tagged fish, four chinook and one cutthroat were detected among the 7,115 estuary fish processed (Table 5). The four chinook were tagged at the upper Redwood Creek trap (rm 33) in 2013, and the one cutthroat tagged at the lower Redwood Creek trap in June 2012.

Chinook fork length growth between tagging and release at the upper trap at river mile 33 and capture in the estuary at the mouth of Redwood Creek ranged between 0 mm and 1 mm for the shortest time period of seven days, 3 mm at 13 days, and 13 mm at 37 days. The cutthroat grew 90 mm over 446 days.

KVC Wetland Fish Trapping - The two open wetland channels adjacent to the South Slough/KVC parking lot were trapped on September 24, 2013. At the boardwalk channel, five sites were sampled and only dragonfly and damselfly nymphs and threespine stickleback were captured. At the east channel, two sites were sampled and one threespine stickleback was captured. A beaver dam was observed at both channels (Figure 7).

Figure 7. Boardwalk channel with beaver dam in KVC wetland (RNP photo September 24, 2013).

Table 4. Mean condition factor (K'), sample size, standard deviation, minimum and maximum values of captured salmonids measured (fork length cm) and weighed (g) from the Redwood Creek embayment, Humboldt County, California, during the Summer of 2013. Condition factor is calculated as: $K' = 100W_{(g)} / FKL_{(cm)}^{b}$. Slope (b) was calculated as: $\log_{10}$ Weight $_{(g)} = \log_{10} a + b \log_{10}$ Fork Length $_{(cm)}$.

Condition Factor (K') - Redwood Creek Estuary 2013					
Date (week of)	**6/3/2013**	**7/08/2013**	**8/19/2013**	**9/16/2013**	**Summer/ Fall 2013**
Chinook Salmon (b =3.0326**)**					
Mean	1.0337	1.0461	1.0297	1.0358	1.0362
Standard Deviation	0.1712	0.0636	0.0803	0.0651	0.1051
Minimum	0.8087	0.9261	0.7963	0.9320	0.7963
Maximum	1.8193	1.2407	1.2056	1.2302	1.8193
Count	32	30	31	30	123
Coho Salmon (b = 3.0693**)**					
Mean	0.9432	---	0.8772	---	0.9427
Standard Deviation	0.0760	---	--	---	0.0760
Minimum	0.7741	---	0.8772	---	0.7741
Maximum	1.3139	---	0.8772	---	1.3139
Count	140	---	1	---	141
Steelhead Trout (b = 3.0012**)**					
Mean	1.0668	1.1321	1.0853	1.1233	1.1016
Standard Deviation	0.0675	0.0659	0.0524	0.0725	0.0697
Minimum	0.8486	1.0047	0.9547	0.9950	0.8486
Maximum	1.1518	1.2903	1.2319	1.2556	1.2903
Count	31	30	30	30	121
Cutthroat Trout (b = 3.2964**)**					
Mean	0.3844	0.4190	---	0.4162	0.4117
Standard Deviation	0.0307	0.0353	---	0.0207	0.0304
Minimum	0.3640	0.3607	---	0.3886	0.3607
Maximum	0.4297	0.4807	---	0.4459	0.4807
Count	4	9	---	10	23

Table 5. CDFW PIT tagged fish recaptured in the Redwood Creek estuary in 2013.

Species	PIT Tag #	Estuary Date Recapture	Fork Length (mm)	Weight (g)	Date Tagged	Location	Fork Length Initial	Weight Initial	Days	Increase Fork Length	Increase Weight
Chinook	5993910	6/3/2013	69	3.5	5/27/2013	Upper Trap (CDFW)	69	3.5	7	0	0
Chinook	5983803	6/3/2013	67	2.7	5/27/2013	Upper Trap (CDFW)	66	3.0	7	1 *	-0.3
Chinook	6102455	6/4/2013	76	4.6	5/22/2013	Upper Trap (CDFW)	73	4.5	13	3	0.1
Chinook	5269759	8/22/2013	83	7.1	7/17/2013	Upper Trap (CDFW)	70	3.8	37	13	3.3
Cutthroat	53384859	9/19/2013	373	666	6/30/2012	Lower Trap (CDFW)	283	---	446	90	---
* Difference in FL is within uncertainty of measurement, + or – 1 mm.											

Physical Monitoring

Water Temperature - In summer/fall 2013, Redwood Creek embayment water temperature (°C) was measured hourly from June 1 through October 28. (Figure 8). The maximum and minimum temperatures measured between June 1 and October 28 were 21.6°C (9/16 at 17:00) and 9.6°C (10/12 at 07:00), respectively. The average water temperature for this period was 16.6°C.

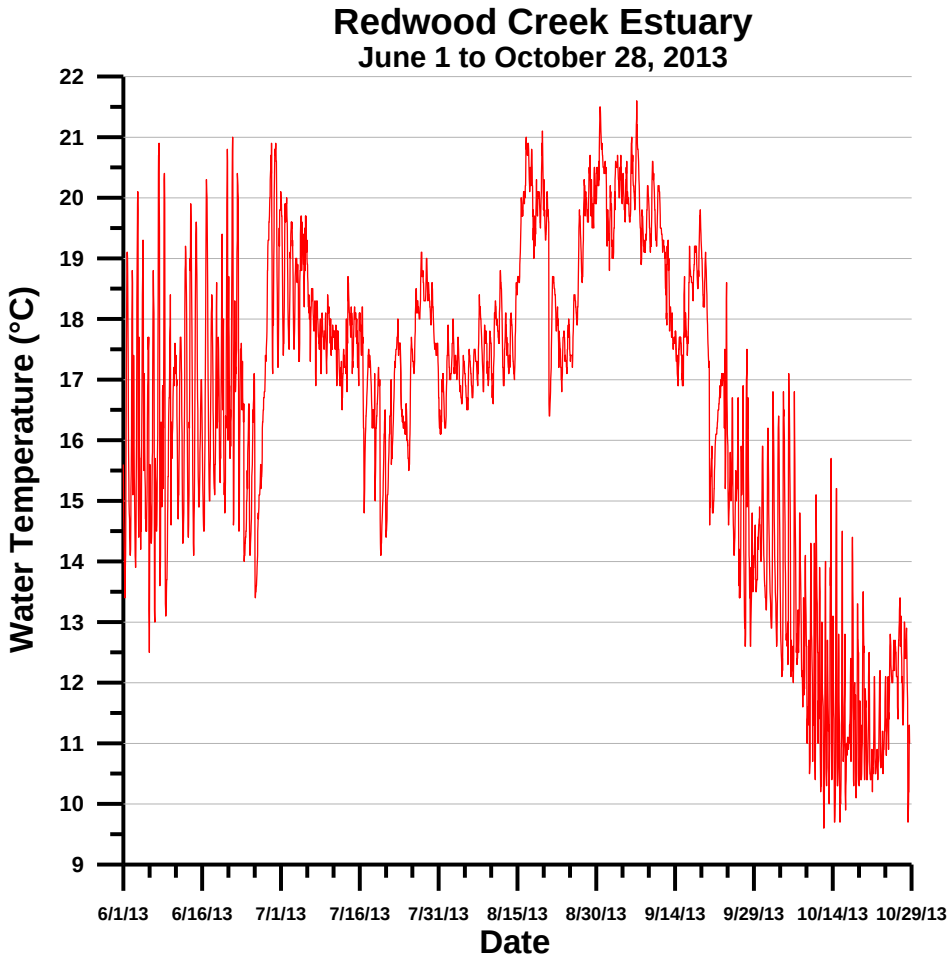


Figure 8. Redwood Creek estuary water temperatures (°C) measured by an Onset Tidbit temperature logger located in the embayment beyond the ends of the north and south levees. The temperature logger, located one foot above the bottom, recorded water temperature every hour from June 1 to October 28, 2013.

The maximum and minimum water temperatures from July 1 to August 31, a warmer period of the summer, were 21.5 °C and 14.1°C, respectively. The average water temperature for that period was 18.0°C. Maximum weekly average temperature (MWAT) was 19.6°C, and maximum weekly maximum temperature (MWMT) was 20.3°C.

Water temperature was equal to or greater than 18.0°C 42.4 percent of time during July and August. August at 18.4°C average water temperature was the warmest month of the summer, followed by September at 17.8°C, July at 17.5°C, June at 16.6°C, and October 1 to 28 at 12.2°C.

The large daily temperature ranges in the embayment when the mouth was open are the result of tidal action; the minimums influenced by the cooler ocean water entering the estuary at high tide, and the maximums influenced by the warmer water from upstream at low tide. After the closure of the mouth the diurnal ranges were less.

Tides at the Mouth of Redwood Creek - The maximum and minimum tide at the mouth of Redwood Creek (based on verified tides at Crescent City, California) was 4.4 ft MSL and -6.2 ft MSL, respectively, a range of 10.7 feet. Tidal data is presented in Appendix II and included in Figure 13.

Stream Flow - Calendar year 2013 stream flow data, January 1 through December 31, is presented in Appendix III. 2013 was a drought year. The maximum flow was 3,390 cfs on September 30. The gage measured a minimum flow of 8 cfs at various times between September 9 and 20. The first flow event of the fall occurred on September 20, when after 1.2 inches of rain, flow increased from 9 cfs to a peak of 97 cfs on September 22 (Figure 9). (The flow data is provisional and subject to revision by the California Department of Water Resources.)

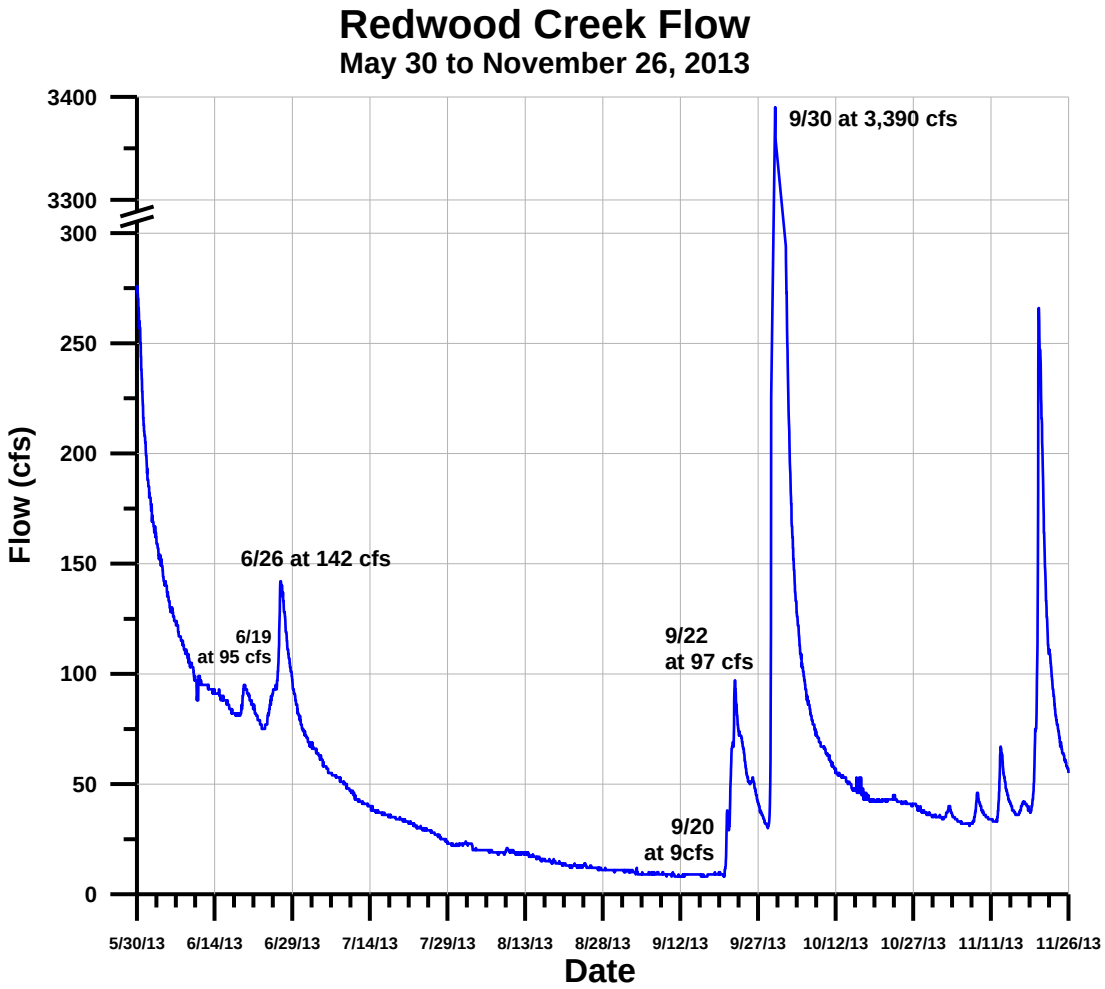


Figure 9. Redwood Creek flow (cfs) at Orick for May 30 to November 26, 2013.

Ocean Wave Height – There is no ocean buoy data for directly offshore of Redwood Creek. Wave heights (ft) for St. Georges buoy #46027 off Crescent City was downloaded from the NOAA site for calendar year 2013. Wave heights ranged from 1.4 ft to 19.5 ft (Appendix IV).

Illegal Breach Attempt- On the morning of August 19, the first day of a population estimate, a ditch that appeared to have been hand dug through the width of the sand berm between the estuary and ocean was discovered (Figure 10). The breaching attempt failed. Water had flowed through it but was not flowing when found. Park staff filled it in by kicking in the banks and the pushing the adjacent sand piles into the channel (Figure 11). The next morning wave overwash had filled in the excavated channel even more (Figure 11). Several weeks later, any evidence of the attempt could not be discerned. During the night of August 18-19, 10pm to 6am, recorded estuary water level fluctuated by 0.1 ft, the mean elevation was 5.0 ft, an elevation where adjacent roads or fields are not inundated.

Figure 10. Illegal estuary breach attempt August 19, 2013; looking toward the estuary (left); looking toward the ocean (right). Person in ditch is on their knees. (RNP photo)

Figure 11. Ditch filled in from sides on August 19 (left) and results of wave overwash filling in more of the ditch with sand overnight on August 20, 2013. (RNP photo)

Embayment Water Level Gaging

Redwood Creek embayment water elevation (feet MSL) was recorded every 15 minutes with a ventless U20 Onset water level data logger. The temporary embayment gage was installed near the end of the south levee on May 30 and retrieved on November 18, 2013.

The embayment gage site at the end of the south levee measures lower embayment water elevations than in the south slough. The lowest water levels in the south slough are limited by the invert of the south slough culvert gates and sand deposited in the south slough outlet channel.

Closure, Breaching and Estuary Response - Based on observations and the embayment recording water level gage data, the Redwood Creek estuary closed and breached four times (Figure 12). The estuary mouth first closed on June 8 and breached on June 9, closed for 0.6 days; closed a second time on June 25 and breached on June 27, closed for 1.2 days; closed a third time on July 4 and breached on July 8, closed for 3.3 days; and closed on July 18 and breached on September 23, closed for 66.5 days. The estuary was closed for a total of 71.6 days.

June 8 Closure and June 9 Breach - The mouth of the Redwood Creek closed on June 8th at an estuary water elevation of 2.3 ft MSL (Figure 12) after a series of increasing high tides (Figure 13).

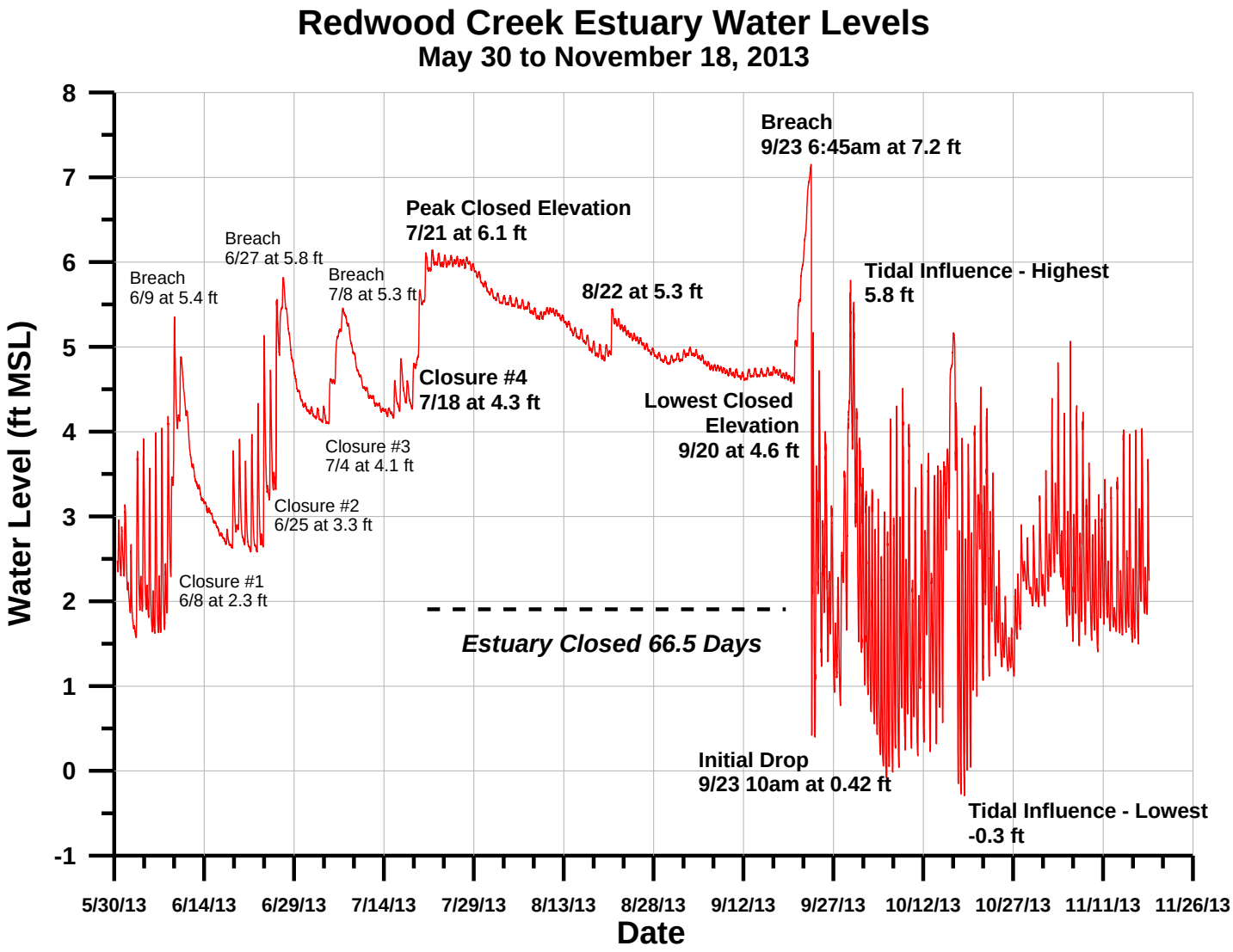


Figure 12. Water level elevations (ft Mean Sea Level [MSL]) recorded in the Redwood Creek estuary, Humboldt County, California for May 30 to November 18, 2013.

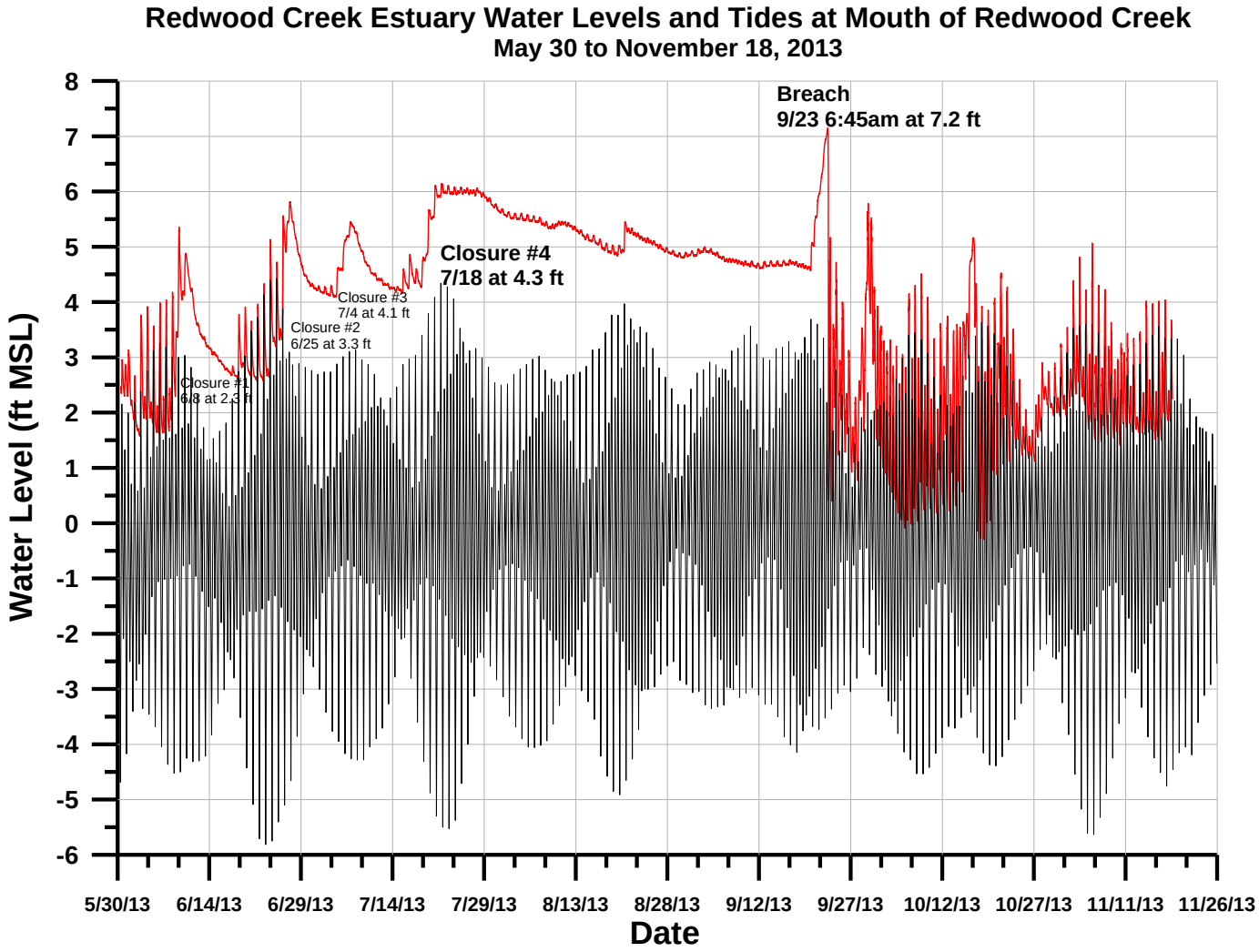


Figure 13. Redwood Creek estuary water levels and tides at the mouth of Redwood Creek May 30 to November 18, 2013.

Redwood Creek flow at the time was 109cfs and ocean wave height at buoy station 46027 off Crescent City at 9.2 ft (Figure 14). The mouth breached on June 9 at 5.4 ft MSL. Flow was at 107 cfs and wave height at 14.4 ft.

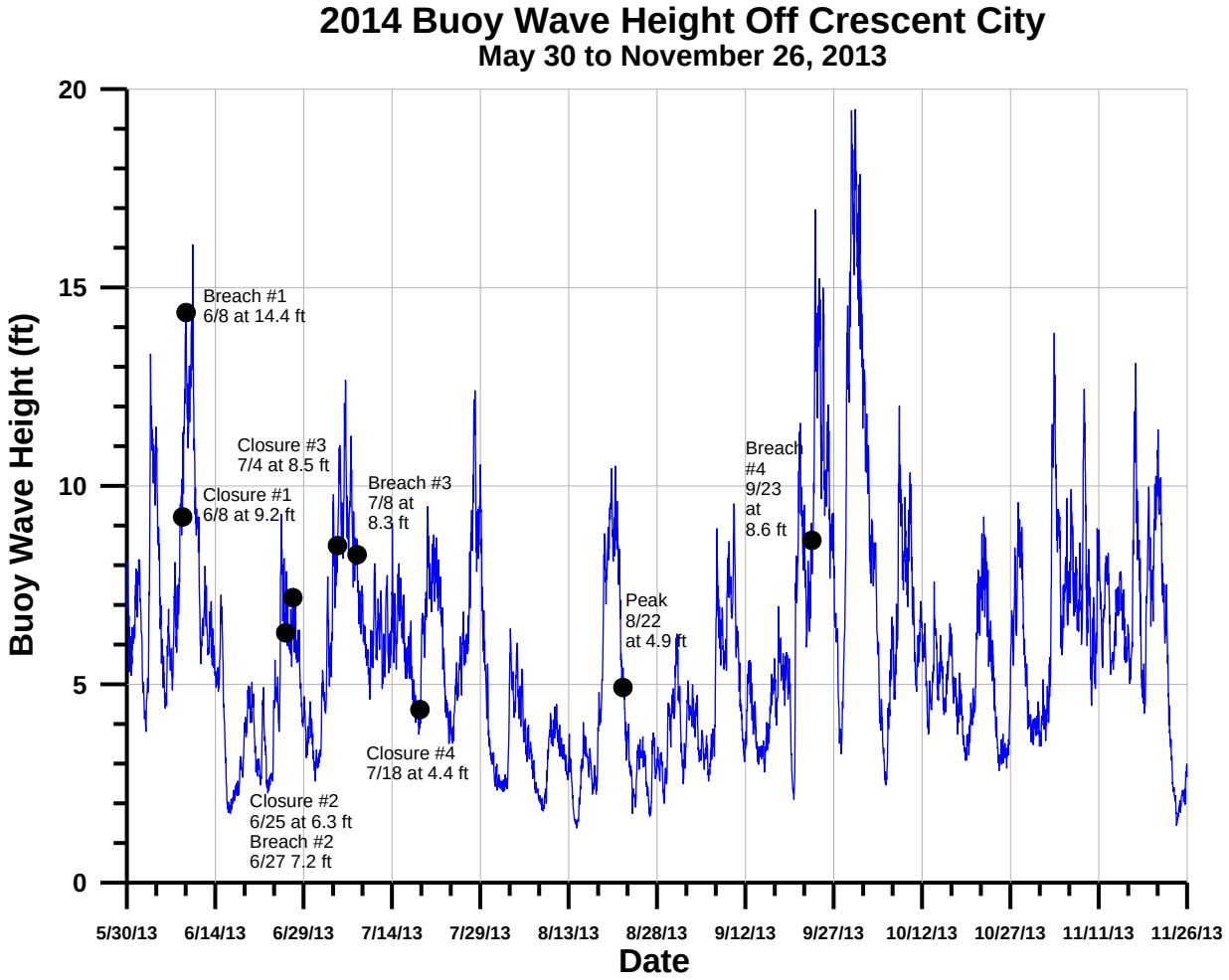


Figure 14. Ocean wave heights (ft) measured hourly at Buoy 4627 located 8 nm NW of Crescent City, California and the wave heights at Redwood Creek closure and breaching occurrences for May 30 to November 26, 2013.

June 25 Closure and June 27 Breach – The mouth closed for the second time on June 25 at an estuary water elevation of 3.3 ft MSL (Figure 12). Flow was at 93 cfs and wave height was 6.3 ft (Figure 14). The mouth breached on June 27 at 5.8 ft MSL. Flow was 135 cfs and wave height 7.2 ft.

July 4 Closure and July 8 Breach – The mouth closed for a third time on July 4 at an estuary water elevation of 4.1 ft MSL (Figure 12). Flow was 61 cfs and wave height 8.5 ft (Figure 14). The mouth breached on July 8 at 5.3 ft MSL. Flow was 53 cfs and wave height 8.3 ft.

July 18 Closure and September 23 Breach - The mouth of Redwood Creek closed again for the fourth and final time on July 18 at an estuary water elevation of 4.3ft and period of increasing high tides (Figure 13). Redwood Creek flow was 35cfs and ocean wave height 4.4 ft (Figure 14).

The end of the outlet channel filled in with sand from wave overwash (Figure 15).

Figure 15. Mouth of Redwood Creek closed to the ocean, the end of the outlet channel filled in with sand from wave overwash, July 23, 2013 (RNP photo).

The mouth closed, estuary water elevation initially peaked at 6.1ft on July 21, and slowly decreased but peaked again on August 22 at 5.3 ft (Figure 12). Stream flow was 13cfs and wave height at 4.9 ft at the time of the second peak. Water elevation continued to decline to 4.6 ft on September 20, which was the lowest closed elevation. On September 20 also, the water elevation began to increase, flow was 9 cfs but high tides and ocean wave height were increasing in height (Figures 13 and 14).

The berm breached on September 23 at a height of 7.2 ft at 6:45 am (Figure 12). Flow at the time was 74 cfs and wave height 8.6 ft (Figure 14). A combination stream flow and wave overwash most likely caused the estuary to fill in a short 2.8 day period and cause the sandspit to breach. On September 20, the second storm of the season dropped 1.2 inches of rain between 1pm and September 21 at 7am, causing Redwood Creek flow to increase from 9cfs to a peak of 97 cfs on September 22. (Figure 9). [The first storm of fall on September 17 dropped 0.32 inches in six hours with no increase of flow.] Ocean wave buoy data recorded a peak height of 11.6 ft on September 21, but was 8.6 ft at the time of the breach (Figure 14).

The estuary remained closed for 66.5 days. The average water elevation during the 66.5 day closure was 5.2 ft MSL.

Once breached, estuary water elevation dropped 6.7 feet in three hours and 15 minutes to 0.42 ft MSL at 10 am, before tidal influence increased the water elevation (Figure 12). The highest and lowest estuary water elevations recorded after the breach were 5.8 ft MSL on September 29 and -0.3 ft MSL on October 18, respectively before the gage was removed.

Estuary Cross Sections

All five estuary embayment cross sections, E-1 through E-5, were surveyed on June 5, 2013 and are presented in Appendix V. The mouth of Redwood Creek was open to the ocean at the time of the survey. It was the 12th time the cross sections had been surveyed since 1998. Generally, the channel thalweg and form is more variable with distance from the static levees, E-5 the cross-section closest to the Redwood Creek mouth having the most year-to-year change.

Estuary Volume - Also calculated for the embayment (excluding the north and south sloughs and the area of the embayment/channel upstream of the ends of the levees) was embayment volume (ft^3) for varying water elevations (Appendix VI). Calculated embayment volume ranged from 1,882 ft^3 at -3ft MSL to 2,093,240 ft^3 at 7 ft MSL. At 0ft MSL the volume was 216,444 ft^3.

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 and closed before the first storms of the fall/winter season. The three culvert gates were cracked a couple of inches on May 20, lowering the water level slowly, fully opened several days later, and closed on November 18, 2013.

CDFG Redwood and Prairie Creek Downstream Migrant Trapping

Population Abundance - At the lower Redwood Creek downstream rotary screw trap (river mile 4), Sparkman et al. (2014a) estimated 566,859 0+ and 6 1+ chinook; 170 0+ and 122 1+ coho salmon; 22,586 1+ steelhead and 4,393 2+ steelhead; and 94 coast cutthroat trout passed by the trap in 2013 (Table 6). The trap, first a rotary trap and later a fyke net trap fished from April 3 to September 4, 2013, fishing 150 of 154 days.

Of the chinook captured, 145,212 were 0+ age ocean type (i.e. estuary rearing), and 4 were 1+ age stream type (i.e. stream rearing). This predominant estuary life history population demonstrates the need for a restored fully functioning Redwood Creek estuary.

At the Prairie Creek trap located near the mouth of Prairie Creek, Sparkman et al. (2014b) estimated 96,817 0+ chinook and 1 1+ chinook; 3,281 0+ and 23,580 1+ coho; 6,735 1+ and 4,020 2+ steelhead; and 5,043 cutthroat immigrated out of the Prairie Creek watershed into Redwood Creek (Table 6). The rotary trap fished March 10 through August 13, 2013, fishing 155 of 156 days.

Peak month(s) and week migration for each trap is listed in Table 6. Most migration tapered off in June except for Redwood Creek steelhead. Potentially, 733,707 salmonids migrated to the

lower river and estuary in 2013. The large estimated number of estuary chinook in June and early July reflect those trap numbers.

Table 6. Estimated population, peak monthly migration and percentage of population, and peak week of juvenile salmon and steelhead, and cutthroat trout migration from CDFW downstream migrant rotary screw trapping on Lower Redwood Creek and the at the mouth of Prairie Creek, 2013.

2013 CDFW Downstream Migrant Rotary Screw Trapping Population Estimates							
Downstream Migrant Trap	0+ Chinook	1+ Chinook	0+ Coho	1+ Coho	1+ Steelhead	2+ Steelhead	Cutthroat
Lower Redwood	566,859	6	170	122	22,586	4,393	94
Peak Month(s)	May (42%)	April (50%)	July (49%)	May (64%)	June (43%)	July (42%)	July (62%)
	May/June (78%)	May (50%)	June/July (84%)	May/June (96%)	June/July (72%)	June/July (65%)	June/July (83%)
Peak Week	5/07 - 13	--	7/9 - 15	6/04 - 10	6/04 - 10	7/23 - 29	7/23 - 29
Prairie Creek	96,817	1[a]	3,281	23,580	6,735	4,020	5,043
Peak Month(s)	May (44%)	---	April (87%)	April (43%)	May (46%)	May (59%)	April (42%)
	April/May (76%)		April/May (96%)	April/May (79%)	April/May (76%)	April/May (85%)	April/May (81%)
Peak Week	4/30 – 5/06	---	4/09 - 15	4/23 - 29	4/30 – 5/06	4/30 – 5/06	4/30 – 5/06
Total	663,676	7	3,451	23,702	29,321	8,413	5,137

[a] = actually caught
From Sparkman, et al. 2014a and 2014b

Growth – Seasonal mean fork length (mm) and weight (g) of fish measured at the CDFW Lower Redwood and Prairie Creek downstream rotary traps are presented in Table 7. Mean 0+ chinook fork length and weight for lower Redwood and June estuary fish are essentially the same, 61mm and 2.8 g versus 60 mm and 2.6 g, respectively. The difference is that the chinook with extended rearing in the estuary were averaging 85 mm in September.

Mean 1+ coho measurements were similar though the estuary coho were slightly larger and heavier. Prairie Creek 1+ coho were 101.2 mm and 11.01 g and estuary coho were 109 mm and 14.6 g in June.

We did not break down steelhead by age class. Lower Redwood Creek trap 1+ and 2+ steelhead fork lengths were 93.4 g and 142.6 mm, respectively. Prairie Creek trap 1+ and 2+ steelhead were 97.2 mm and 145.6 mm. In the estuary, steelhead were 115 mm in June and 122 mm in September.

Mean cutthroat fork length from the Lower Redwood Creek and Prairie Creek traps were 177.1 mm and 148.5 mm respectively. In the estuary, June, July, and August mean fork lengths were 241 mm, 273 mm, and 321 mm, respectively, all longer as well as heavier that cutthroat captured at the upstream traps.

Table 7. Seasonal mean fork length (mm) and weights (g) from downstream salmonids measured at the CDFW downstream migrant rotary screw traps at lower Redwood Creek and mouth of Prairie Creek (From Sparkman, et al. 2014a and 2014b).

2013 CDFW Downstream Migrant Rotary Screw Trapping Mean Fork length and Weight							
Downstream Migrant Trap	0+ Chinook	1+ Chinook	0+ Coho	1+ Coho	1+ Steelhead	2+ Steelhead	Cutthroat
Lower Redwood	61.0 mm 2.76 g	100.1 mm ---	63.4 mm 3.3 g	105.2 mm 12.8 g	93.4 g 9.68 g	142.6 mm 32.21 g	177.1 mm 66.56 g
Prairie Creek	54.6 mm 2.31 g	---	38.4 mm 0.62 g	101.2 mm 11.01 g	97.2 mm 10.52 g	145.6 mm 33.21 g	148.5 mm 39.49 g
From Sparkman, et al. 2014a and 2014b							

References

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. 365pp.

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. 2pp.

Sparkman, M.D. 2014a. Lower Redwood Creek juvenile salmonid (smolt) abundance project, study year 2013: a report to the Fisheries Restoration Grants Program (Project No. P0810509). CDFW AFRAMP, study 2a7. 85 pp.

Sparkman, M.D., W.D. Duffy, and T.R. Moore. 2014. Prairie Creek Monitoring Project, 2011-2013 Seasons: a report to the Fisheries Restoration Grants Program (Project No. P01010302). 92 pp.

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. 365pp.

Prepared by: David G. Anderson – REDW Fishery Biologist
Redwood National Park and State Parks
P.O. Box 7
121200 Highway 101, Orick, CA 95555
(707) 465-7771
david_g_anderson@nps.gov

2013 Acknowledgements

David Anderson, RNP Fishery Biologist, led the Redwood Creek estuary biological and physical monitoring activities. The monitoring project could not have been done without the assistance and contributions of the following people.

Estuary Seining
Fish and Wildlife Branch: David Anderson, Kyle Max, Heather Brown, Susannah Manning, Joanna DiTommaso, Chris Burley, Brandon Piper
RNP Roads and Trails: Mark Vargas
RNP Vegetation: Steve Bustamante
RNP Geology: Kendall
HSU Fish Coop: Tancy Moore
Volunteer-in-the park (VIP): Kalvin, Emily, Tara Balden

KVC Wetland Fish Trapping
Fish and Wildlife Branch: David Anderson, Brandon Piper, and Chris Burley

Estuary Water Level Monitoring (Installation and Removal)
Fish and Wildlife Branch: David Anderson and Kyle Max

Water Temperature Monitoring
Fish and Wildlife Branch: David Anderson and Kyle Max (placement and retrieval)
Geology Branch: Carrie Jones (data download, calibration of probes)

Embayment Cross-Sections
Fish and Wildlife Branch: David Anderson (rod)
RNP Geology: Carrie Jones (instrument and graphing) and Vicki Ozaki (rod)
RNP Vegetation: Tim

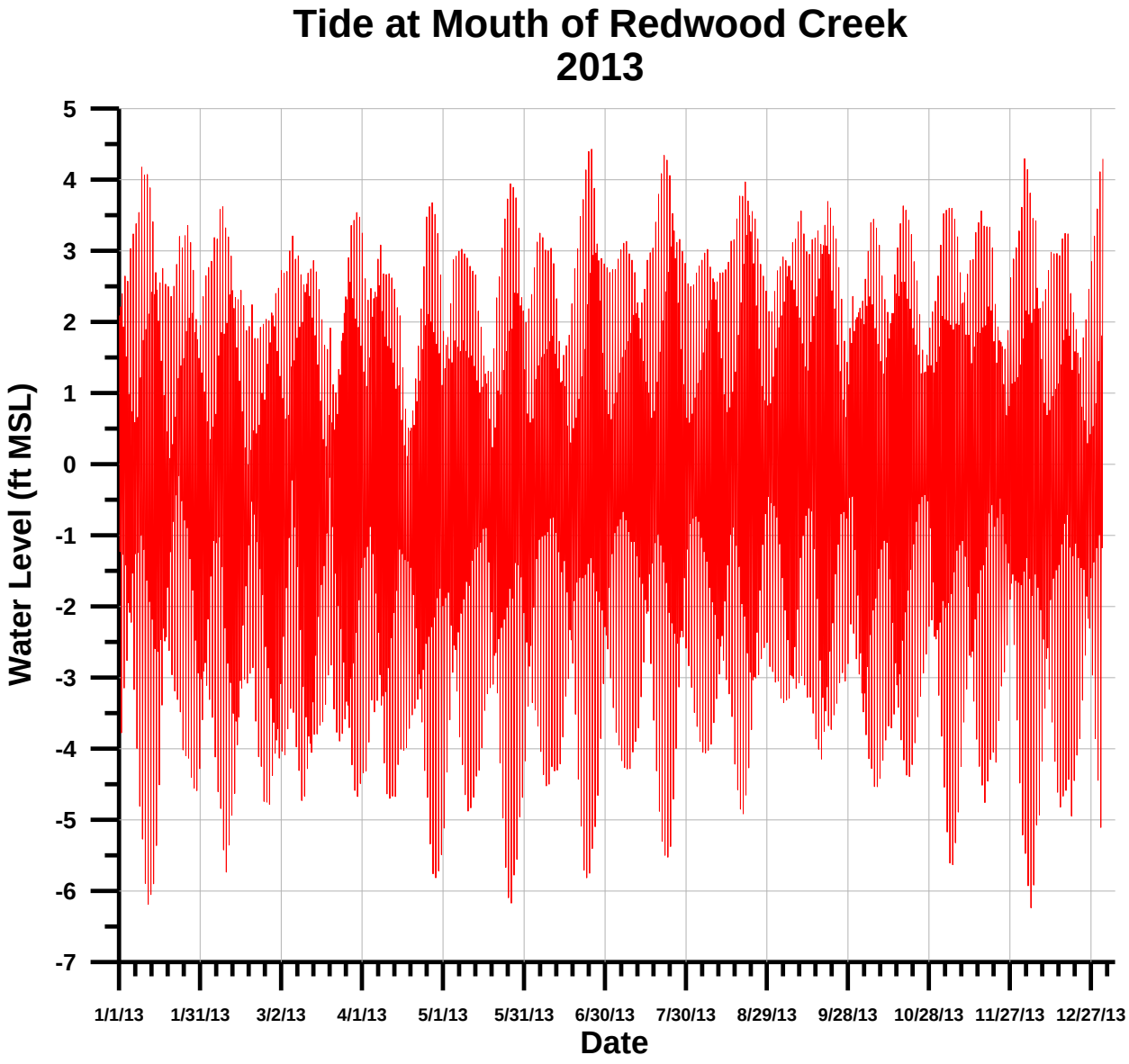
Appendix I. Number of salmonid fish marked, marked recaptures, total individuals captured in the second sample, and total number of seines from the RNP Redwood Creek, estuary mark and recapture population estimates during the Summer of 2013. Fish fin locations: top, middle, and bottom caudal, and anal fin marked with a Panjet needleless injector using Alcian Blue dye. Formulas used to calculate population estimate and its 95% confidence interval.

2013		A = Number of Fish Marked in Two Days B = Marked Fish Recaptured on Third Day C=Total No. of Fish Captured on Third Day				Total No. of Seines (Daily totals)	Panjet Fin Marks
		Chinook	Coho	Steelhead	Cutthroat		
June 3,4	**A**	1,644	81	37	4	11 (4+3+4)	Bottom Caudal
June 6	**B**	63	0	0	0		
	C	2,429	60	20	0		
July 8, 9	**A**	1,234	0	476	8	8 (2+3+3)	Top Caudal
July 11	**B**	14	0	3	0		
	C	1,210	0	73	1		
August 19, 20	**A**	218	0	129	0	17 (4+5+8)	Anal
August 22	**B**	7	0	6	0		
	C	187	1	68	0		
Sept 16, 17	**A**	68	0	149	7	19 (4+7+8)	Middle Caudal
September 19	**B**	1	0	9	0		
	C	43	0	114	3		

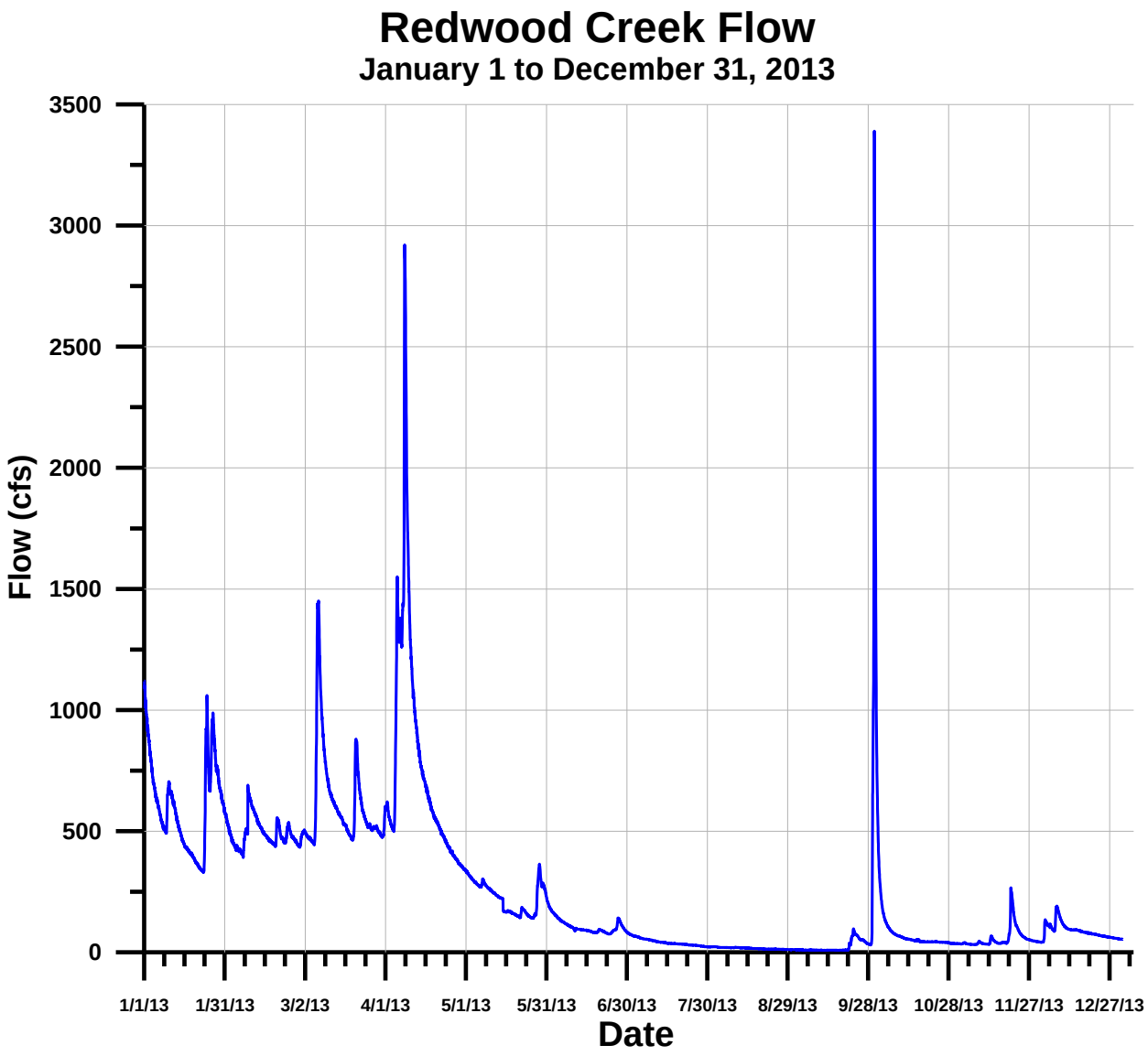
$$\text{Population Estimate (N)} = \frac{(\mathbf{A}\text{ No. of fish marked}) \times (\mathbf{C}\text{ total no. captured in second sample})}{(\mathbf{B}\text{ No. of marked fish recaptured in second sample})}$$

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

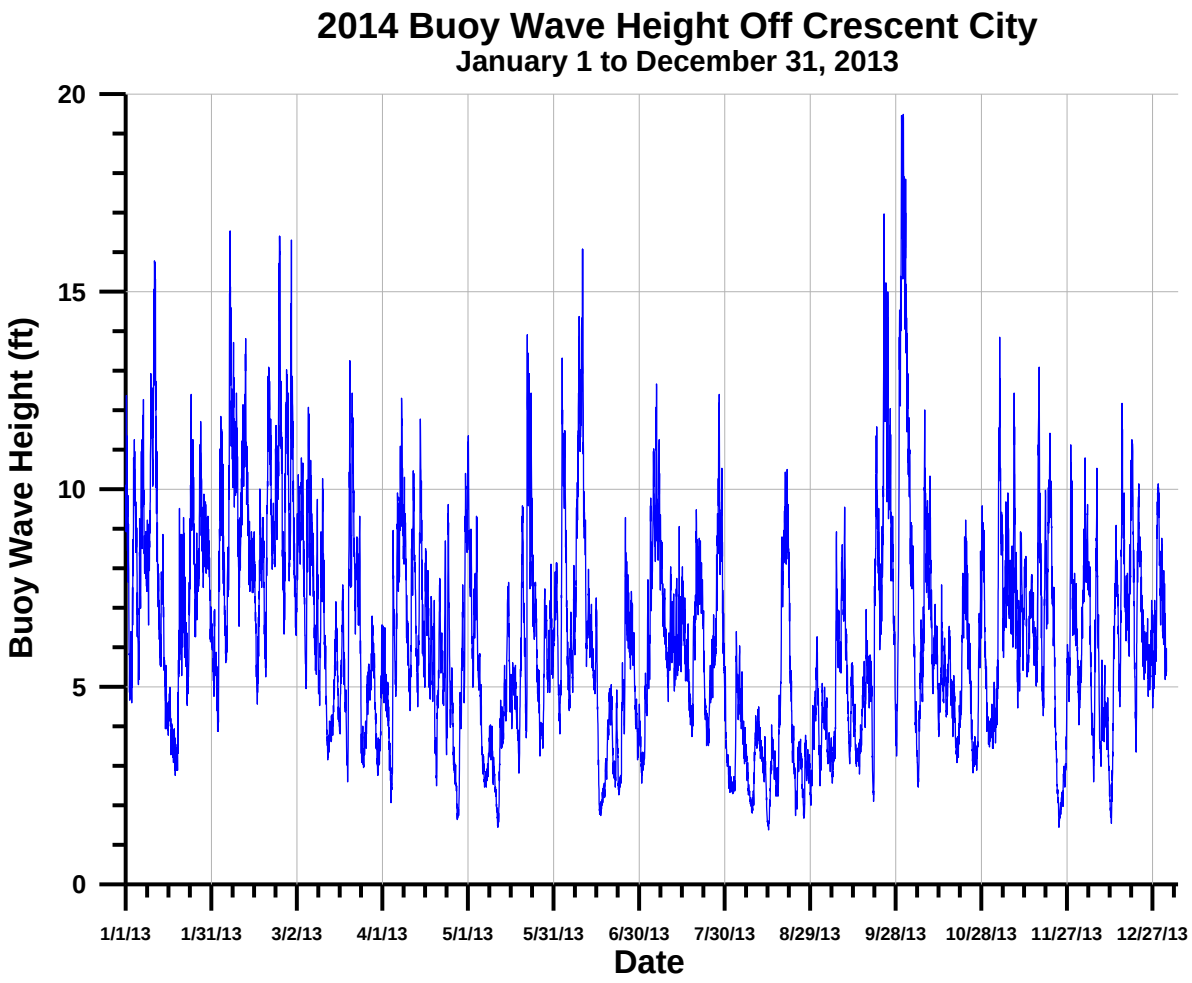
Appendix II. Tides (ft. MSL) calculated at the mouth of Redwood Creek for calendar year 2013.



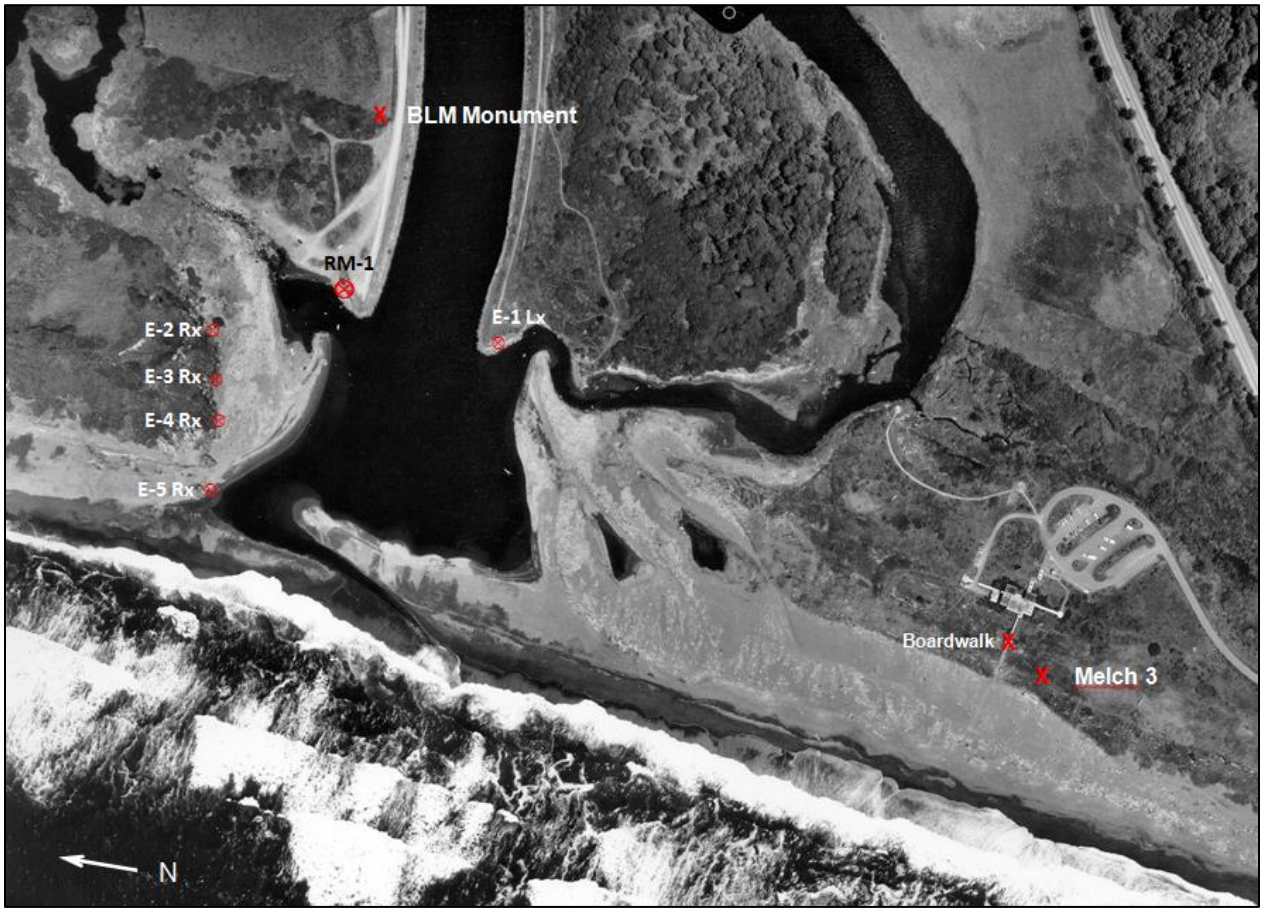
Appendix III. Redwood Creek flow (cfs) at Orick for calendar year 2013.



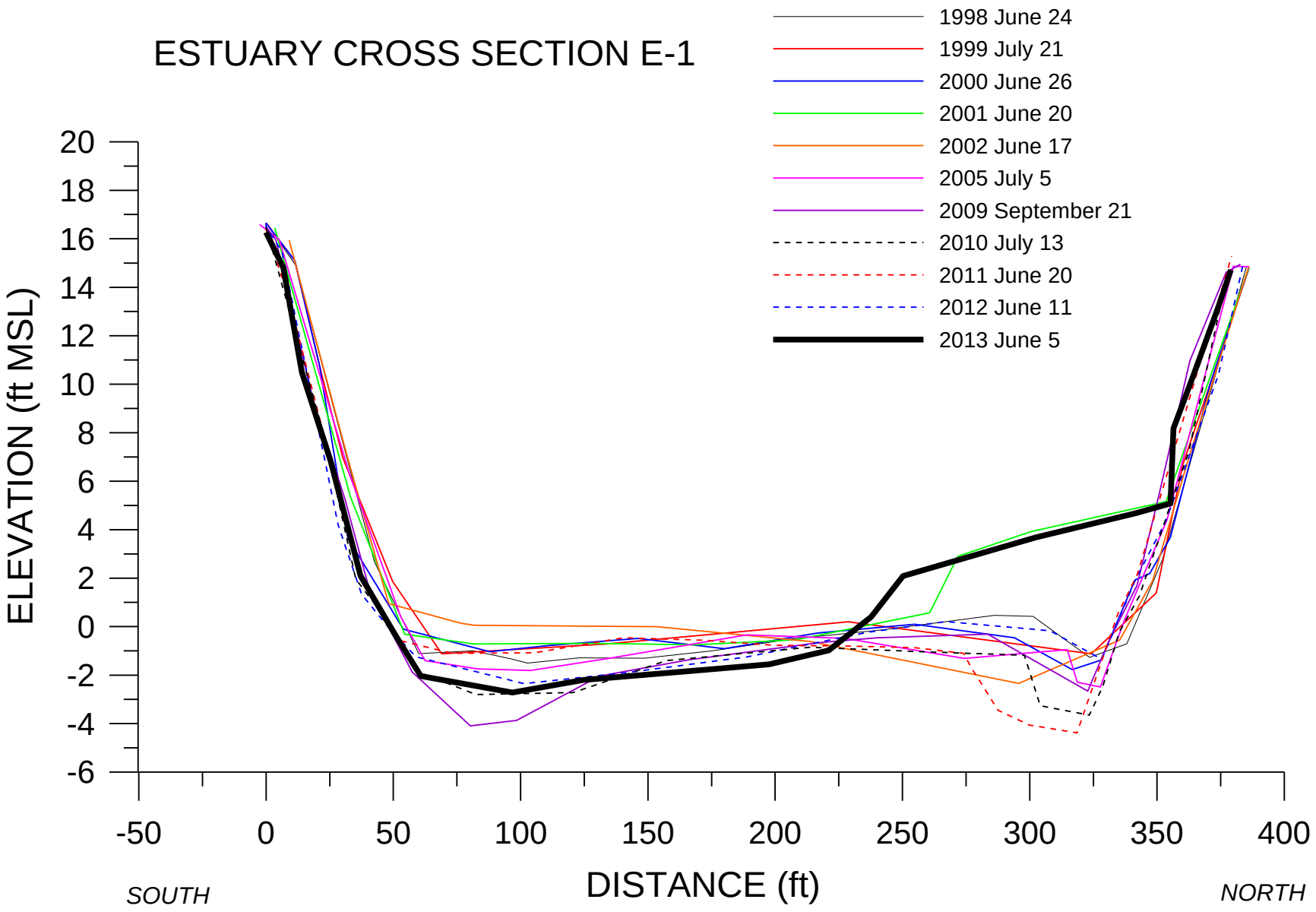
Appendix IV. Ocean wave heights (ft) measured hourly at St. Georges Buoy 46027 located 8 nm NW of Crescent City, California for 2013.

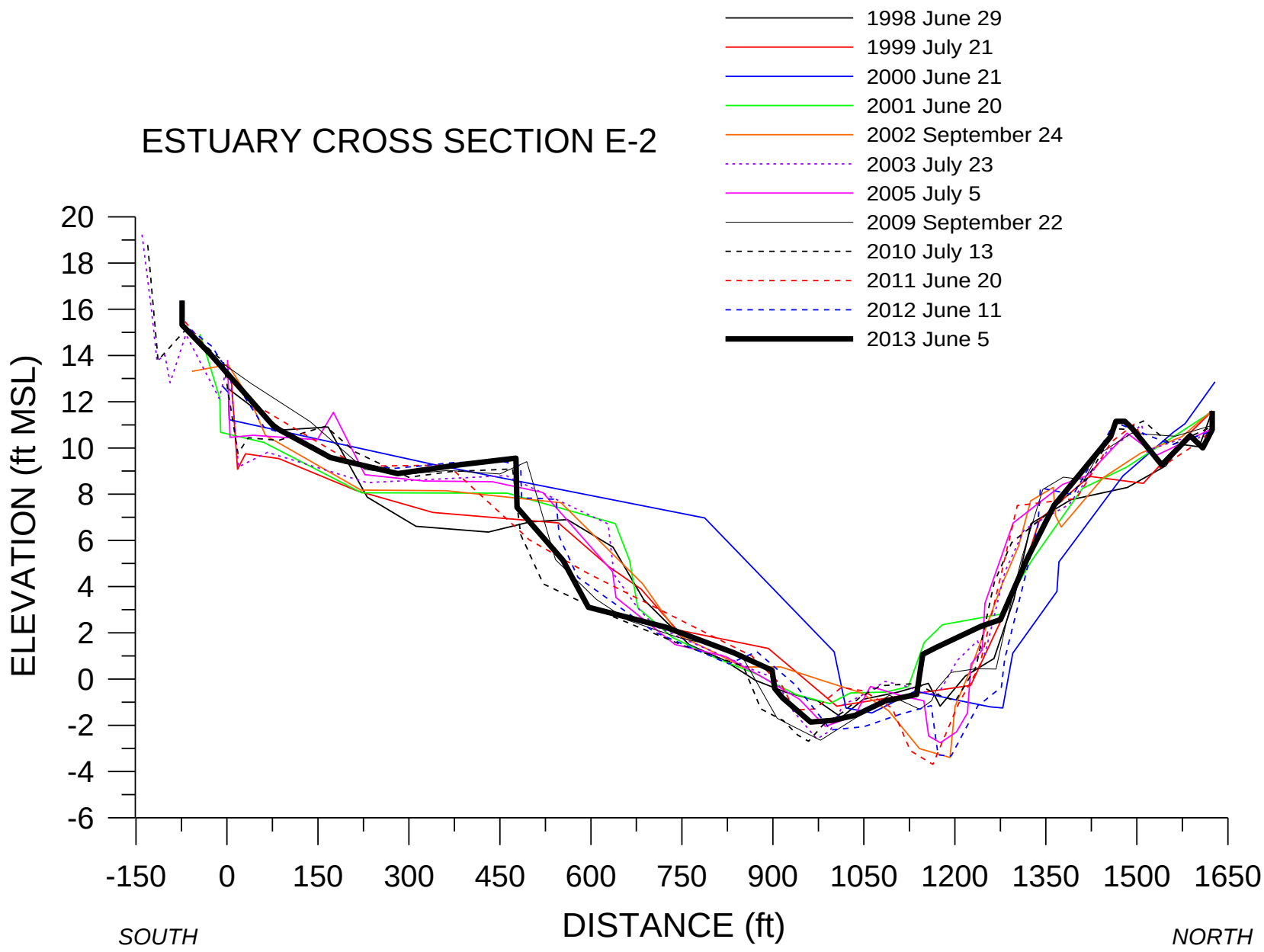


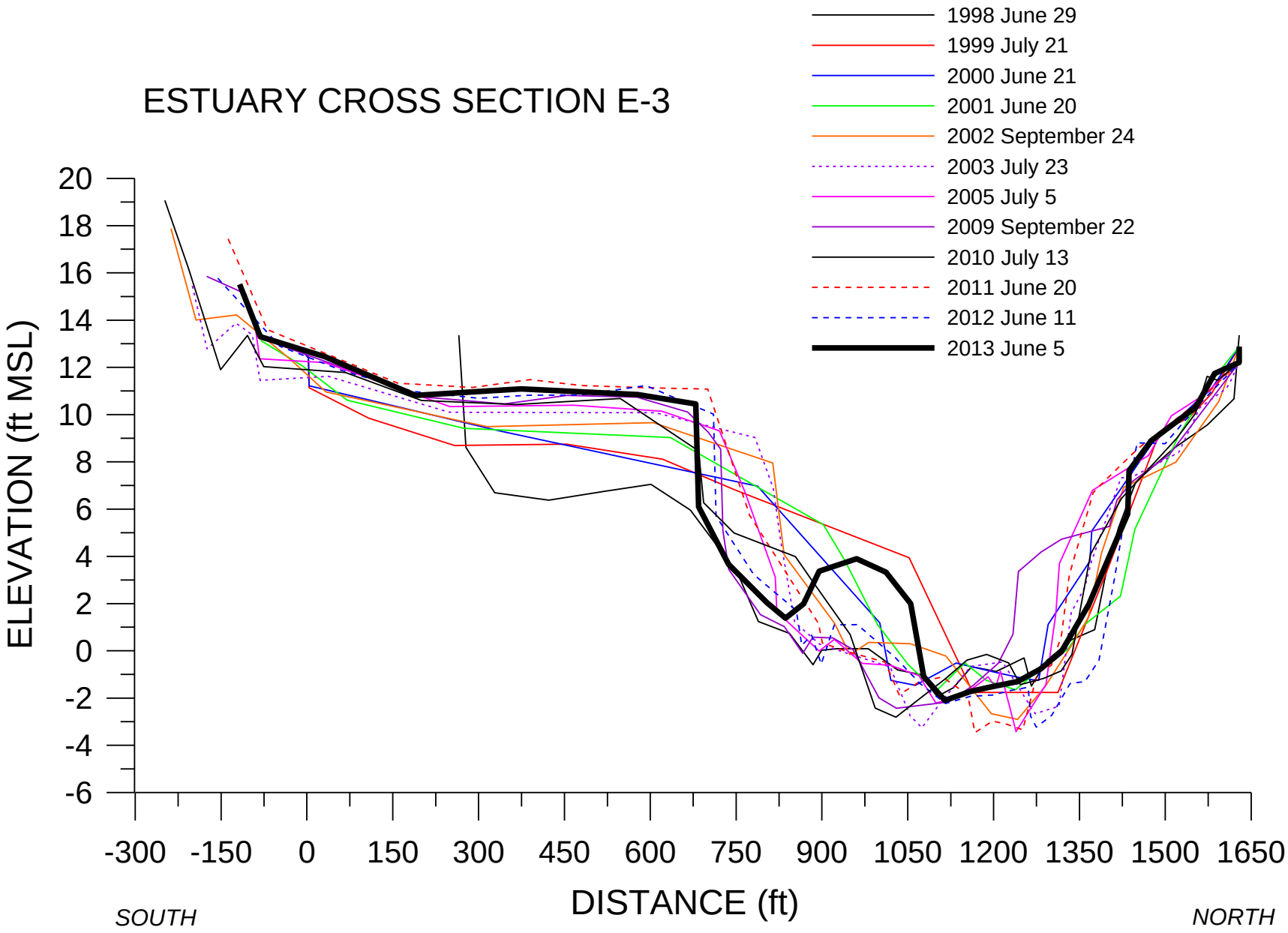
Appendix V. Five permanent cross-sections (E-1 through E-5) surveyed June 5, 2013 in the Redwood Creek estuary embayment perpendicular to the channel. Established in 1998, each cross-section was shot at a bearing of 170° from the north endpoints through the embayment to the sand dunes on the south. The five parallel cross-sections start between the ends of the levees with E-1 and end at the west with E-5 at the sea stack adjacent to the beach.

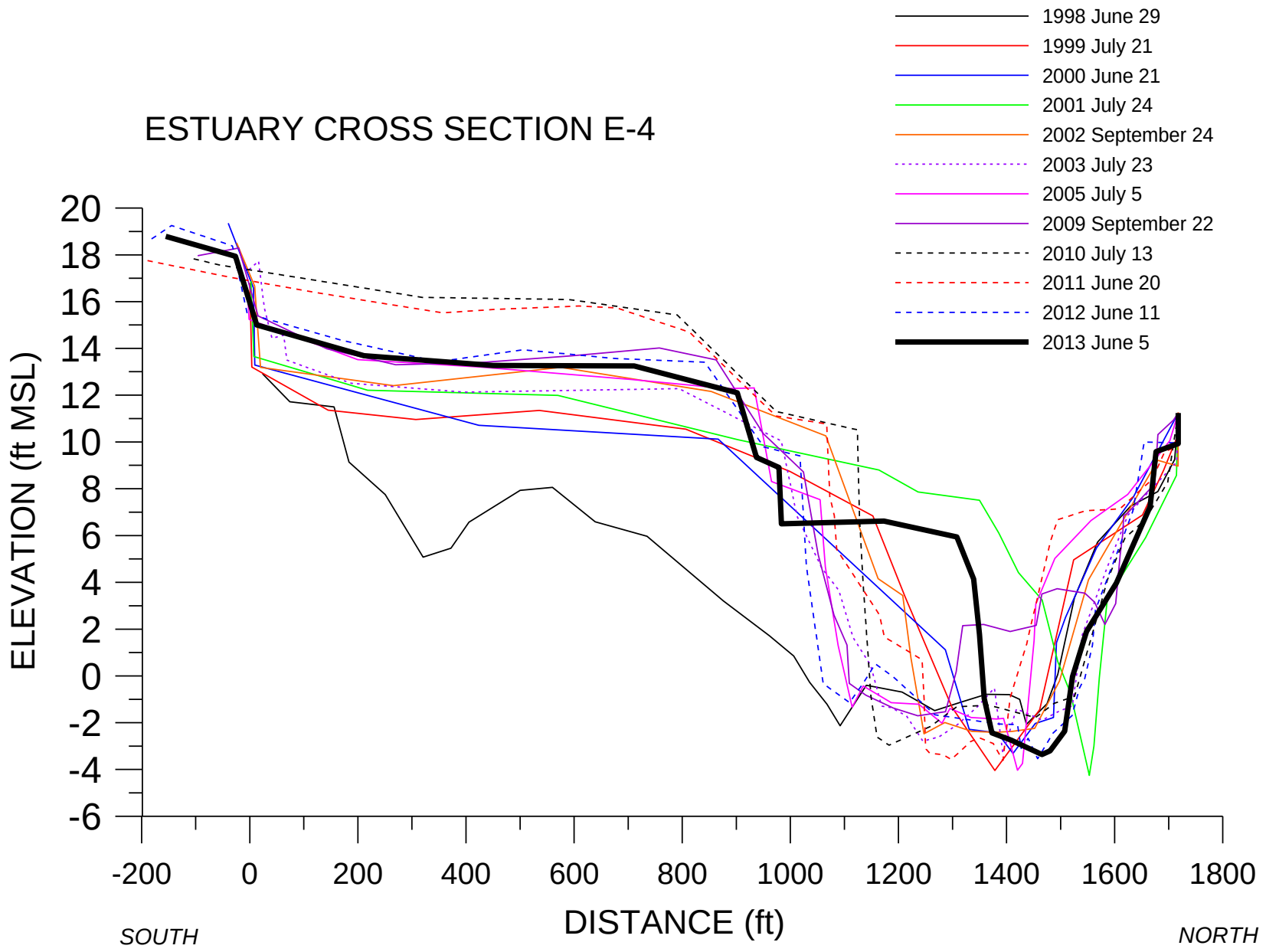


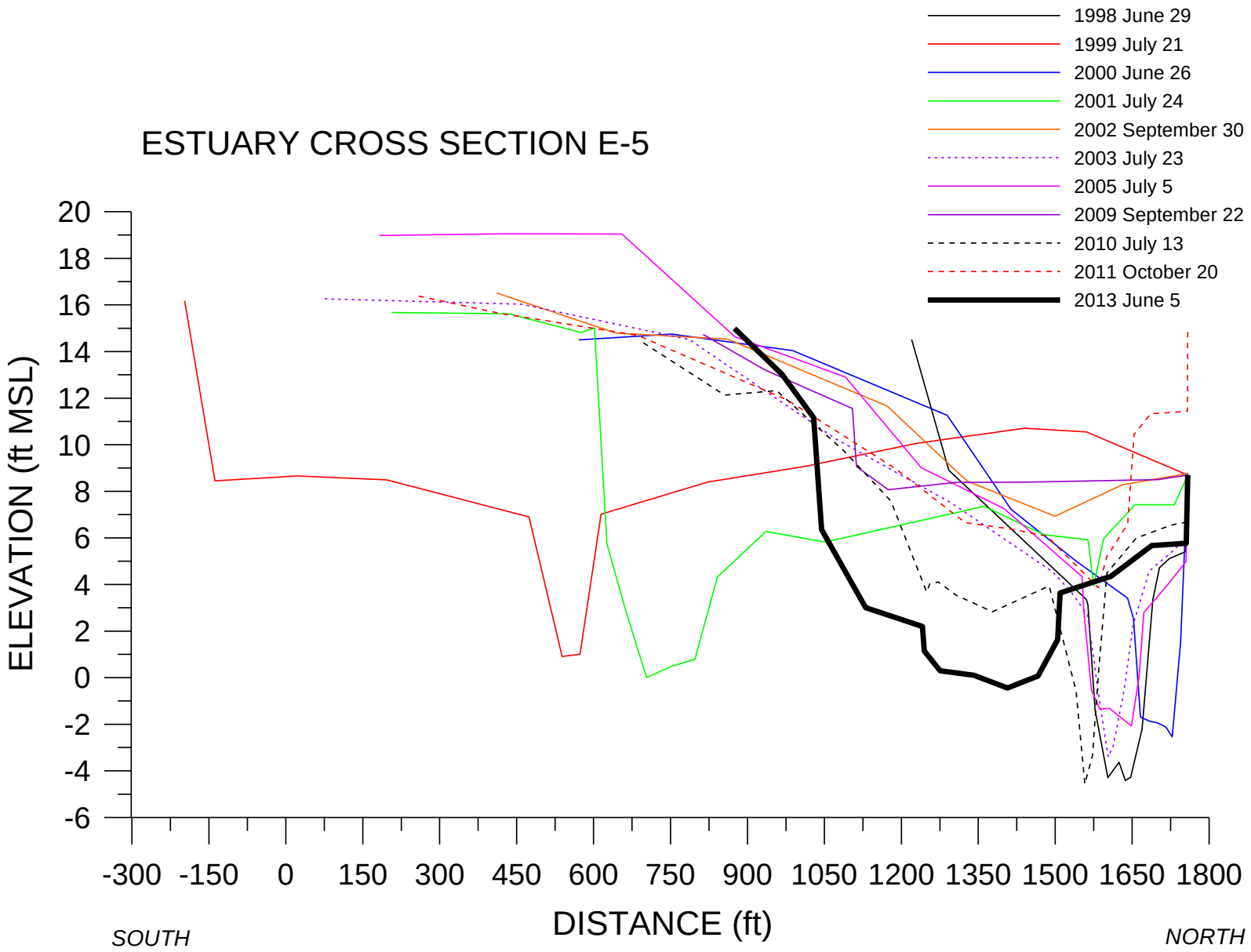
Redwood Creek Estuary Cross Section End Points and Reference Monuments


ESTUARY CROSS SECTION E-1
1998 June 24
1999 July 21
2000 June 26
2001 June 20
2002 June 17
2005 July 5
2009 September 21
2010 July 13
2011 June 20
2012 June 11
2013 June 5
ELEVATION (ft MSL)
20
18
16
14
12
10
8
6
4
2
0
-2
-4
-6
-50
0
50
100
150
200
250
300
350
400
DISTANCE (ft)
SOUTH
NORTH


ESTUARY CROSS SECTION E-2
1998 June 29
1999 July 21
2000 June 21
2001 June 20
2002 September 24
2003 July 23
2005 July 5
2009 September 22
2010 July 13
2011 June 20
2012 June 11
2013 June 5
ELEVATION (ft MSL)
20
18
16
14
12
10
8
6
4
2
0
-2
-4
-6
-150
0
150
300
450
600
750
900
1050
1200
1350
1500
1650
DISTANCE (ft)
SOUTH
NORTH

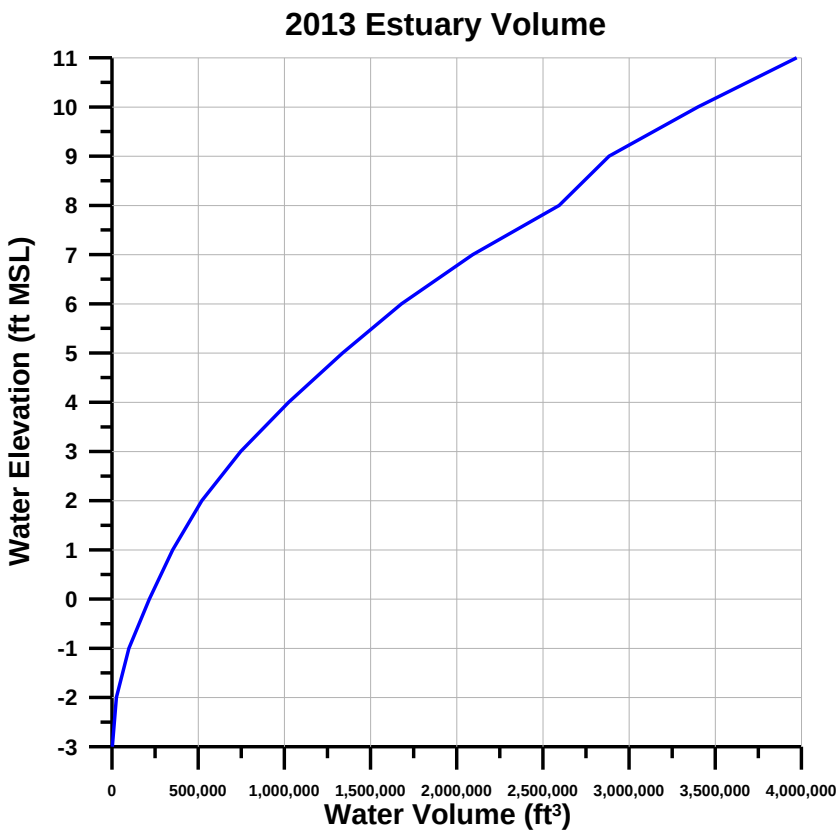

ESTUARY CROSS SECTION E-3
1998 June 29
1999 July 21
2000 June 21
2001 June 20
2002 September 24
2003 July 23
2005 July 5
2009 September 22
2010 July 13
2011 June 20
2012 June 11
2013 June 5
ELEVATION (ft MSL)
20
18
16
14
12
10
8
6
4
2
0
-2
-4
-6
-300
-150
0
150
300
450
600
750
900
1050
1200
1350
1500
1650
DISTANCE (ft)
SOUTH
NORTH


ESTUARY CROSS SECTION E-4
1998 June 29
1999 July 21
2000 June 21
2001 July 24
2002 September 24
2003 July 23
2005 July 5
2009 September 22
2010 July 13
2011 June 20
2012 June 11
2013 June 5
ELEVATION (ft MSL)
20
18
16
14
12
10
8
6
4
2
0
-2
-4
-6
-200
0
200
400
600
800
1000
1200
1400
1600
1800
DISTANCE (ft)
SOUTH
NORTH


ESTUARY CROSS SECTION E-5
1998 June 29
1999 July 21
2000 June 26
2001 July 24
2002 September 30
2003 July 23
2005 July 5
2009 September 22
2010 July 13
2011 October 20
2013 June 5
ELEVATION (ft MSL)
20
18
16
14
12
10
8
6
4
2
0
-2
-4
-6
-300
-150
0
150
300
450
600
750
900
1050
1200
1350
1500
1650
1800
DISTANCE (ft)
SOUTH
NORTH

Appendix VI. Calculated volume (ft^3) of the Redwood Creek embayment at water elevations of –3 to 11 ft MSL based on the five cross sections E-1 through E-5 surveyed on June 5, 2013 (left). Volume of embayment is defined as the area west of the ends of the north and south levee and not including the north or south outlet channels or sloughs. Embayment water elevation versus volume (right).

Water Elev. (MSL ft)	Estuary Volume (ft^3)
11	3,972,857
10	3,398,407
9	2,883,842
8	2,594,229
7	2,093,240
6	1,679,603
5	1,338,332
4	1,024,443
3	746,538
2	521,091
1	352,241
0	216,444
-1	97,906
-2	25,366
-3	1,882



Appendix VII. Photographs of 2013 Redwood Creek Estuary Monitoring.

Chinook salmon at feet of person in the shallows along the shore of the Redwood Creek estuary on June 6, 2013. Fish did not appear to be scared and hung around where people were standing and walking. When the sand was disturbed the fish would swim through, maybe looking for food.

Juvenile Dungeness crab seined in Redwood Creek estuary on July 9, 2013.

Pink sand verbena (Abronia umbellate), a coastal dune plant found growing in the sand next to the estuary (July 11, 2013). Not federally or state listed, the plant is ranked as seriously endangered in California by the California Native Plant Society.

New Zealand Mud Snails (Potamopyrgus antipodarum) in the South Slough Outlet Channel after the estuary breached (September 23, 2013).

Sacramento Sucker (Catostomus occidentalis) seined in the Redwood Creek estuary on August 22, 2013.

KVC wetland fish trapping with minnow traps adjacent to the South Slough in the 'boardwalk channel (September 24, 2013).

Dewatered Corophium tubes and Corophium (circled) after the Redwood Creek estuary breach (September 23, 2013).

Deposited driftwood in the North Slough outlet channel (September 23, 2013).

Redwood National and State Parks were established to preserve significant examples of the primeval coastal redwood forests and the prairies, streams, seashore, and woodlands with which they are associated for purposes of public inspiration, enjoyment, and scientific study, and to preserve all related scenic, historical, and recreational values.