

Redwood

National Park

National Park Service
US Department of the Interior



2015 Redwood Creek Estuary Monitoring



Fish and Wildlife Branch
June 2016



Front Cover (Summer/Fall 2015 – RNP photos)

Top Left: Retrieving water level gage in Redwood Creek Estuary.

Top Right: Processing tent and boat at sand berm of Redwood Creek Estuary.

Middle: A very large staghorn sculpin seined in the Redwood Creek Estuary.

Middle Right: Towing the boat out of the water through the sand.

Bottom: Fish and Wildlife Branch crewmembers and volunteer (backrow) with students and instructors from the OMSI documentary film camp (front row).

Back Cover (Winter 2015 – RNP photos)

Top: King tide at the mouth of Redwood Creek on December 23, 2015.

Bottom: Waves propagating up Redwood Creek Estuary during King Tide of December 23, 2015

Table of Contents

2015 Estuary Monitoring Summary.....	1
Introduction	2
Location	2
Methods.....	2
Fish Monitoring.....	2
Population Estimates.....	2
Growth Estimates.....	4
Condition Factor	4
PIT Tagged Fish.....	4
Physical Monitoring.....	4
Water Temperature	4
Embayment Water Level Gaging.....	4
Tide, Ocean Waves, Stream Flow, and Precipitation	5
Estuary Cross-sections	5
2015 Results.....	5
Fish Monitoring.....	5
Sampling Dates	5
Seines and Fish Handled.....	5
Fish Presence	6
Other Species	10
Population Estimates.....	11
Chinook Salmon.....	11
Coho Salmon.....	11
Steelhead Trout	13
Coastal Cutthroat Trout.....	13
Snorkel Survey.....	13
Other Species	13
Growth Estimates.....	13
Chinook Salmon.....	13
Coho Salmon.....	15
Steelhead Trout	15
Coastal Cutthroat Trout.....	17

Condition Factor (K')	17
PIT Tagged Fish.....	17
Physical Monitoring.....	19
Water Temperature	19
Tides at the Mouth of Redwood Creek	20
Ocean Wave Height	20
Stream Flow	20
Embayment Water Level Gaging.....	20
July 26 Closure	20
Events Leading Up to the November 15 Breach	24
November 15 Breach	25
Estuary Cross Sections.....	25
Estuary Volume	25
South Slough Culvert Gates.....	25
Other	25
OMSI.....	25
Homeless Encampments	25
CDFW Downstream Migrant Trapping.....	25
Population Abundance	25
Growth	26
References	27
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 2015. Fish fins; top, middle, and bottom caudal, and anal fins were marked with a Panjet needleless injector using Alcian Blue dye. Formulas used to calculate population estimate and its 95% confidence interval.....	28
Appendix II. Tides (ft. MSL) calculated at the mouth of Redwood Creek for calendar year 2015.....	29
Appendix III. Redwood Creek flow (cfs) for 2015 calendar year as measured at the Orick (ORK) gaging station.....	30
Appendix IV. Five permanent cross-sections (E-1 through E-5) surveyed June 8, 2015 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 to the west with E-5 at the sea stack adjacent to the beach. 31

Appendix V. Top: Calculated volume (ft³) of the Redwood Creek embayment at water elevations of –3 to 11 ft MSL based of the five cross sections E-1 through E-5 surveyed on June 8, 2015. 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. Bottom: Embayment water elevation versus volume.....37

Acknowledgements.....38

List of Figures

- Figure 1. Aerial photo of the Redwood Creek Estuary, Humboldt County, California, including the embayment, north and south sloughs, levees, and south levee gated culverts (Google Earth July 14, 2015) 3
- Figure 2. Juvenile Chinook salmon (top) and steelhead trout (bottom) seined October 28, 2015 in the Redwood Creek Estuary (RNP 2015 6
- Figure 3. Rockfish juvenile (top left), Cabezon juvenile (top right), Pacific Herring (bottom left), and Shiner Surfperch (bottom right), fish caught in the Redwood Creek estuary during the Summer/Fall 2015 sampling period (RNP 2015). 10
- Figure 4. Floating algal mats at river mile 1.4 in lower Redwood Creek between the levees on September 3, 2015 (RNP 2015). 11
- Figure 5. Fork length (mm) versus frequency (%) histogram of Redwood Creek estuary juvenile chinook sampled June 1 through October 28, 2015. The fork length intervals were 10-mm increments 15
- Figure 6. Fork length (mm) histogram of Redwood Creek estuary juvenile coho salmon sampled June 1, 2, 4, and July 7, 2015. The fork length intervals were 5-mm 16
- Figure 7. Fork length (mm) versus frequency (%) histogram of Redwood Creek estuary juvenile steelhead trout sampled June 1 through October 28, 2015. The fork length intervals were 10-mm increments. Several age classes are present.....16
- 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 from the bottom, recorded water temperature every 1-hour from June 4 to October 28, 2015.....19

Figure 9. Ocean wave heights (ft) measured hourly by Buoy 46022 located 17 nm WSW of Eureka and Buoy 46027 located 8 nm NW of Crescent City, California, and Redwood Creek estuary closure and breaching dates	21
Figure 10. Water level elevations (ft. Mean Sea Level [MSL]) recorded in the Redwood Creek estuary, Humboldt County, California for May 13 to November 18, 2015.....	22
Figure 11. Redwood Creek estuary water levels and tides at the mouth of Redwood Creek May 13 to November 18, 2015.....	23
Figure 12. Redwood Creek flow (cfs) for May 10 to November 21, 2015.....	24

Lists of Tables

Table 1. List of salmonid and non-salmonid fish seined, birds, amphibians, mammals, invertebrates, and algae observed at the Redwood Creek estuary, Redwood National Park, Humboldt County, California during the summer/fall 2015 fish sampling (shading denotes presence).....	7
Table 2. Population estimates and 95 percent confidence intervals for juvenile chinook and coho salmon, juvenile steelhead, and coastal cutthroat trout seined in the Redwood Creek estuary embayment, Humboldt County, California, summer/fall 2015. Mouth of creek denotes if Redwood Creek mouth was open or closed to the Pacific Ocean during the estimate.	12
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/fall of 2015 from June 1 to October 28. Mouth denotes if creek mouth was open or closed.....	14
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 estuary, Humboldt County, California, during the summer and fall of 2005. Condition factor is calculated as: $K' = 100W_{(g)} / FKL_{(cm)}^b$. Slope (b) was calculated as: $\log_{10} \text{Weight}_{(g)} = \log_{10} a + b \log_{10} \text{Fork Length}_{(cm)}$	18
Table 5. PIT tagged fish recaptured in the Redwood Creek estuary in 2015	17
Table 6. Estimated population abundance of juvenile salmonids from CDFW downstream migrant rotary screw trapping on lower Redwood Creek and the mouth of Prairie Creek, 2015	26

2015 Estuary Monitoring Summary

The Redwood Creek estuary was monitored in Summer/Fall 2015. Four juvenile salmonid population estimates were conducted, the weeks of June 1, July 6, August 10, and September 14. Five growth estimates were conducted, four in conjunction with population estimates and one on October 28. Embayment water elevations were recorded every 15 minutes from May 13 to November 18. A temperature logger recorded water temperature in the embayment every hour from June 4 through October 28. The five estuary cross sections were surveyed on June 8.

- Estimated estuary salmonid populations decreased through the summer.
 - The estuary chinook population decreased 81 % from 39,110 in June to 7,350 in July.
 - The estuary steelhead population crashed in July with only 16 steelhead caught.
 - A total of 126 juvenile coho salmon were caught in the estuary during summer 2015, 125 during the week of June 1, and two the week of July 6. This is similar to previous years where coho do not reside in the estuary throughout the summer and fall
 - A total of 2 coastal cutthroat trout were caught during the 2015 season.
 - Only 17 chinook and 6 steelhead were caught on October 28.
 - The total number of seine hauls in 2015 was 107. Increased seining effort later in the season did not result in increased numbers of fish caught.
- Mean lengths and weights of juvenile chinook and steelhead increased during the summer and fall. Fish that remained in the estuary were larger than those that immigrated to the ocean prior to the July 26 closure. The larger size would confer increased survival in the ocean.
 - Mean chinook fork length increased from 71 mm in June to 113 mm in October, a 42 mm increase.
 - Mean steelhead fork length increased from 113 mm in June to 176 mm in October, a 63 mm increase.
 - Mean coho salmon fork length was 109 mm in June.
- Water temperatures in the embayment were warm. The maximum and minimum temperatures measured between June 4 and October 28 were 21.9°C and 12.4°C, respectively. The average water temperature for this period was 16.8°C.
 - The warmest month was August, the mean at 18.6°C, followed by September at 18.0°C.
 - Diurnal water temperatures, minimums and maximums, were related to the tidal cycle when the mouth was open.
- The Redwood Creek estuary closed on July 26 and remained closed for 112.6 days until it breached on November 15 at 9.0 ft MSL.
 - Based on flow and precipitation data, the estuary breaching was presumed to be a natural event and not human caused.
 - The highest recorded water elevation in the estuary was 9.0 ft MSL, the lowest 0.75 ft MSL.

2015 Redwood Creek Estuary Monitoring

Introduction

This report summarizes 2015 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 estuary monitoring is to estimate fish population numbers and growth; record estuary water quality and water elevations; determine cross section changes; and document breaching incidents.

Monitoring was initiated to determine how fish were using the estuary. Monitoring continued because the Redwood Creek estuary is impaired. The Redwood Creek Flood Control Project in Orick, 3.4 miles of levees and associated infrastructure completed by the US Army Corps of Engineers in 1968 altered the form, function, resiliency, and biological productivity of the estuary and lower river. The flood control levees changed the estuary configuration and water circulation reducing water quality. Approximately 50% of the estuary has filled in with sediment and/or become isolated from the embayment. As a consequence, quantity and quality of salmonid habitat has decreased. The estuary is not entirely within the national park. Private lands, primarily agricultural pastures, occupy areas that once contained sloughs, high-flow channels and riparian floodplain forest, key elements that contributed to the biological functioning of the estuary. Restoration of hydraulic, sediment transport, and floodplain processes is needed to help the estuary regain some of its former form and physical and biological function to support salmonid habitat.

Threatened juvenile salmonids rear in the Redwood Creek estuary in summer and fall. Impaired estuary function is a limiting factor for salmonid production in the Redwood Creek watershed. Fish studies on extended estuary rearing for chinook (Riemers 1973) and steelhead (Bond, et al. 2008) has shown increased ocean survival and return as spawning adults.

Location

Redwood Creek estuary is located 2.5 miles west of Orick, California at the confluence of Redwood Creek with the Pacific Ocean. Redwood Creek is 108 km long and the watershed is 720 km² in area. The U.S. Army Corps of Engineers flood control levees bisect and terminate in the estuary. The estuary consists of the north and south sloughs, and the embayment (Figure 1). Historically, the south slough was the last meander of the river and is bypassed by the south levee. The south slough is now connected to mainstem Redwood Creek by gated culverts.

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-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 north and south levee rip-rap. A blue mark was applied to the upper, middle, or lower caudal fin or anal fin



Figure 1. Aerial photo of the Redwood Creek Estuary, Humboldt County, California, including the embayment, north and south sloughs, levees, and south levee gated culverts (Google Earth July 14, 2015)

of Alka-Seltzer Gold 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 are 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 are conducted, one each in June, July, August, and September.

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 $\pm$ 0.01g capacity balance for smaller fish, and a 5,000 g $\pm$ 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 and a fifth in October.

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: $K' = (100 \times \text{Weight}_{(g)}) / \text{Fork Length}_{(cm)}^b$ (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) and Humboldt State University USGS Cooperative Fish and Wildlife Unit (Fish Coop) coho studies in Prairie Creek and its tributaries are tagged with passive integrated transponders (PIT) tags. Each tag has an individual unique number and are implanted in the body cavity of the fish. During processing of the fish seined in the estuary, a PIT tag reader is used to scan every fish. A separate reader was borrowed from the Fish Coop in June and July when coho would be present as the park reader did not read their tags.

Physical Monitoring

Water Temperature - In summer/fall 2015, water temperature ($^{\circ}\text{C}$) was measured hourly in the Redwood Creek embayment with an Onset TIDBIT temperature logger (S/N 2401073). It was located in the Redwood Creek channel beyond the ends of the north and south flood control levees (UTM 408801E/4571716N 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 coastal, stream, and floodplain processes that influence estuary volume, the location of the creek mouth, opening and closing of the mouth, and flooding in the lower valley. Redwood Creek embayment water elevation (feet 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 (UTM 408801E/4571708N NAD83). The estuary data logger is a temporary gaging station, installed in May when the creek mouth is

open to the ocean 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 SOC, 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 was 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 NOAA buoy 46022 located 17 nautical miles (nm) WSW of Eureka and 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 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 from 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.

2015 Results

Fish Monitoring

Sampling Dates –The Redwood Creek estuary embayment was sampled five times during the summer/fall of 2015 for four population and five growth estimates. Population sample dates were; June 1, 2, and 4; July 6, 7, and 9; August 10, 11, and 13; and September 14, 15, and 17, 2015. Growth measurements were conducted during the four populations estimates and a fifth on October 28.

Seines and Fish Handled - The total number of estuary seine hauls in 2015 was 107. The numbers of salmonid fish processed were 3,232 juvenile chinook (9 incidental mortalities, 0.28%), 525 steelhead (0 incidental mortality), 127 coho smolts (0 incidental mortality), and 2 coastal cutthroat (0 incidental mortality) for a total of 3,885 fish and nine mortalities (0.23%). Authorization for handling threatened fish was under Redwood National Park's 4(d) NOAA/CDFW permit #19153, CDFW Scientific Collecting Permit #SC-10028, and CDFW CESA MOU for coho salmon.

Fish Presence – During the summer/fall of 2015 four salmonid species were seined in the Redwood Creek embayment; chinook, coho, and steelhead and coastal cutthroat trout (Table 1 and Figure 2). Juvenile chinook and steelhead were present on all sample dates between June 1 and October 28. Cutthroat were captured in June. Coho salmon were captured in June and an additional two on July 7.



Figure 2. Juvenile Chinook salmon (top) and steelhead trout (bottom) seined October 28, 2015 in the Redwood Creek Estuary (RNP 2015).

In addition to the juvenile salmonids, 10 additional fish species were captured, five that are usually associated with estuaries: Staghorn Sculpin (*Leptocottus armatus*), Prickly Sculpin (*Cottus asper*), Threespine Stickleback (*Gasterosteus aculeatus*), Starry Flounder (*Platichthys stellatus*) and Shiner Surfperch (*Cymatogaster aggregate*), and five associated with the marine environment: Surfsmelt (*Hypomesus pretiosus*), Pacific Herring (*Clupea pallasii*), Saddleback Gunnel (*Pholis ornate*), Cabezon (*Scorpaenichthys marmoratus*), and rockfish juveniles (*Sebastes sp.*) (Figure 3). Marine species presence is due to the mouth of the creek being open to the ocean and tidal action into the estuary.

Of the fish captured, chinook (California Coastal Chinook Salmon Evolutionarily Significant Unit [ESU]), coho (Southern Oregon/Northern California Coast Coho ESU), and steelhead

Table 1. List of salmonid and non-salmonid fish seined, birds, amphibians, mammals, invertebrates, and algae observed at the Redwood Creek estuary, Redwood National Park, Humboldt County, California during the summer/fall 2015 fish sampling (shading denotes presence).

Species		2015 Observations				
Common Name	Scientific Name	June 1 ^a	July 6 ^a	August 10 ^a	September 14 ^a	October 28
Salmonid Fish						
Chinook Salmon *	<i>Oncorhynchus tshawytscha</i>					
Coastal Cutthroat Trout	<i>Oncorhynchus clarki</i>					
Coho Salmon *	<i>Oncorhynchus kisutch</i>					
Steelhead Trout *	<i>Oncorhynchus mykiss</i>					
Other Fish						
Cabezon (juvenile)	<i>Scorpaenichthys marmoratus</i>					
Pacific Herring	<i>Clupea pallasii</i>					
Prickly Sculpin	<i>Cottus asper</i>					
Rockfish (juvenile)	<i>Sebastes sp.</i>					
Saddleback Gunnel	<i>Pholis ornata</i>					
Shiner Surfperch	<i>Cymatogaster aggregata</i>					
Staghorn Sculpin	<i>Leptocottus armatus</i>					
Starry Flounder	<i>Platichthys stellatus</i>					
Surf Smelt	<i>Hypomesus pretiosus</i>					
Three Spine Stickleback	<i>Gasterosteus aculeatus</i>					
Birds						
Aleutian Cackling Geese	<i>Branta hutchinsii leucopareia</i>					
American Crow	<i>Corvus brachyrhynchos</i>					
American Goldfinch	<i>Carduelis tristis</i>					
American Pipit	<i>Anthus rubescens</i>					
American Robin	<i>Turdus migratorius</i>					
Anna's Hummingbird	<i>Calypte anna</i>					
Barn Swallow	<i>Hirundo rustica</i>					
Belted Kingfisher	<i>Ceryle alcyon</i>					
Black Oystercatcher	<i>Haematopus bachmani</i>					
Black Phoebe	<i>Sayornis nigricans</i>					
Black-capped Chickadee	<i>Poecile atricapillus</i>					
Black-crowned Night Heron	<i>Nycticorax nycticorax</i>					
Brown Pelican	<i>Pelecanus occidentalis</i>					
Brown-headed Cowbird	<i>Molothrus ater</i>					
California Gull	<i>Larus californicus</i>					
Canada Goose	<i>Branta canadensis</i>					
Caspian Tern	<i>Sterna caspia</i>					
Cassin's Vireo	<i>Vireo cassinii</i>					
Cedar Waxwing	<i>Bombycilla cedrorum</i>					
Chestnut-backed Chickadee	<i>Poecile rufescens</i>					
Cliff Swallow	<i>Petrochelidon pyrrhonota</i>					

Species		2015 Observations				
Common Name	Scientific Name	June 1 ^a	July 6 ^a	August 10 ^a	September 14 ^a	October 28
Common Merganser	<i>Mergus merganser</i>					
Common Murre	<i>Uria aalge</i>					
Common Raven	<i>Corvus corax</i>					
Common Yellowthroat	<i>Geothlypis trichas</i>					
Dark-eyed Junco	<i>Junco hyemalis</i>					
Double-crested Cormorant	<i>Phalacrocorax auritus</i>					
Downy Woodpecker	<i>Picoides pubescens</i>					
Elegant Tern	<i>Sterna elegans</i>					
Glaucous-winged Gull	<i>Larus glaucescens</i>					
Golden-crowned Kinglet	<i>Regulus satrapa</i>					
Great Blue Heron	<i>Ardea herodias</i>					
Great Egret	<i>Ardea alba</i>					
Greater Yellowlegs	<i>Tringa melanoleuca</i>					
Heermann's Gull	<i>Larus heermanni</i>					
Horned Grebe	<i>Podiceps auritus</i>					
Hutton's Vireo	<i>Vireo huttoni</i>					
Killdeer	<i>Charadrius vociferus</i>					
Least Sandpiper	<i>Calidris minutilla</i>					
Mallard Duck	<i>Anas platyrhynchos</i>					
Merlin	<i>Falco columbarius</i>					
Mew Gull	<i>Larus canus</i>					
Northern Flicker	<i>Colaptes auratus</i>					
Orange-crowned Warbler	<i>Vermivora celata</i>					
Osprey	<i>Pandion haliaetus</i>					
Pacific Loon	<i>Gavia pacifica</i>					
Pacific-slope Flycatcher	<i>Empidonax difficilis</i>					
Pacific Wren	<i>Troglodytes pacificus</i>					
Peregrine Falcon	<i>Falco peregrinus</i>					
Purple Finch	<i>Carpodacus purpureus</i>					
Red Crossbill	<i>Loxia curvirostra</i>					
Red-shouldered Hawk	<i>Buteo lineatus</i>					
Ring-billed Gull	<i>Larus delawarensis</i>					
Ruby-crowned Kinglet	<i>Regulus calendula</i>					
Sanderling	<i>Calidris alba</i>					
Song Sparrow	<i>Melospiza melodia</i>					
Semipalmated Plover	<i>Charadrius semipalmatus</i>					
Spotted Sandpiper	<i>Actitis macularius</i>					
Spotted Towhee	<i>Pipilo maculatus</i>					
Steller's Jay	<i>Cyanocitta stelleri</i>					
Surf Scoter	<i>Melanitta perspicillata</i>					
Swainson's Thrush	<i>Catharus ustulatus</i>					
Tree Swallow	<i>Tachycineta bicolor</i>					
Turkey Vulture	<i>Cathartes aura</i>					
Unidentified Cormorants	Phalacrocoracidae					
Unidentified Duck	Anatinae sp.					

Species		2015 Observations				
Common Name	Scientific Name	June 1 ^a	July 6 ^a	August 10 ^a	September 14 ^a	October 28
Unidentified Gull	<i>Larus sp</i>					
Unidentified Hummingbird	<i>Trochilidae sp.</i>					
Unidentified Hawk	<i>Accipiter</i>					
Unidentified Loon	<i>Gavia sp.</i>					
Unidentified Sandpiper	<i>Scolopacidae</i>					
Unidentified Scoters	<i>Melanitta</i>					
Unidentified Sparrow	<i>Passeridae</i>					
Unidentified Swallow	<i>Hirundidae sp</i>					
Unidentified Yellowleg	<i>Scolopacidae</i>					
Vaux's Swift	<i>Chaetura vauxi</i>					
Violet-green Swallow	<i>Tachycineta thalassina</i>					
Warbling Vireo	<i>Vireo gilvus</i>					
Western Grebe	<i>Aechmophorus occidentalis</i>					
Western Gull	<i>Larus occidentalis</i>					
Western Sandpiper	<i>Calidris mauri</i>					
White-crowned Sparrow	<i>Zonotrichia leucophrys</i>					
White-tailed Kite	<i>Elanus leucurus</i>					
Willet	<i>Tringa semipalmata</i>					
Wilson's Warbler	<i>Wilsonia pusilla</i>					
Wrentit	<i>Chamaea fasciata</i>					
Mammals						
Harbor Seal	<i>Phoca vitulina</i>					
Black Bear	<i>Ursus americanus</i>					
Invertebrates						
Amphipod	<i>Corophium sp.</i>					
Caddisfly (larvae)	<i>Limniphilidae</i>					
Comb Jelly	<i>Ctenophora</i>					
Dungeness Crab	<i>Cancer magister</i>					
Isopod	<i>Gnorimosphaeroma sp.</i>					
Mysid Shrimp	<i>Neomysis mercedes</i>					
New Zealand Mud Snail	<i>Potamopyrgus antipodarum</i>					
Sea Slug	<i>Nudibranch</i>					
Scud	<i>Gammarus</i>					
Algae						
Sea Lettuce	<i>Ulva sp.</i>					
Green Algae	<i>Unidentified filamentous species</i>					
^a = the week of						
* = Federally listed as Threatened						



Figure 3. Rockfish juvenile (top left), Cabezon juvenile (top right), Pacific Herring (bottom left), and Shiner Surfperch (bottom right), fish caught in the Redwood Creek estuary during the Summer/Fall 2015 sampling period (RNP 2015).

(Northern California Steelhead Distinct Population Segment) are federally listed as threatened. No endangered tidewater gobies (*Eucyclogobius newberryi*) were captured during estuary seining in 2015. They are no longer present and are presumed extirpated. No threatened eulachon (*Thaleichthys pacificus*) were caught, but two were caught in the CDFW Prairie Creek and Lower Redwood downstream migrant trap in April and May (Sparkman et al. 2016a & b). Pink salmon (*O. gorbuscha*), are known to occur in Redwood Creek, but none were seined in the estuary, though juveniles were captured at the lower (one) and upper (six) CDFW traps (Sparkman 2016a, 2016c).

Other Species - Other non-fish aquatic species were caught, those associated with estuaries: *Corophium*, *Gnorimosphaeroma*, Mysid shrimp, and Dungeness crab; those associated with freshwater, Limniphilid stone case caddisfly nymphs and Gammarus amphipods; and those associated with the ocean, Ctenophora comb jellies and Nudibranch sea slugs. Invasive New Zealand Mud Snails (*Potamopyrgus antipodarum*) were also present in the estuary. A harbor seal and black bear were also seen. Initially when sampling began, sea lettuce (*Ulva sp*) was growing from the gravel substrate of the estuary, but when the mouth closed, unidentified filamentous green algae took over. Upstream of the gated culverts and around the bend, floating algal mats were present in the channel (Figure 4).

In addition, 75 bird species were identified in and adjacent to the Redwood Creek estuary. Several of those are fish predators including the Belted Kingfisher, Common Merganser, Great Blue Heron, Great Egret, Double-crested Cormorant, Caspian and Elegant Terns, and gulls.



Figure 4. Floating algal mats at river mile 1.4 in lower Redwood Creek between the levees on September 3, 2015 (RNP 2015).

Population Estimates – Low numbers of salmonids were estimated in the estuary for Summer/Fall 2015. Later in the season where mark-recapture estimates were not possible due to marked fish not being recaptured, the number of fish caught declined even with increased seining effort.

Four population estimates were conducted on Monday, Tuesday, and Thursday during the weeks of June 1, July 6, August 10, and September 14 (Table 2). The mouth of Redwood Creek was open to the ocean during the June and July estimates, and closed for the remaining two. The number of fish marked, marked recaptures, total individuals captured in the ‘second sample’, total number of seines, and fins marked are presented in Appendix I.

Chinook Salmon - The first juvenile chinook salmon estimate, the week of June 1 was 39,110 (95% Confidence Interval [CI] 24,170 to 54,060). The estimate for the week of July 6 was 7,350 (95% CI 2,850 to 11,840), a decrease of 81percent. For the week of August 10, where no estimate was possible, only 212 chinook were caught in 33 seine hauls. For the week of September 14 estimate, again a mark-recapture estimate was not possible. Only 68 chinook were caught in 29 seine hauls. Though the October 28 growth estimate was not set up as a population estimate, only 17 chinook were caught in eight seine hauls.

Coho Salmon – The week of June 1 population estimate was 2,160 (95% CI 123 [actually caught] to 6,280). During the week of July 6, only two were seined. None were captured the rest of the season.

Table 2. Population estimates and 95 percent confidence intervals for juvenile chinook and coho salmon, juvenile steelhead, and coastal cutthroat trout seined in the Redwood Creek estuary embayment, Humboldt County, California, summer/fall 2015. Mouth of creek denotes if Redwood Creek mouth was open or closed to the Pacific Ocean during the estimate.

2015 DATE	Mouth of Creek (Open or Closed)	Chinook Salmon		Coho Salmon	
		Population Estimate	95% Confidence Interval	Population Estimate	95% Confidence Interval
6/1, 2, 4	OPEN	39,110	$\pm 14,940$ (24,170 – 54,060)	2,160	$\pm 4,120$ (123 ^b - 6,280)
7/6, 7, 9	OPEN	7,350	$\pm 4,490$ (2,850 – 11,840)	2 ^a	---
8/10, 11, 13	CLOSED	212 ^a	---	None Caught	---
9/14, 15, 17	CLOSED	68 ^a	--	None Caught	---
		Steelhead Trout		Cutthroat Trout	
6/1, 2, 4	OPEN	9, 110	$\pm 7,110$ (2,010 – 16,220)	2 ^a	---
7/6, 7, 9	OPEN	16 ^a	---	None Caught	---
8/10, 11, 13	CLOSED	50	± 81 13 ^b - 130	None Caught	---
9/14, 15, 17	CLOSED	18 ^a	---	None Caught	---
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					

Steelhead Trout - The first estimate, the week of June 1 was 9,110 (95% CI 2,010 to 16,220) The estimate for the week of July 6 was not possible. Only 16 steelhead were caught in 24 seine hauls. For the week of August 10, the estimate was 50 (95% CI 13 [actually caught] to 130). The week of September 14 estimate again was not possible, only 18 steelhead were caught in 29 seine hauls. Though the October 28 growth estimate was not set up as a population estimate, only six steelhead were caught in eight seine hauls.

Coastal Cutthroat Trout - For cutthroat trout, two fish were caught during the week of June 1, and none the rest of the season.

Snorkel Survey – On September 3, 2015, four Fish and Wildlife Branch personnel, all with snorkeling experience on Redwood Creek, snorkeled 1.3 km of lower Redwood Creek and estuary ending at the ends of the levees to determine if juvenile fish were abundant above the area usually seined. Only a few fish, including cutthroat were observed along the rip-rapped alder vegetated north levee, none in the center of the channel. At the area of the gated culverts several hundred juvenile salmonids were congregating, possibly ‘pushed’ downstream by the snorkelers. A smaller school of salmonids was encountered downstream of the gated culverts where the two teams of snorkelers met – one swimming upstream from the end of the south levee and the other swimming downstream along the south levee. There were large expanses where no fish were observed.

Other Species – Though not a mark-recapture estimate, on July 9, 2015 several thousand surf smelt were seined near the open mouth along the berm inside the Redwood Creek estuary. During the 2015 season, there were a fair number of juvenile threespine stickleback that were captured in the seine hauls, most small enough to pass through the seine net quarter inch mesh.

Growth Estimates – Five growth estimates were conducted, four in conjunction with the four population estimates during the weeks of June 1, July 6 August 10 and September 15 and a fifth on October 28, 2015 (Table 3). The absence of fish made it difficult to attain the 200 length measurements for chinook in September and October and for steelhead in July, August, September, and October.

Chinook Salmon – A total of 721 juvenile chinook salmon were measured. The fish grew over the summer fall season (Figure 5). Mean fork length increased from 71 to 113 mm, an increase of 42 mm between the week of June 1 and October 28. The smallest fish were measured in June at 50 mm. The largest fish measured was 122 mm in October. The minimum and maximum fork lengths measured the week of June 1 were 50 and 90 mm, respectively; 57 and 94 mm for the week of July 6; 71 and 102 mm for the week of August 10; 82 and 110 mm for the week of September 14; and 100 and 122 mm on October 28.

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/fall of 2015 from June 1 to October 28. Mouth denotes if creek mouth was open or closed.

Growth - Redwood Creek Estuary – Summer/Fall 2015									
2015 DATE	MOUTH	FORK LENGTH (mm)				WEIGHT (g)			
		No. Measured	Mean	Std. Dev	Range	No. Weighed	Mean	Std. Dev.	Range
JUVENILE CHINOOK SALMON									
6/1, 2	OPEN	223	71	8.1	50 - 90	33	4.0	1.3	2.1 – 7.5
7/6	OPEN	206	76	5.7	57 - 94	31	4.9	0.7	3.5 – 6.3
8/10, 11	CLOSED	205	87	4.9	71 - 102	30	7.7	0.9	6.1 – 9.7
9/14, 15, 17	CLOSED	70	93	4.8	82 - 110	30	8.3	1.4	5.9 – 13.3
10/28	CLOSED	17	113	6.3	100 - 122	17	17.4	3.3	10.4 – 21.6
JUVENILE COHO SALMON									
6/1, 2, 4	OPEN	123	109	8.1	91 - 132	103	14.0	3.2	8.4 – 26.1
7/7	OPEN	2	105	9.9	98 - 112	2	11.7	2.5	9.9 – 13.4
8/10, 11, 13	CLOSED	0	---	---	---	0	---	---	---
9/14, 15, 17	CLOSED	0	---	---	---	0	---	---	---
10/28	CLOSED	0	---	---	---	0	---	---	---
JUVENILE STEELHEAD TROUT									
6/1, 2	OPEN	217	113	15.8	61 - 153	30	17.1	7.1	6.1 – 34.1
7/6, 7, 9	OPEN	16	138	19.4	91 - 162	16	29.6	11.0	9.7 – 46.2
8/10, 11, 13	CLOSED	13	106	17.9	84 - 144	13	14.4	7.8	6.8 - 32.9
9/14, 15, 17	CLOSED	18	138	36.1	98 - 195	18	33.3	23.9	10.3 – 73.8
10/28	CLOSED	6	176	45.2	126 - 244	6	62.1	59.1	23.1 - 180
CUTTHROAT TROUT									
6/1, 2, 4	OPEN	2	154	0.0	154 - 154	2	37.4	3.2	35.1 – 39.6
7/6, 7, 9	OPEN	0	---	---	---	0	---	---	---
8/10, 11, 13	CLOSED	0	---	---	---	0	---	---	---
9/14, 15, 17	CLOSED	0	---	---	---	0	---	---	---
10/28	CLOSED	0	---	---	---	0	---	---	---

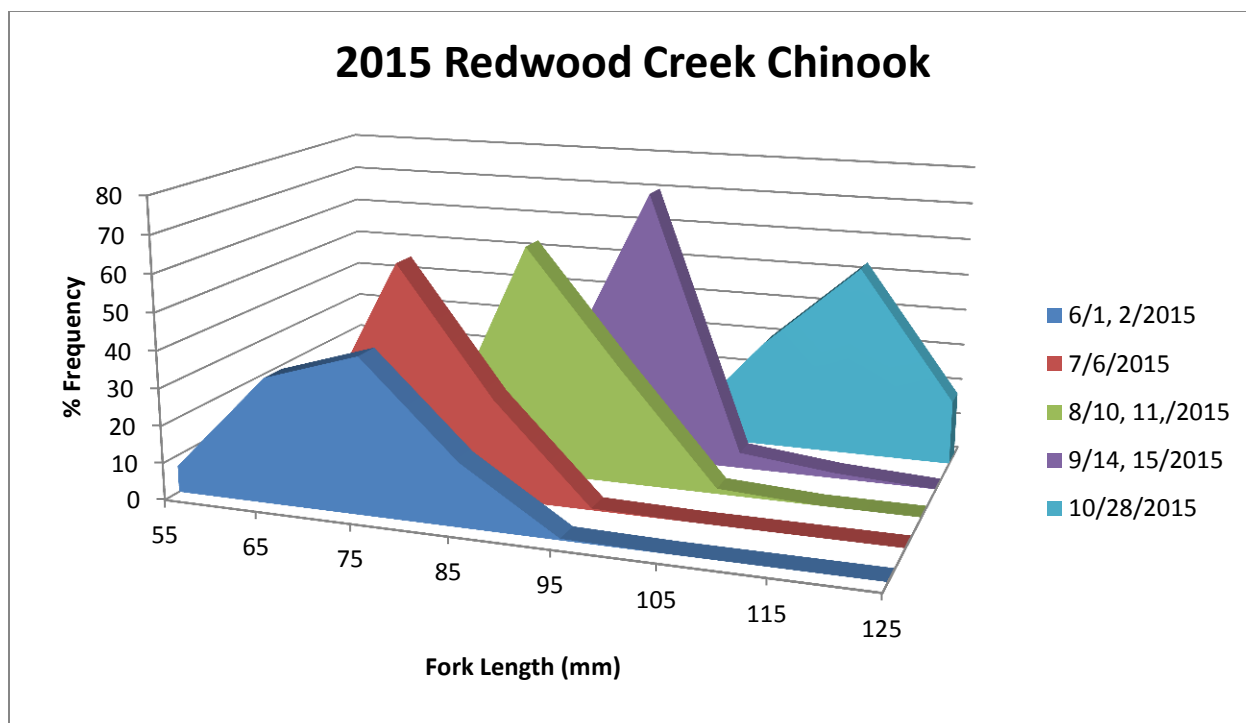


Figure 5. Fork length (mm) versus frequency (%) histogram of Redwood Creek estuary juvenile chinook sampled June 1 through October 28, 2015. The fork length intervals were 10-mm increments.

Of a total of 141 chinook weighed, mean weight increased from 4.0 g to 17.4 g between the weeks of June 1 and October 28, an increase of 13.4 g. During the sample season the minimum and maximum chinook weights were 2.1 g and 21.6 g, respectively.

Coho Salmon - Of the 125 juvenile coho measured, fork lengths ranged from 91 to 132 mm (Table 3 and Figure 6). Mean fork length the week of June 1 was 109 mm and for the two fish caught in July, 105 mm. Mean weight in June was 14.0 g and the two fish caught in July was 11.7 g. Coho weight ranged from 8.4 to 26.1 g.

Steelhead Trout - A total of 270 juvenile steelhead were measured. Mean fork length increased from 113 mm to 176 mm, an increase of 63 mm between the week of June 1 and October 28 (Table 3). For the season, the smallest fish measured was 61 mm, the largest 244 mm. Several age classes were present but few young-of-the-year fish were captured (Figure 7). Mean juvenile weight increased from 17.1 g to 62.1 g, and increase of 45 grams between the week of June 1 and October 28. The minimum and maximum weight measured during the sample season was 6.1 g and 180 g, respectively.

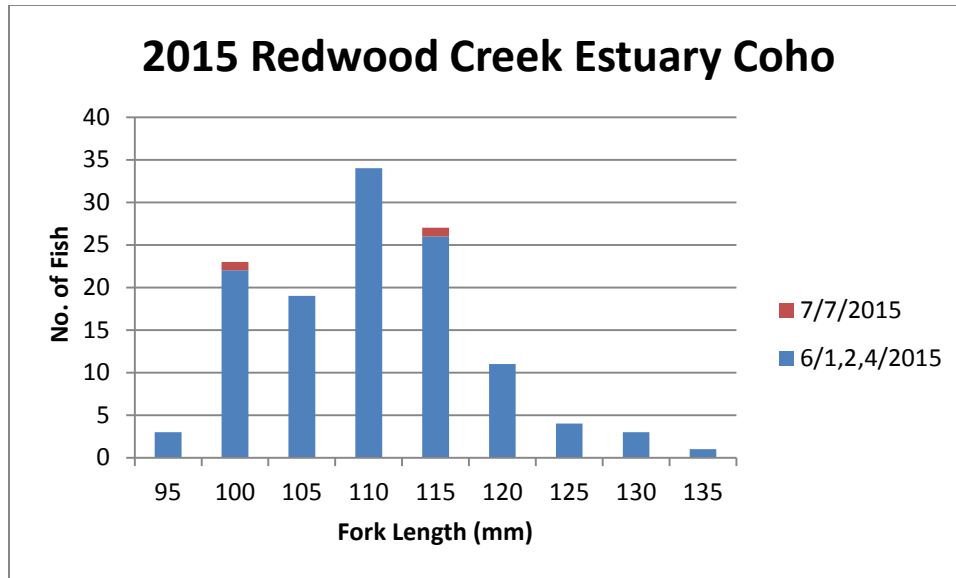


Figure 6. Fork length (mm) histogram of Redwood Creek estuary juvenile coho salmon sampled June 1, 2, 4, and July 7, 2015. The fork length intervals were 5-mm.

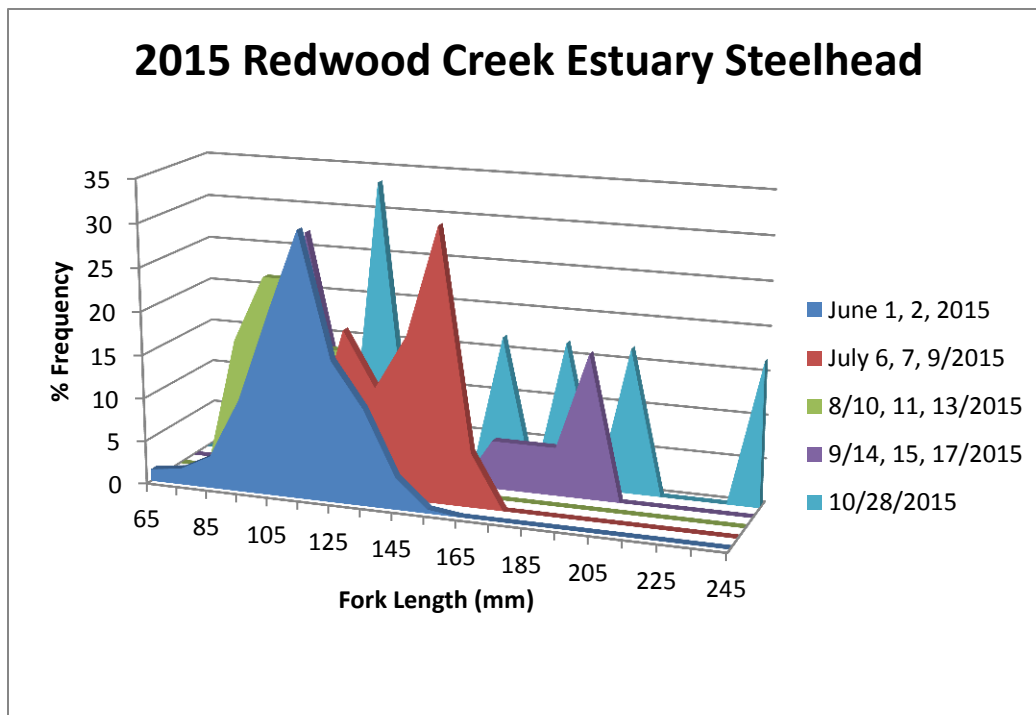


Figure 7. Fork length (mm) versus frequency (%) histogram of Redwood Creek estuary juvenile steelhead trout sampled June 1 through October 28, 2015. The fork length intervals were 10-mm increments. Several age classes are present.

Coastal Cutthroat Trout - Only two coastal cutthroat trout were captured, a small number compared to previous years. Both fish, caught the week of June 1, were 154 mm FKL, their weights 35.1 g and 39.6 g.

Condition Factor (K') – Fish condition factors are presented in Table 4. Species mean condition factors of each sample week remained approximately the same throughout the season. Mean chinook K' for five sample dates ranged from 0.8660 to 0.9500 but individual K' ranged between 0.7223 and 1.0890. The seasonal mean for all chinook was 0.8923. The seasonal mean for all 105 coho was 2.8605. Mean steelhead K' for sample dates ranged from 1.5124 to 1.6094, but individual coho K' ranged between 1.0888 and 2.0145. The seasonal mean for all steelhead was 1.5899. Mean cutthroat K' was 1.0227.

PIT Tagged Fish – In 2015, six PIT tagged salmon, four chinook and two coho, were detected among the 3,885 fish processed (Table 5). The chinook were tagged in 2015 at the upper downstream migrant trap at river mile 33 in Redwood Valley (Personal Communication – Mike Sparkman, CDFW). The two coho were tagged in 2014 at Streelow Creek, a westside tributary to lower Prairie Creek (Personal Communication Peter Drobny – Fish Coop Unit).

Table 5. PIT tagged fish recaptured in the Redwood Creek estuary in 2015.

Species	PIT TAG#	Estuary Date Recaptured	FKL (mm)	WT (g)	Date Tagged	Where Tagged	FKL (mm) Initial	Wt (g) Initial	Increase FKL	Increase WT
KS	9105994081	6/1/2015	76	4.7	5/21/2015	Upper Trap (CDFW)	72	4.0	4	0.7
KS	9106099356	6/1/2015	76	4.7	5/8/2015	Upper Trap (CDFW)	71	3.5	5	1.2
KS	9106143160	6/2/2015	80	5.3	5/21/2015	Upper Trap (CDFW)	77	4.7	3	0.6
KS	6100819	7/6/2015	80	5.2	6/7/2015	Upper Trap (CDFW)	79	4.9	1	0.3
COHO	2260006548 56	6/1/2015	116	18.2	8/2014	Streelow Creek (HSU)	86	8.1	30	10.1
COHO	2260006549 57	6/2/2015	123	19.2	8/2014	Streelow Creek (HSU)	95	9.7	28	9.5

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 estuary, Humboldt County, California, during the summer and fall of 2005. 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 2015						
Date (week of)	6/1/2015	7/6/2015	8/10/2015	9/14/2015	10/28/2015	Summer/ Fall 2015
Chinook Salmon (b = 3.0890)						
Mean	0.9083	0.8921	0.8660	0.8688	0.9500	0.8924
Standard Deviation	0.0538	0.0529	0.0540	0.0480	0.0775	0.0613
Minimum	0.8014	0.7371	0.7859	0.7413	0.7223	0.7223
Maximum	1.0542	0.9738	1.0356	0.9486	1.0890	1.0890
Count	33	31	30	30	17	141
Coho Salmon (b = 2.5856)						
Mean	2.8646	2.6523	---	---	---	2.8605
Standard Deviation	0.2618	0.0798	---	---	---	0.2610
Minimum	1.8880	2.5959	---	---	---	1.8880
Maximum	4.0974	2.7087	---	---	---	4.0974
Count	103	2	0	0	0	105
Steelhead Trout (b = 2.8479)						
Mean	1.5822	1.6094	1.5882	1.6126	1.5124	1.5899
Standard Deviation	0.1091	0.0949	0.1053	0.0877	0.3936	0.1384
Minimum	1.3963	1.4795	1.3910	1.5040	1.0888	1.0888
Maximum	1.8566	1.8139	1.7569	1.8112	2.0145	2.0145
Count	30	16	13	18	6	83
Cutthroat Trout (b = 3)						
Mean	1.0227	---	---	---	---	1.0227
Standard Deviation	0.0871	---	---	---	---	0.0871
Minimum	0.9610	---	---	---	---	0.9610
Maximum	1.0843	---	---	---	---	1.0843
Count	2	0	0	0	0	2

Physical Monitoring

Water Temperature - Estuary water temperature was measured hourly from June 4 through October 28, 2015 (Figure 8). Similar to other years, placement of the probe was delayed prior to the recommended June 1 date because the Redwood Creek mouth was open. It was feared the probe would be stolen when visible at lower water levels.

The maximum and minimum temperatures measured between June 4 and October 28 were 21.9°C (September 2 – 3 11pm to 3am) and 12.4°C (June 5 at 1 am), respectively. The average water temperature for this period was 16.8°C.

For the season, the warmest average monthly estuary water temperature was August at 18.6°C, followed closely by the month of September at 18.0°C. The water temperature was equal to or greater than 18.0°C 60 percent of time during August and September. For June 4 to the 30th, the average water temperature was 15.0°C; for the month of July, 15.9°C; and for October 1 to 28, 16.2°C.

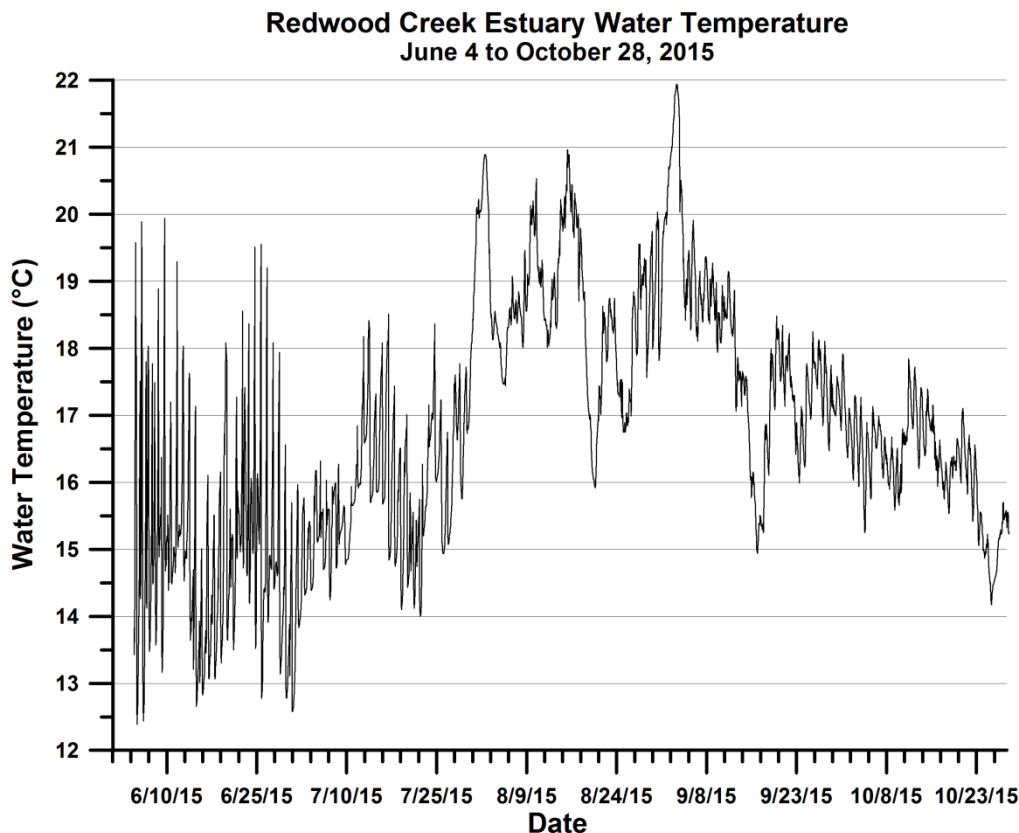


Figure 8. Redwood Creek estuary water temperatures (°C) measured by an Onset Tidbit temperature logger located in the embayment beyond the ends of the north and south levees. The temperature logger, located one foot from the bottom, recorded water temperature every 1-hour from June 4 to October 28, 2015.

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 mouth closed 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 4.9 ft MSL and -5.5 ft MSL, respectively, a range of 10.4 feet. Tidal data is included in Figure 11 and Appendix II.

Ocean Wave Height – There is no ocean buoy data available for directly offshore of Redwood Creek. Wave heights (ft) off the coast, Eureka and Crescent City were downloaded from the NOAA site for 2015. Wave height data for buoy 46022 off Eureka was available for March 11 to September 30 and November 18 to December 31. Wave height data for buoy 46027 off Crescent City was available for October 27 to December 31. Where the dates overlapped, wave conditions were the similar except for magnitude (Figure 9). Wave heights ranged from 1.7 ft to 34.8 ft.

Stream Flow - Calendar year 2015, January 1 through December 31, stream flow data measured at the Orick station is presented in Appendix III. The maximum flow was 15,400 cfs on December 13. The gage measured a minimum flow of 7 cfs several times between October 10 and 24. The first flow event of the fall occurred on October 28, when after 0.84 inches of rain, the flow went from 9 cfs to a peak of 36 cfs. (The flow data is provisional and subject to revision by the California Department of Water Resources.)

Embayment Water Level Gaging

Redwood Creek embayment water depth 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 13 and removed on November 18, 2015. The minimum and maximum water elevations measured during the period of gaging were 0.75ft and 9.0ft MSL, a difference of 8.3ft.

Based on observations and the recording water level gage in the embayment, the Redwood Creek estuary closed and breached once (Figure 10). The estuary mouth closed on July 26 and breached on November 15. It remained closed for a total of 112.6 days. Prior to the closure, the estuary was subject to tidal influence, the lowest water elevation level at 0.75 ft on May 25, the highest on June 13 at 5.5 ft MSL, a range of 4.8 ft.

July 26 Closure - The mouth of Redwood Creek closed on July 26 07:00 (PST) at an estuary water elevation of 4.6ft MSL during a series of increasing high tides (Figure 11) and ocean wave height (Figure 9) that would have filled the outlet channel with sand. Wave height off Eureka increased from 3.0 ft July 24 to 7.3ft on July 26. Redwood Creek flow at the time was 17 cfs. The water elevation peaked at 5.9 ft MSL on July 30, declined, peaked again at 5.8 ft on August 31 during another series of increasing tides, that probably washed over the sand berm. In addition, a 0.6 inch rain event on August 29 raised the stream flow to 18cfs (Figure 12). Another water elevation increase peaked at 5.0 ft on September 27, the result of a September 16-17 rainfall event of 0.6 inches that caused creek flow to increase to 20 cfs and possible wave over

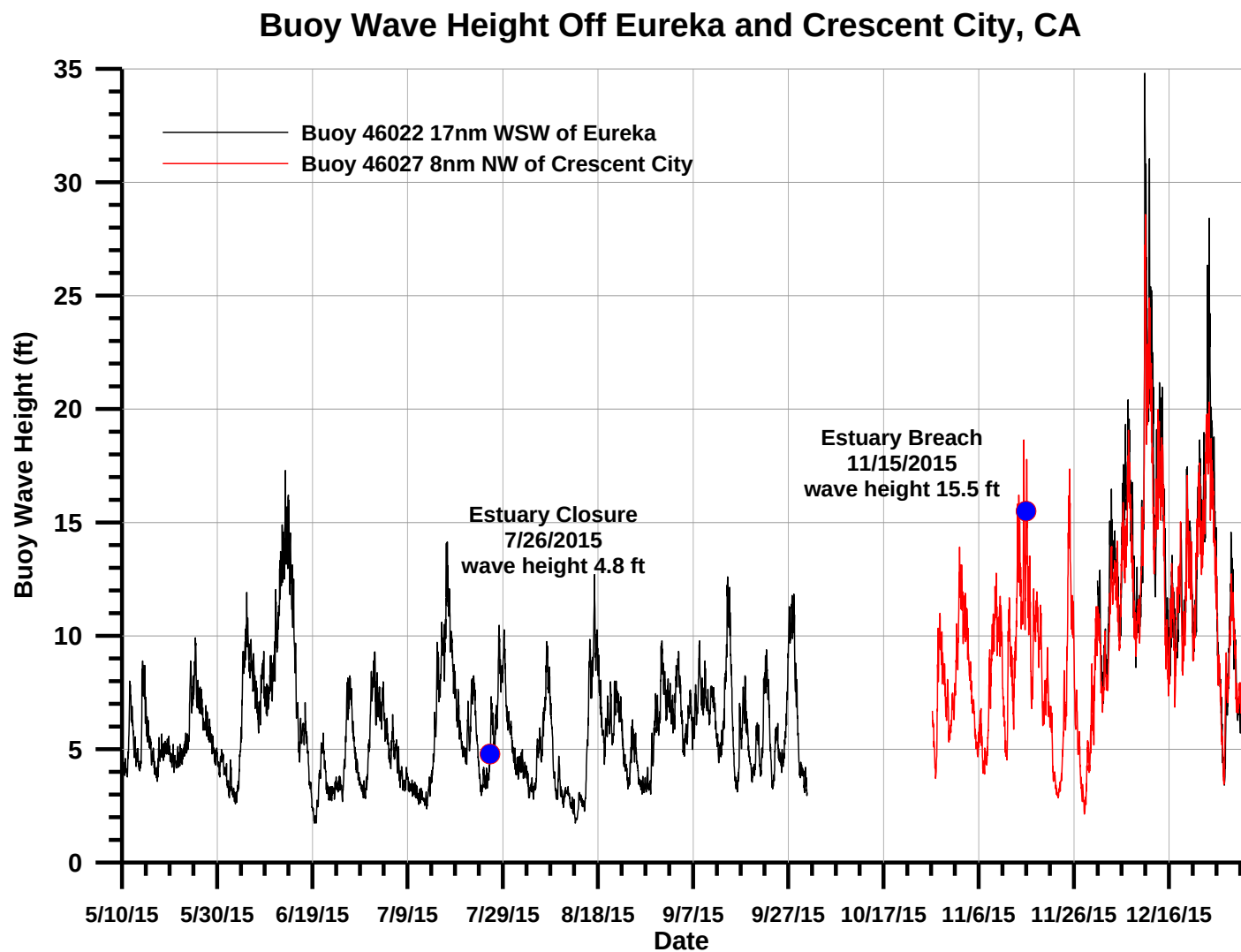


Figure 9. Ocean wave heights (ft) measured hourly by Buoy 46022 located 17 nm WSW of Eureka and Buoy 46027 located 8 nm NW of Crescent City, California, and Redwood Creek estuary closure and breaching dates.

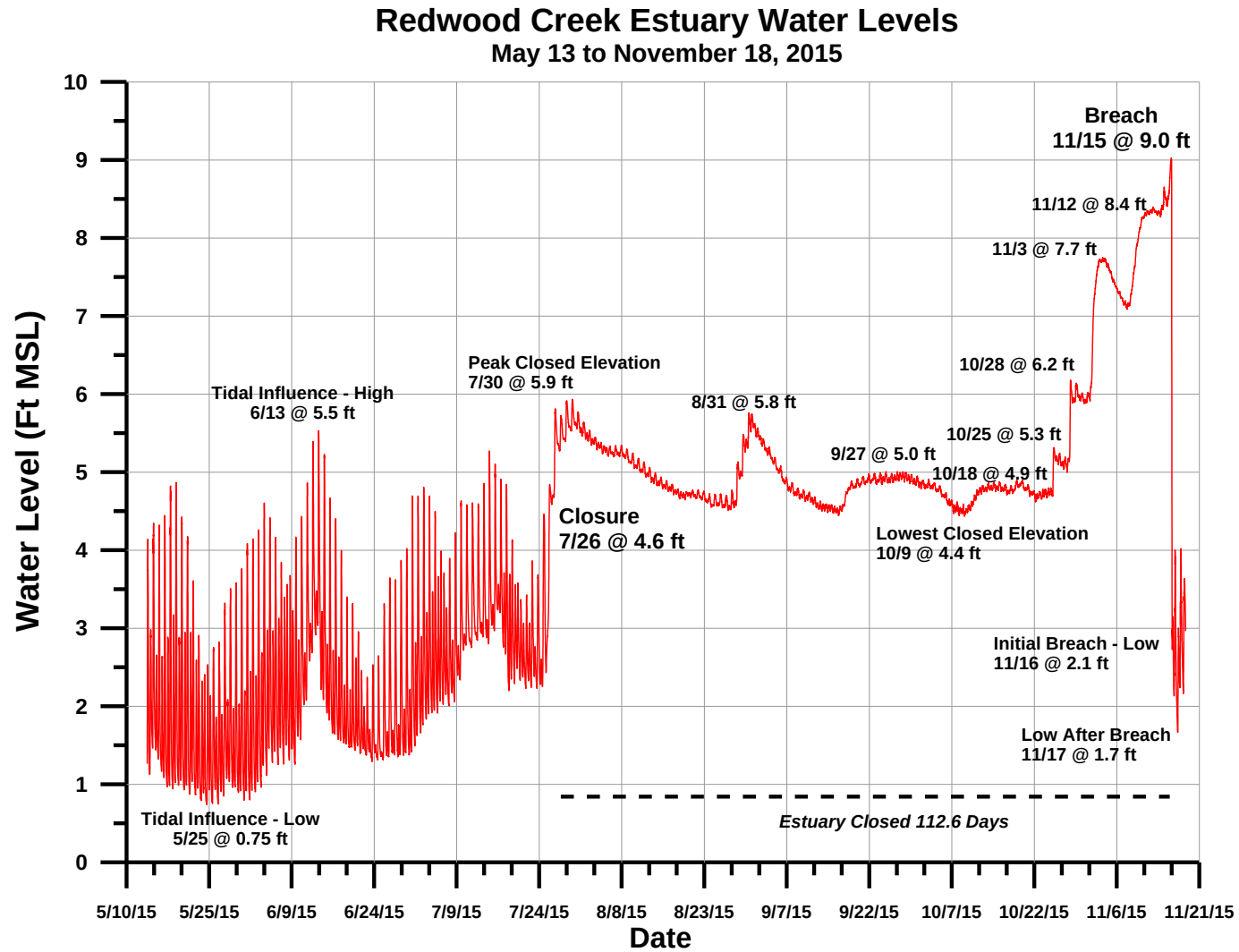


Figure 10. Water level elevations (ft. Mean Sea Level [MSL]) recorded in the Redwood Creek estuary, Humboldt County, California for May 13 to November 18, 2015.

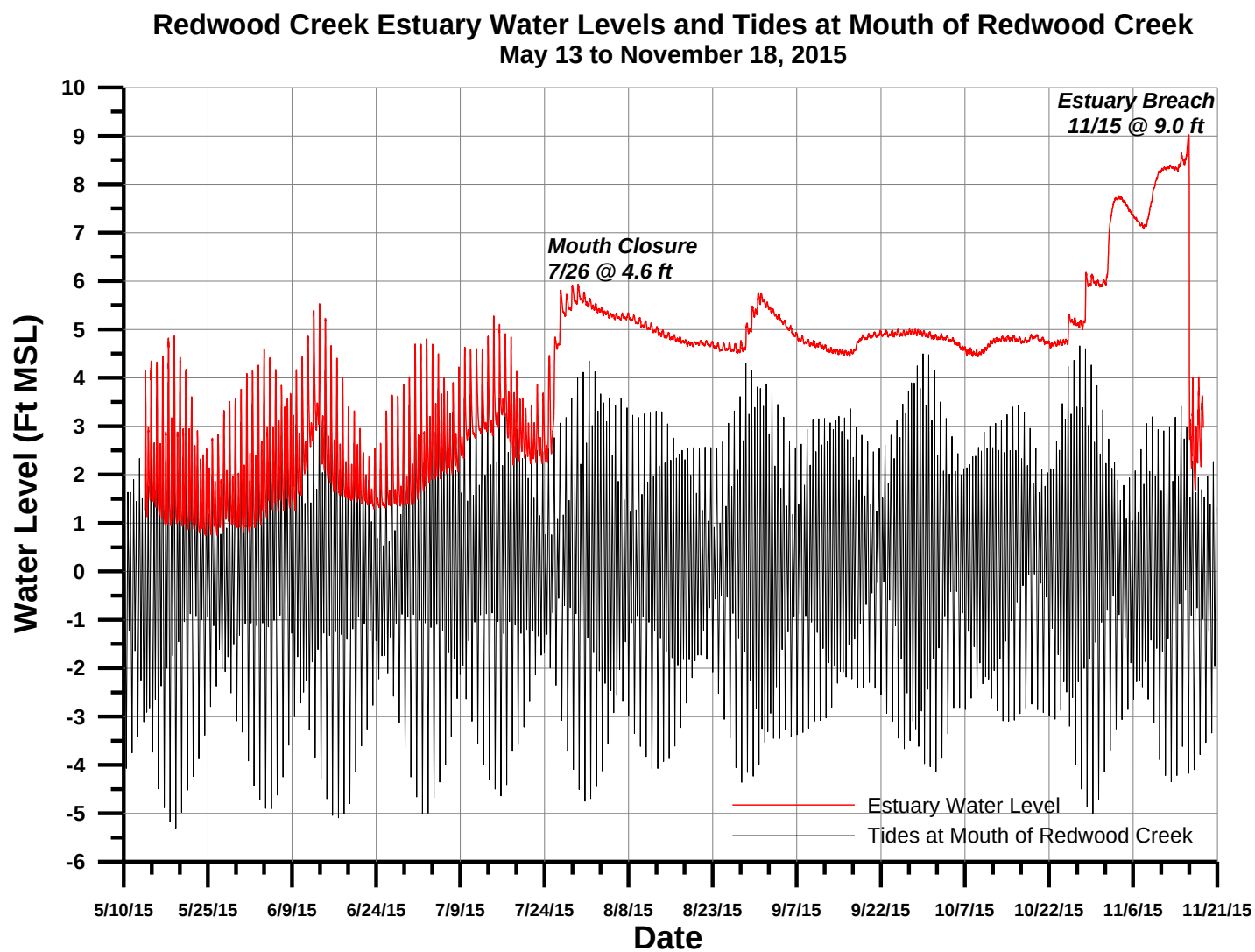


Figure 11. Redwood Creek estuary water levels and tides at the mouth of Redwood Creek May 13 to November 18, 2015.

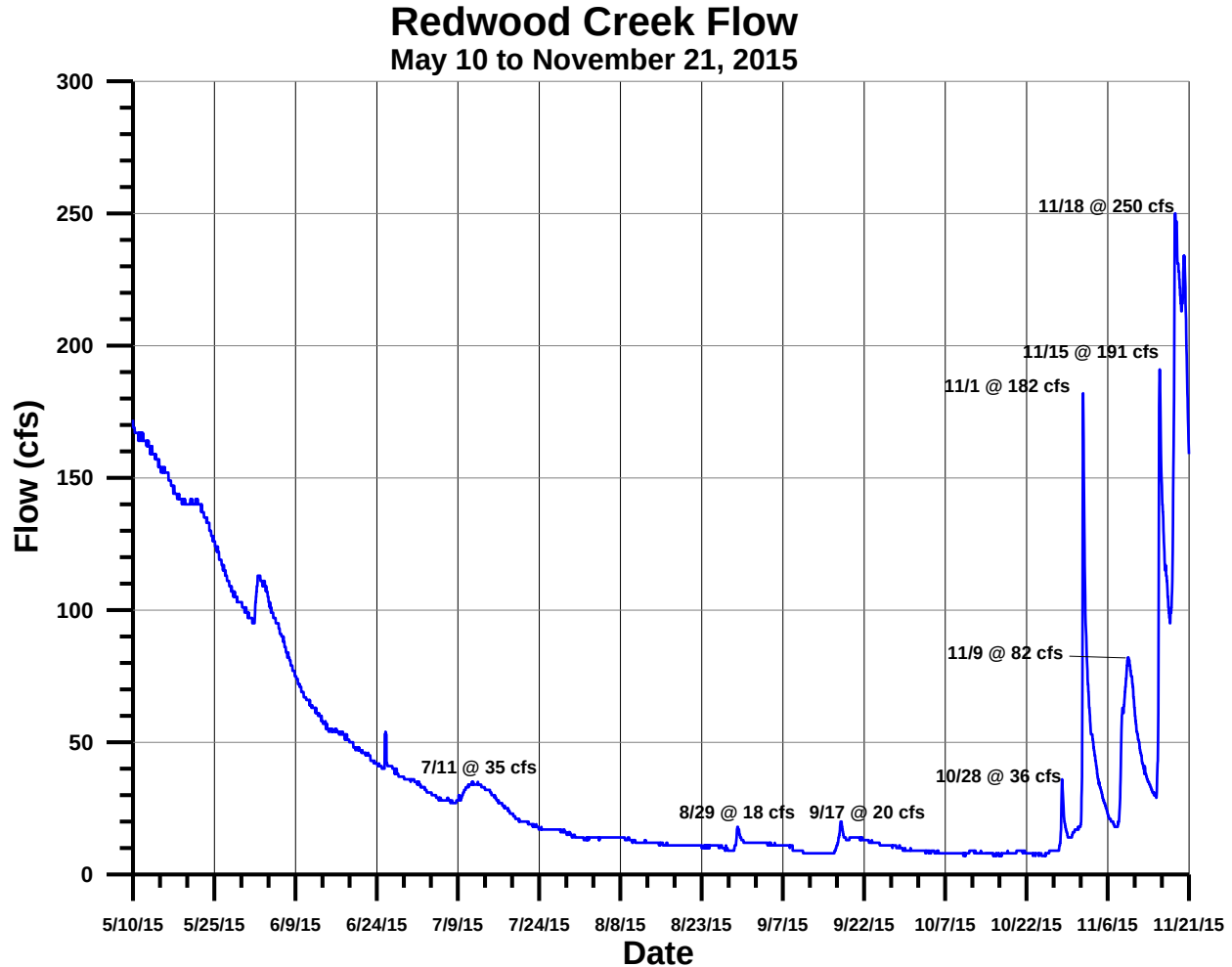


Figure 12. Redwood Creek flow (cfs) for May 10 to November 21, 2015.

wash during the high tide series. The third water elevation increase on October 18, 4.9 ft MSL, was probably related to the high tide series as it did not rain during this period.

When closed, the lowest estuary water elevation was 4.4 ft MSL on October 9. The average water elevation during the 112.6 day closure was 5.3 ft MSL.

Events Leading Up to the November 15 Breach - Estuary water elevation stair-stepped four times starting in late October, before breaching the sand bar on November 15 at 9.0 ft MSL. The first stair-step increase peaked on October 25 14:45 at 5.3 ft. This increase was probably due to the high tide wave overwash (Figure 11), as only 0.08 inches of rain fell prior to the increase. The water level stair-stepped to a peak of 6.2 ft on October 28 16:15 and is related to 0.84 inches of rain causing Redwood Creek flow to peak at 36 cfs that afternoon at 1400 (Figure 12). The third peak of 7.7 ft MSL on November 3 is most likely due to Redwood Creek flow of 182 cfs which peaked on November 1 at 11:00. The fourth stair-step to 8.4 ft MSL on November 12 is likely the result of increased Redwood Creek flow which peaked on November 9 at 82 cfs.

November 15 Breach - The Redwood Creek estuary breached on November 15 22:15 (PST) at a water elevation of 9.0 ft MSL. Flow that day peaked at 191 cfs at 15:00 in the afternoon. Between 01:00 and 17:00, 1.04 inches of rain had fallen. Coinciding with the rain event were high seas that peaked at 18.6 ft at noon which would have caused ocean waves to wash over the berm and raise the estuary water elevation (Figure 9). Between October 25 09:00 and November 15 17:00, 4.08 inches of rain fell; the antecedent rainfall was 0.12 inches since the new water year started on October 1, 2015.

Once open, the estuary water elevation initially decreased from 9.0 ft to 2.1 ft MSL on November 16 09:45, a 6.9 ft drop in 11.5 hours, before increasing due to the tide. The lowest elevation measured was 1.7 ft MSL on November 17 before the gage was removed the next day.

Estuary Cross Sections

All five estuary embayment cross sections, E-1 through E-5, were surveyed on June 8, 2015 and are presented in Appendix IV. The mouth of Redwood Creek was open to the ocean at the time. It was the 14th 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 (ft³) for varying water elevations (Appendix V). Calculated embayment volume ranged from 373 ft³ at -3 ft MSL to 2,629,045 ft³ at 9 ft MSL. At 0 ft MSL the volume was 229,365 ft³.

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. However, in 2015 the gates were not manipulated due to a question that their operation may require Section 7 consultation. Data and reports were provided to the NOAA Fisheries Arcata Office for review and analyses to determine best operating procedures.

Other

OMSI - The Oregon Museum of Science and Industry (OMSI) held a summer documentary film class for high school students at the Wolf Creek Outdoor School. The students under the direction of two instructors from NW Documentary, a storytelling non-profit located in Portland, Oregon, made a documentary called The Last Meander (<https://vimeo.com/album/3568012/video/137880842>) on the Redwood Creek estuary and restoration of Strawberry Creek. The film included estuary seining scenes.

Homeless Encampments – People are camping along Redwood Creek in the riparian vegetation between the levees upstream and downstream of the HWY 101 bridge during the summer.

CDFW Downstream Migrant Trapping

Population Abundance - At the lower Redwood Creek downstream migrant trap (river mile 4), Sparkman (2016a) estimated 295,664 0+ chinook passed by the trap in 2015, 1.3 times the 11 year average; 74,175 1+ and 2+ steelhead; and 2,226 0+ and 1+ coho (Table 6). Only 17 1+

chinook were estimated, showing the life history of chinook in Redwood Creek is ocean type not riverine rearing, and the importance the Redwood Creek estuary as rearing habitat. May and June were the peak months for 0+ Chinook and 1+ steelhead and April and May for 2+ steelhead and 1+ coho. The trap, first rotary and later a fyke net, fished from March 20 to August 5, 2015.

At the Prairie Creek trap, Sparkman et al. (2016b), estimated 22,562 0+ chinook, 12,306 1+ and 2+ steelhead, 24,163 0+ and 1+ coho, and 8,572 juvenile cutthroat. The months of greatest migration were March, April, and May.

Table 6. Estimated population abundance of juvenile salmonids from CDFW downstream migrant rotary screw trapping on lower Redwood Creek and the mouth of Prairie Creek, 2015.

2015 CDFW Redwood Creek Watershed Downstream Migrant Rotary Screw Trapping						
Downstream Migrant Trap	0+ Chinook	0+ Coho	1+ Coho	1+ Steelhead	2+Steelhead	Cutthroat
Lower Redwood	295,664	303	1,923	56,020	18,155	825
Prairie Creek	22,562	1,601	21,536	7,786	4,520	8,572
Total	318,226	1,904	9,709	63,806	22,675	9,397
From Sparkman, et al. 2016 a & b						

This drought year, Sparkman (2016a) reported Redwood Creek went subsurface in late July downstream of the lower trap and upstream of the trap in mid-late August. This would have precluded any more immigration into the estuary from mainstem Redwood Creek above the Prairie Creek confluence. Prairie Creek maintained its connection to mainstem Redwood Creek.

Potentially, 362,568 juvenile salmonids migrated to the lower river and estuary in 2015. Sparkman et al. (2016a) reported increased migration earlier in the season. A similar occurrence in the estuary might explain the low numbers of salmonids caught after the river mouth closed, the fish had migrated to the ocean.

Growth - Mean chinook fork length and weight for the CDFW trapping season was 64 mm and 3.2 g, respectively at the lower trap. Mean estuary chinook fork length and weight in June was 71 mm and 4.0 g, respectively and increased in the estuary through the sampling period to October. 0+, 1+, and 2+ steelhead mean fork length was 58.2 mm, 102.5 mm, and 157.3 mm respectively at the lower trap. Though we did not differentiate between age classes, the estuary steelhead mean fork length in June was 113 mm and 176 mm at the end in October. Mean fork length for 0+ and 1+ coho was 55.8 mm and 105.5 mm respectively at the lower trap. In the estuary, we caught the last of the 1+ coho smolts migrating out of the estuary to the ocean in June and the two in July, having caught no coho below 91 mm. The average coho fork length in June was 109 mm. In all, the estuary provided extended growth and potentially better ocean survival to those fish that remained or were trapped in the estuary until it breached in November.

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.
- Bond, M.H., S.A. Hayes, C.V. Hanson, and R.B. MacFarlane. 2008. Marine survival of steelhead (*Oncorhynchus mykiss*) enhanced by a seasonally closed estuary. Can. J. Fish. Aquat. Sci. 65: 2242–2252
- 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.
- Reimers, P.E., 1973. The length of residence of juvenile fall chinook salmon in Sixes River, Oregon. Research Reports of the Fish Commission of Oregon. 4(2).
- Sparkman, M.D., R. Park, L. Osborn, S. Holt, and M.A. Wilzbach. 2016a. Lower Redwood Creek juvenile salmonid (smolt) abundance project, study year 2015: a report to the Fisheries Restoration Grants Program (Project No. P1210322). CDFW AFRAMP, study 2a7:85 pp.
- Sparkman, M.D., P.Y. Drobny, M.A. Wilzbach, M.E. Gordon, and C.M.G. Boone. 2016b. Prairie Creek Monitoring Project, 2015 Season: a report to the Fisheries Restoration Grants Program (Project No. P1210321).
- Sparkman, M.D. 2016c. Upper Redwood Creek juvenile salmonid (smolt) abundance project, study year 2015. CDFG AFRAMP, 2a5:73 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.

Personal Communication

Mike Sparkman, Fisheries Biologist, CDFW, Arcata California.

Peter Drobny, HSU Graduate Student, USGS Cooperative Fish and Wildlife Unit, Arcata, California.

Film

The Last Meander. 2015. Filmmakers: Aidan Grenville, Dasha Furrow, Linda Hu and Max Lishka. Made by high school participants in the Documentary Explorers Camp in partnership with OMSI. NW Documentary, Portland Oregon. 7minutes20 seconds. (<https://vimeo.com/album/3568012/video/137880842>)

Report 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

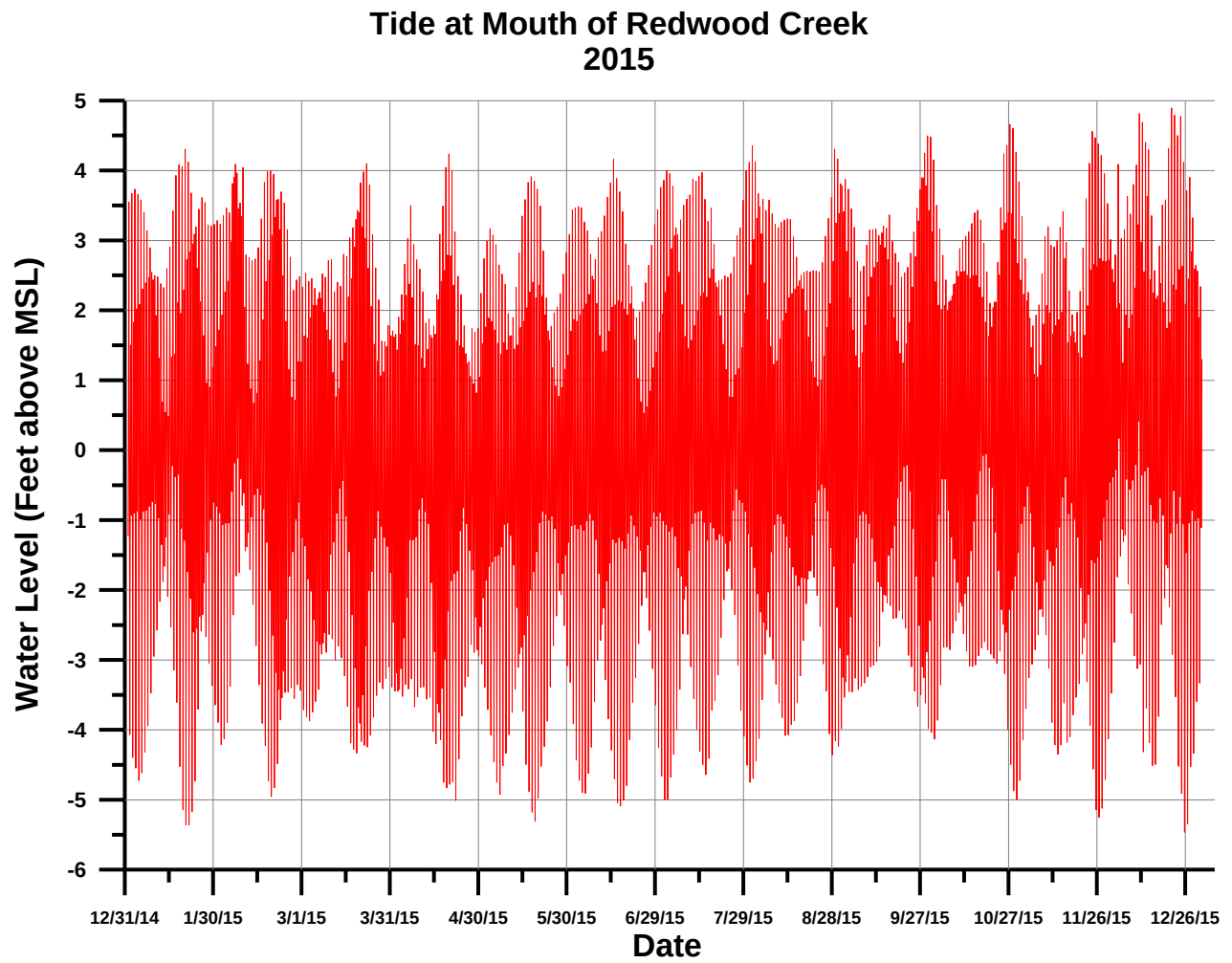
Appendix I. Number of salmonid fish marked, marked recaptures, total individuals captured in the second sample, and total number of seines from the RNP Redwood Creek estuary mark and recapture population estimates during the summer of 2015. Fish fins; top, middle, and bottom caudal, and anal fins were marked with a Panjet needleless injector using Alcian Blue dye. Formulas used to calculate population estimate and its 95% confidence interval.

2015 Date		Number of Fish Marked ^a Marked Fish Recaptured ^b Total No. of Fish Captured in Second Sample ^c				Total No. of Seines	Panjet Fin Mark
		Chinook	Coho	Steelhead	Cutthroat		
June 1 & 2	a	893	103	252	1	13	Top Caudal
June 4	b	25	1	6	0		
	c	1,095	21	217	1		
July 6 & 7	a	837	2	15	0	24	Bottom Caudal
July 9	b	9	0	0	0		
	c	79	0	1	0		
Aug 10 & 11	a	203	0	6	0	33	Anal
August 13	b	0	0	1	0		
	c	9	0	8	0		
Sept 14 & 15	a	44	0	13	0	29	Middle Caudal
September 17	b	0	0	0	0		
	c	24	0	5	0		

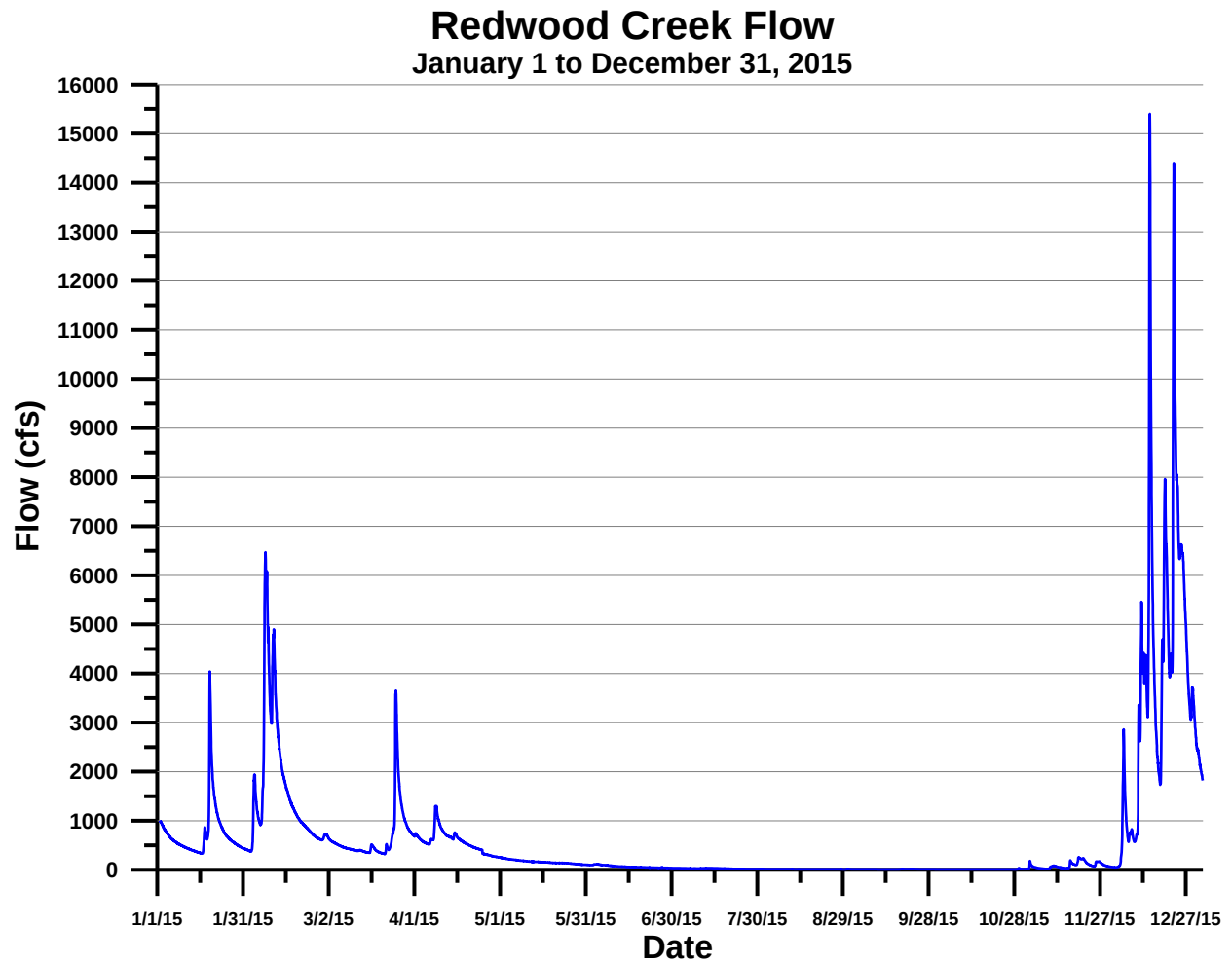
$$\text{Population Estimate (N)} = \frac{(\text{No. of fish marked}) \times (\text{total no. captured in second sample})}{(\text{No. of marked fish recaptured in second sample})}$$

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

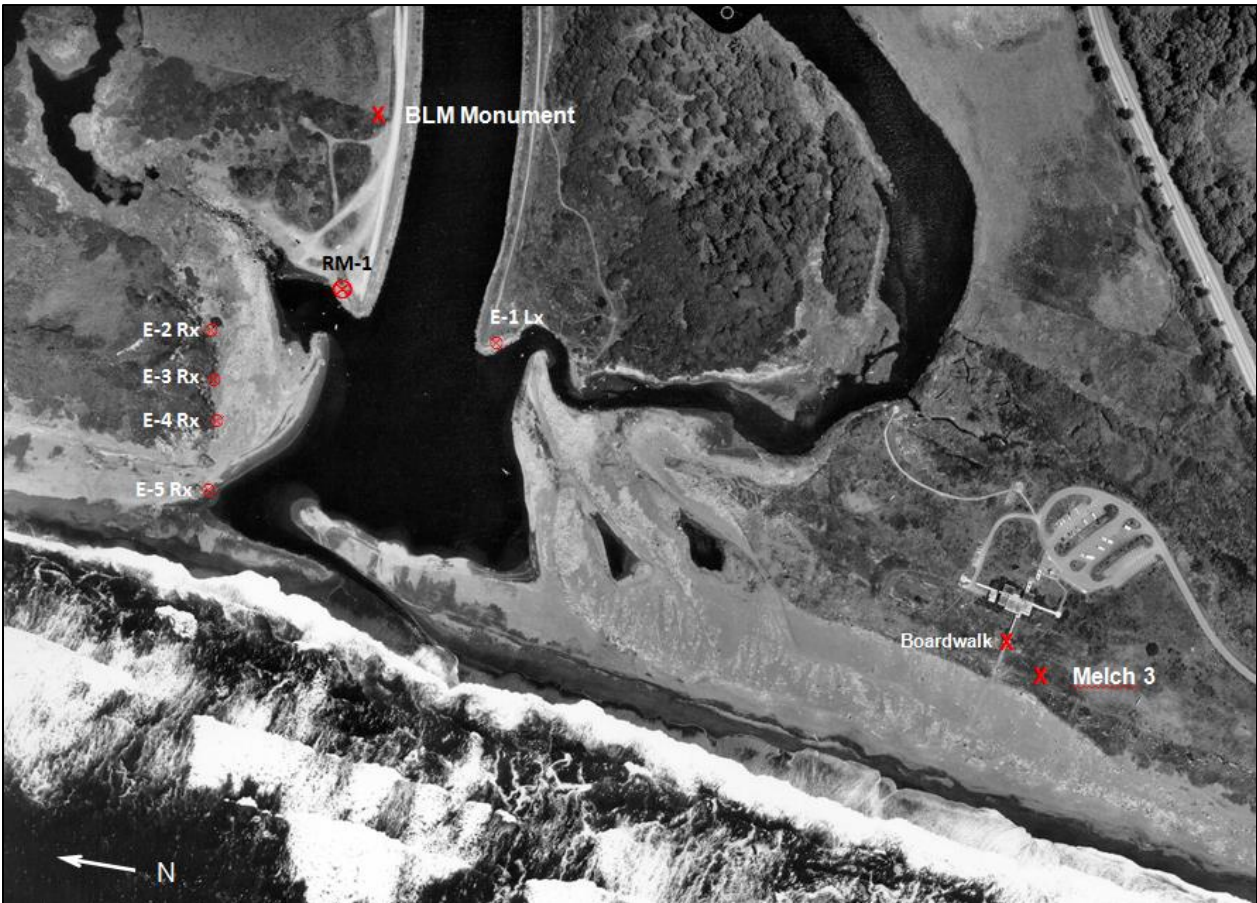
Appendix II. Tides (ft. MSL) calculated at the mouth of Redwood Creek for calendar year 2015.



Appendix III. Redwood Creek flow (cfs) for 2015 calendar year as measured at the Orick (ORK) gaging station.

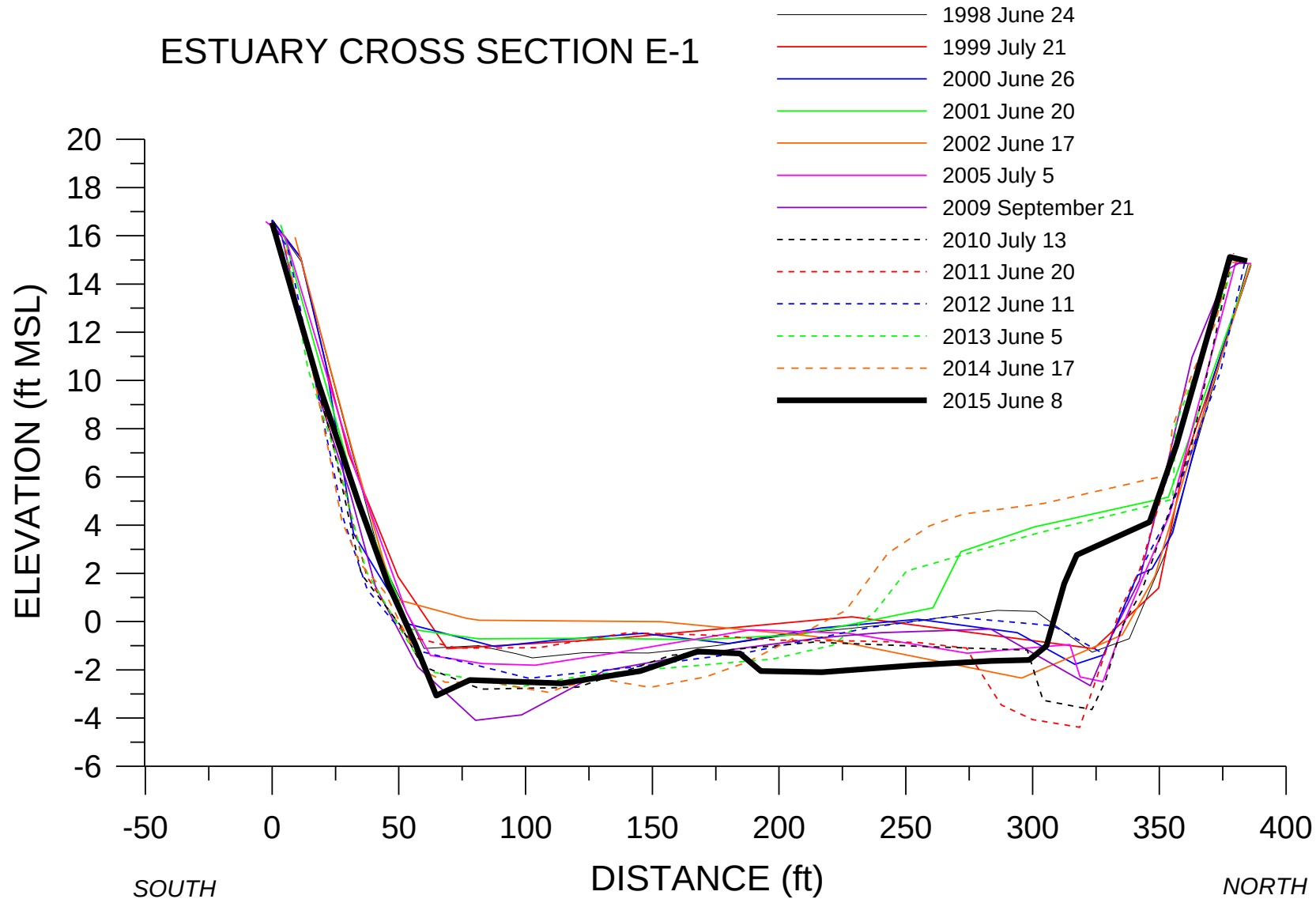


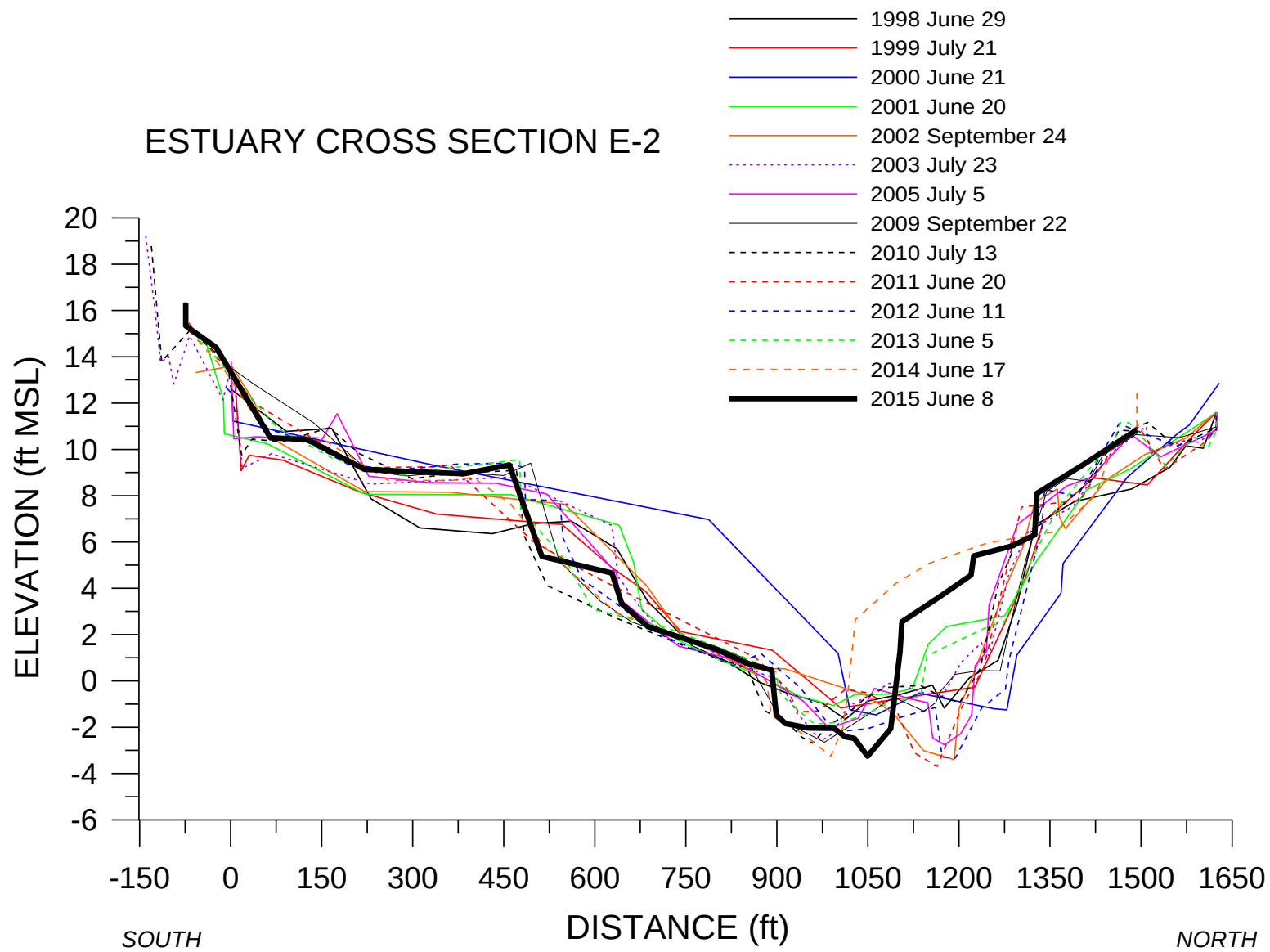
Appendix IV. Five permanent cross-sections (E-1 through E-5) surveyed June 8, 2015 in the Redwood Creek estuary embayment perpendicular to the channel. Established in 1998, each cross-section was shot at a bearing of 170° from the north endpoints through the embayment to the sand dunes on the south. The five parallel cross-sections start between the ends of the levees with E-1 and end to the west with E-5 at the sea stack adjacent to the beach.



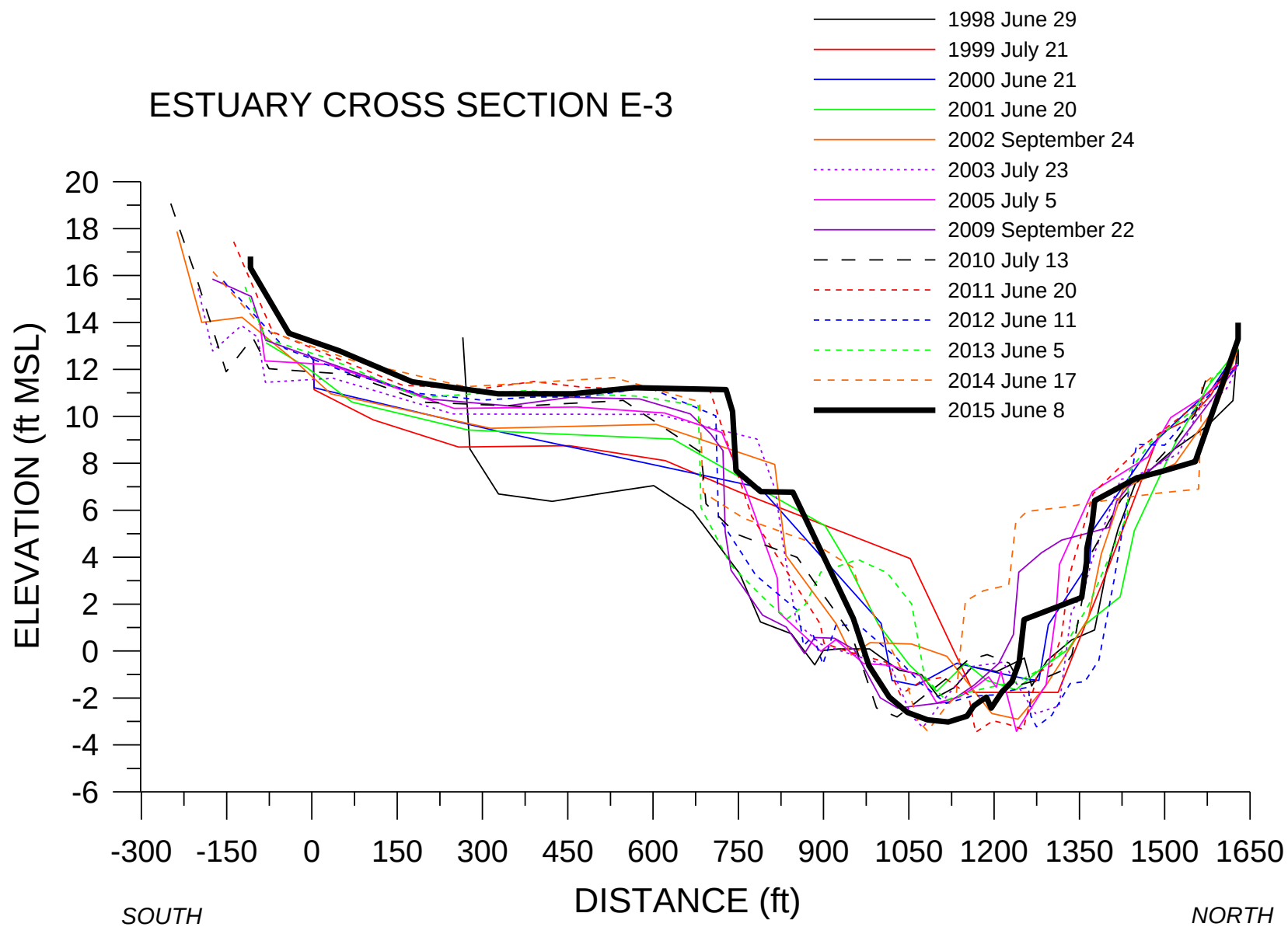
Redwood Creek Estuary Cross Section End Points and Reference Monuments

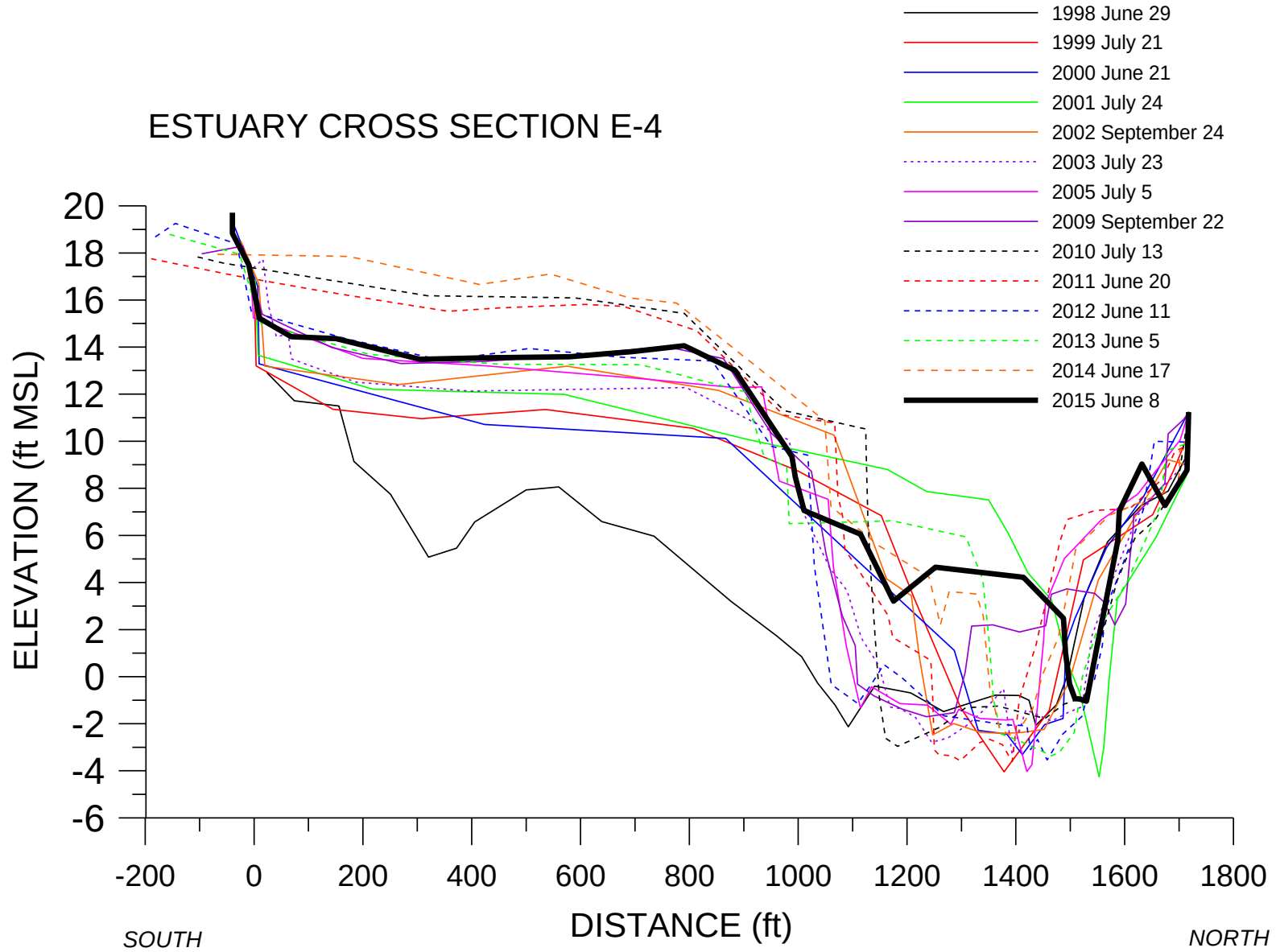
ESTUARY CROSS SECTION E-1

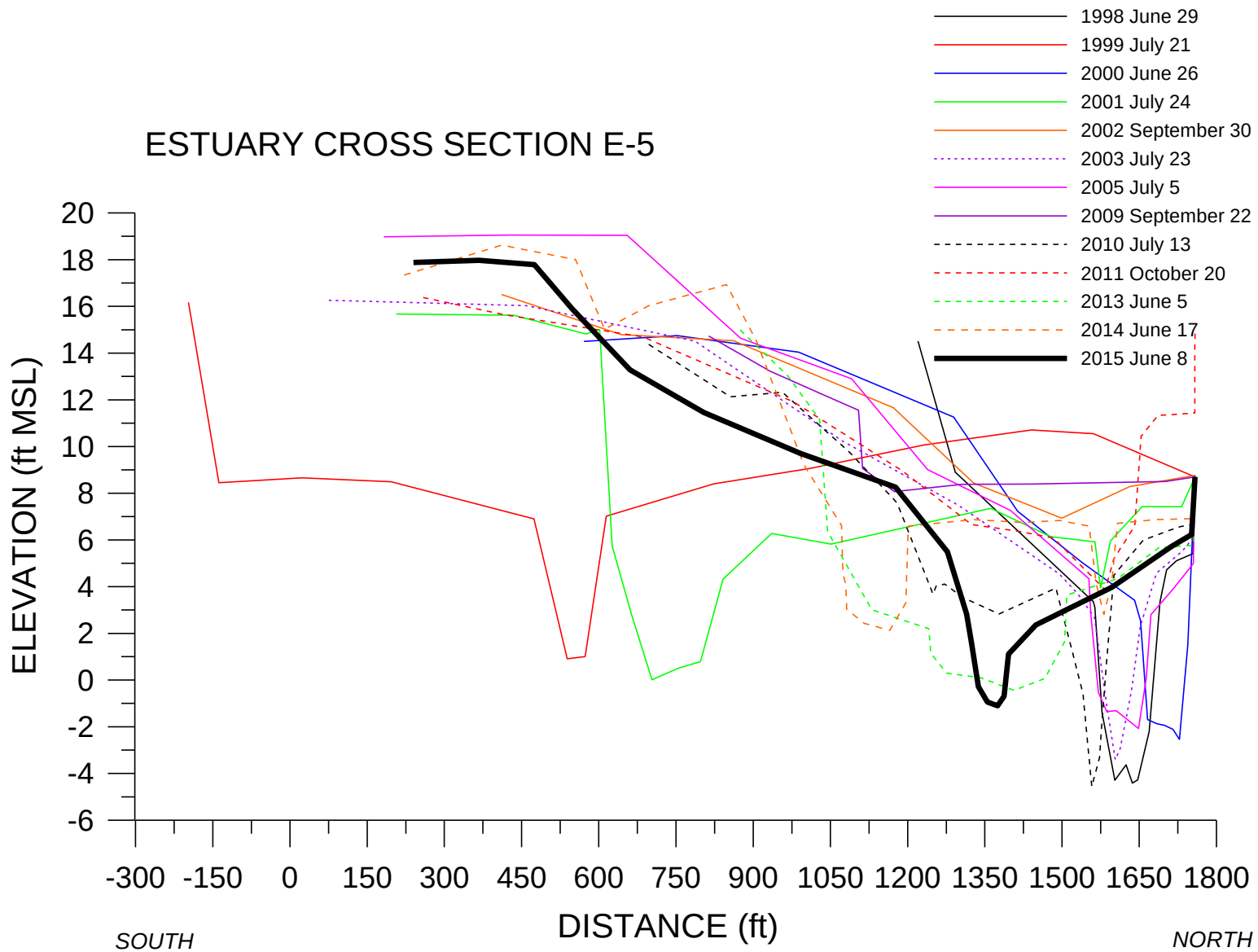




ESTUARY CROSS SECTION E-3

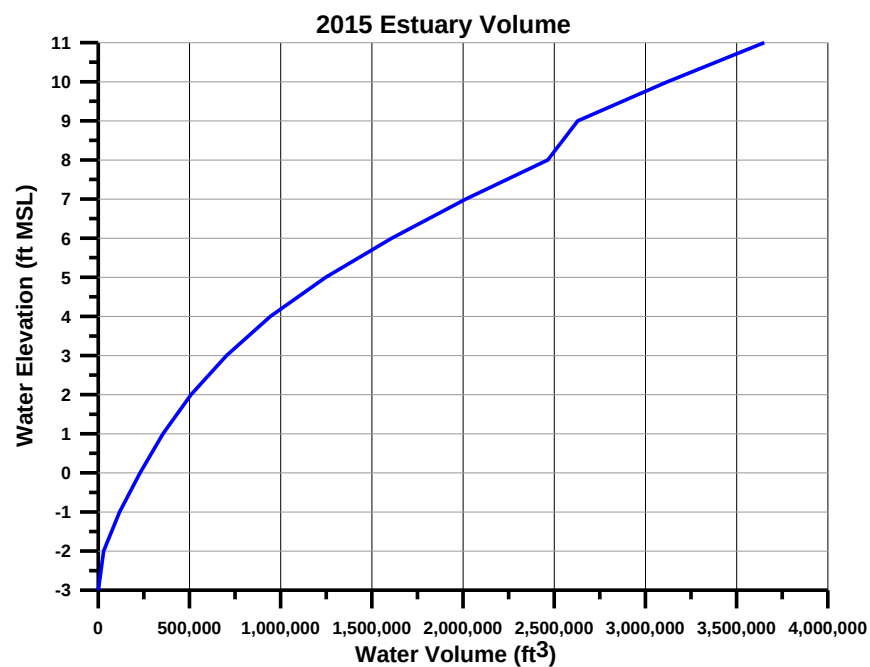






Appendix V. Calculated volume (ft³) of the Redwood Creek embayment at water elevations of -3 to 11 ft MSL based of the five cross sections E-1 through E-5 surveyed on June 8, 2015 (top). Volume of embayment is defined as the area west of the ends of the north and south levee and not including the north or south outlet channels or sloughs. Embayment water elevation versus volume (bottom)..

Water Elev. MSL (ft)	Estuary Volume (ft ³)
11	3,651,452
10	3,120,617
9	2,629,045
8	2,464,558
7	2,015,737
6	1,609,407
5	1,247,621
4	943,985
3	703,619
2	508,822
1	354,831
0	229,365
-1	116,974
-2	29,332
-3	373



2015 Acknowledgements

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

Fish Monitoring (Seining and Processing)

Fish and Wildlife Branch: David Anderson, Terry Hines, Kyle Max, Heather Brown, Alder Gustafson, Brandon Piper, Joanna DiTommaso, Keith Bensen, and Kristin Schmidt

RNP Roads and Trails: Janette Parsons, Andrew Stehr, Haley Allen, Nick Stipsas, and Adrian Sperlich

RNP GIS: Josh Van Buskirk

RNP Interpretation: Laura Perry, Maunda Hagen, and Laura Goforth

RNP Geology: Neal Youngblood

RNP Vegetation: Laura Julian, Sal Amador, and Tim Marsh

Volunteer-in-the-Park: Jacob Escosa

Lower River and Estuary Snorkel Survey

Fish and Wildlife Branch: David Anderson, Terry Hines, Kyle Max, and Brandon Piper

Bird Observations

Fish and Wildlife Branch: Heather Brown

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: Rachael Baker-de Kater (data download and calibration of probes)

Embayment Cross-Sections Survey

Fish and Wildlife Branch: David Anderson (rod)

RNP Geology Branch: Carrie Jones – retired RNP (instrument) and Vicki Ozaki (rod and graphing)

RNP Vegetation: Tim Marsh (notes)

Documentary Filming

OMSI Documentary Film Summer Camp Students and Instructors

Primary Filmmakers: Aidan Grenville, Dasha Furrow, Linda Hu and Max Lishka.