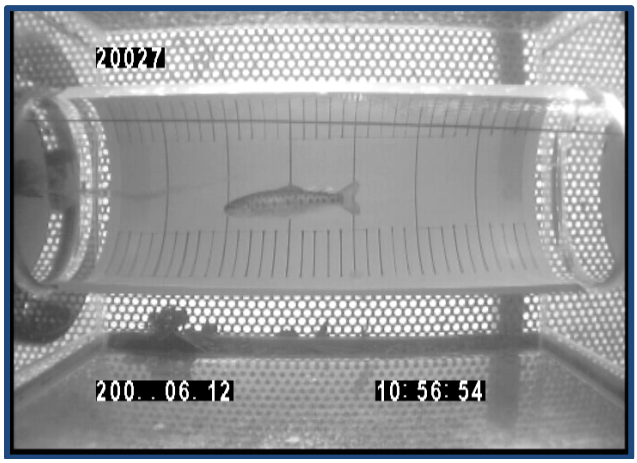
Russian River Biological Opinion
Status and Data Report
Year 2010-11



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1: Introduction

On September 24, 2008 the National Marine Fisheries Service (NMFS) issued a 15 year Biological Opinion for water Supply, flood control operations, and channel maintenance conducted by the U.S. Army Corps of Engineers (USACE), Sonoma County Water Agency (Water Agency), and Mendocino County Russian River Flood Control and Water Conservation Improvement District in the Russian River watershed (NMFS 2008). The Biological Opinion authorizes incidental take of threatened and endangered Chinook salmon, coho salmon, and steelhead pending implementation of a Reasonable and Prudent Alternative (RPA) to status quo management of reservoir releases, river flow, habitat condition, and facilities in portions of the mainstem Russian River, Dry Creek, and Russian River Estuary. Mandated projects to ameliorate impacts to listed salmonids in the RPA are partitioned among USACE and the Water Agency. Each organization has its own reporting requirements to NMFS. Because coho salmon are also listed as endangered by the California Endangered Species Act (CESA), the Water Agency is party to a Consistency Determination issued by the California Department of Fish and Game (CDFG) in November 2009. The Consistency Determination mandates that the Water Agency implement a subset of Biological Opinion projects that pertain to coho and the Water Agency is required to report progress on these efforts to CDFG.

Project implementation timelines in the Biological Opinion, and Consistency Determination, specify Water Agency reporting requirements to NMFS and CDFG and encourage frequent communication among the agencies. The Water Agency has engaged both NMFS and CDFG in frequent meetings and has presented project status updates on many occasions since early 2009. Although not an explicit requirement of the Biological Opinion or Consistency Determination, the Water Agency has elected to coalesce reporting requirements into one annual volume for presentation to the agencies. The following document represents the second report for year 2010-11. The first annual report for 2009-10 (Manning and Martini-Lamb 2011) can be accessed at http://www.scwa.ca.gov/bo-2009-report/.

Water Agency projects mandated by the Biological Opinion and Consistency Determination fall into six major categories:

- Biological and Habitat Monitoring,
- Habitat Enhancement,
- California Environmental Quality Act (CEQA) Compliance and Permitting,
- Planning and Adaptive Management,
- Water and Fish Facilities Improvements, and
- Public Outreach.

This report contains status updates for planning efforts, environmental compliance, and outreach but the majority of the technical information we present pertains to monitoring and habitat enhancement. The Biological Opinion requires extensive fisheries data collection in the mainstem Russian River, Dry Creek, and Estuary to detect trends and inform habitat enhancement efforts. The report presents each data collection effort independently and the primary intent of this document is to clearly communicate recent results. However, because Chinook, coho, and steelhead have complex life history patterns that

integrate all of these environments, we also present a synthesis section to discuss the interrelated nature of the data. Some monitoring programs are extensions of ongoing Water Agency efforts that were initiated a decade or more before receipt of the Biological Opinion.

2: Public Outreach

Biological Opinion Requirements

The Biological Opinion includes minimal *explicit* public outreach requirements. The breadth and depth of the RPAs, however, *implies* that implementation of the Biological Opinion will include a robust public outreach program.

RPA 1 (Pursue Changes to D1610 Flows) mandates two outreach activities. First, it requires the Water Agency, with the support of NMFS staff, to conduct outreach "to affected parties in the Russian River watershed" regarding permanently changing Decision 1610. Second, the RPA requires the Water Agency to update NMFS on the progress of temporary urgency changes to flows during Section 7 progress meetings and as public notices and documents are issued.

RPA 2 (Adaptive Management of the Outlet Channel) requires that within six months of the issuance of the Biological Opinion the Water Agency, in consultation with NMFS, "conduct public outreach and education on the need to reduce estuarine impacts by avoiding mechanical breaching to the greatest extent possible."

Finally, RPA 3 (Dry Creek Habitat Enhancements, refers to public outreach in the following mandate, "Working with local landowners, DFG and NMFS, Water Agency will prioritize options for implementation" of habitat enhancement.

The remaining RPAs do not mention public outreach.

Water Agency Public Outreach Activities – 2010/2011

Meetings

Public Policy Facilitating Committee meeting—The PPFC met in December, 2010 for an update of the year's activities. Notices for the meeting were sent out to approximately 800 individuals and agencies; it was advertised in The Press Democrat and community newspapers; and a press release was issued one week prior to the meeting. Approximately 75 people attended the meeting and heard presentations from Bill Hearn, NMFS; Erik Larson, CDFG; Mike Dillabough, USACOE; and Pam Jeane, David Manning, Erik Brown and Jessica Martini Lamb, Water Agency. The meeting was notable as the last one for Sonoma County Water Agency Director Paul Kelley, who served on the PPFC since its inception in 1998.

Community Meetings -- Several community meetings were held in 2010 and 2011 to update the public and to receive feedback on various aspects of implementation, including:

Community Meetings, Fish Flow – The Water Agency hosted a meeting in Guerneville in June, 2010 to review the conditions of the 2010 Temporary Urgency Change order to D1610. In addition, three scoping meetings were held in November 2010 to provide people an opportunity to solicit input on the preparation of the Fish Flow draft EIR. The scoping meetings, which were held in Monte Rio, Windsor and Ukiah, were attended by about 50 people.

Community Meetings, Dry Creek – Invitations were sent to all property owners in Dry Creek (approximately 400 landowners) to attend a January 27, 2010 meeting at Dry Creek Vineyards to learn about the habitat enhancement and pipeline feasibility studies and to answer questions regarding requests for access (required by studies). Approximately 50 people attended.

In May, 2011, another invitation was issued to Dry Creek property owners to attend a meeting in Tim Bucher's barn to review the draft habitat enhancement and pipeline feasibility studies. The meetings were held in conjunction with the Dry Creek Valley Association and the Dry Creek Winegrowers. Approximately 80 people attended the meeting.

Community Meetings, Estuary – Four public meetings were held in 2010/2011 regarding implementation of the estuary adaptive management plan. A community meeting on general estuary topics was held in June 2010, followed by a separate meeting to solicit input on the preparation of an EIR for the adaptive management plan (a meeting was also held in Santa Rosa to receive input on the EIR preparation). In January 2011, a meeting was held at the Jenner Community Center to receive public comment on the draft EIR on the estuary adaptive management project. In total, the meetings were attended by approximately 220 people.

Stakeholder Process

The Dry Creek Advisory Group (Advisory Group), created in 2009, is a stakeholder group comprised of landowners and representatives from the Water Agency, the USACE, NMFS and DFG. The Advisory Group met three times in 2010 and was joined by representatives from both Inter-Fluve and HDR who reported on progress to date. In 2010, the Advisory Group reviewed and provided input on draft documents regarding both the bypass pipeline and habitat enhancement.

Representatives from Inter-Fluve and HDR joined the Advisory Group again in May 2011 to present the draft feasibility reports for both the habitat enhancement and bypass pipeline. Members were provided access to the draft documents to provide their input.

Other Outreach

Free Media –Articles about the Biological Opinion appeared in The Press Democrat, the Russian River Times, the West County News and Review, and the Russian River Gazette. Press releases were issued on all community meetings, the estuary scoping document, temporary urgency changes, and the D1610 notice of preparation.

Electronic Media – The Water Agency continually updated its Biological Opinion webpage, including links on new documents and meetings. In addition, the Water Agency is producing (internally) a series of videos explaining specific aspects of the Biological Opinion. These videos, which are posted on YouTube, can be accessed via the agency's website. Email alerts regarding activities in the estuary were issued more than a dozen times in 2010 and the first six months of 2011.

Materials – The Water Agency rewrote and redesigned its briefing papers to reflect new information and studies being conducted. These materials were distributed at meetings, conferences, statewide forums, outreach events and through the Water Agency website. In addition, a simple postcard handout was developed for events geared to the general public.

Sonoma County Fair – The Biological Opinion was the focus of the Water Agency's outreach efforts at the Sonoma County Fair in 2010. In order to get a free gift (a reusable grocery bag), attendees needed to take a short "quiz" focused on aspects of the Biological Opinion (questions included "Name one of three fish in the Russian River that is on the endangered species list?" "Why are we asking people to conserve water this summer, even though we aren't in a drought?" "Why is Dry Creek important to your water supply?" and "Can you tell us what an estuary is and whether the Russian River has one?"). These questions provided staff an opportunity to discuss the Biological Opinion with approximately 2,000 people.

3: Pursue Changes to Decision 1610 Flows

Two major reservoir projects provide water supply storage in the Russian River watershed: 1) Coyote Valley Dam/Lake Mendocino, located on the East Fork of the Russian River three miles east of Ukiah, and 2) Warm Springs Dam/Lake Sonoma, located on Dry Creek 14 miles northwest of Healdsburg. The Water Agency is the local sponsor for these two federal water supply and flood control projects, collectively referred to as the Russian River Project. Under agreements with the United States Army Corps of Engineers (USACE), the Water Agency manages the water supply storage space in these reservoirs to provide a water supply and maintain summertime Russian River and Dry Creek streamflows.

The Water Agency holds water-right permits[1] issued by the State Water Resources Control Board (SWRCB) that authorize the Water Agency to divert[2] Russian River and Dry Creek flows and to re-divert[3] water stored and released from Lake Mendocino and Lake Sonoma. The Water Agency releases water from storage in these lakes for delivery to municipalities, where the water is used primarily for residential, governmental, commercial, and industrial purposes. The primary points of diversion include the Water Agency's facilities at Wohler and Mirabel Park (near Forestville). The Water Agency also releases water to satisfy the needs of other water users and to contribute to the maintenance of minimum instream flow requirements in the Russian River and Dry Creek established in 1986 by the SWRCB's Decision 1610. These minimum instream flow requirements vary depending on specific hydrologic conditions (normal, dry, and critical) that are based on cumulative inflows into Lake Pillsbury in the Eel River watershed.

NMFS concluded in the Russian River Biological Opinion that the artificially elevated summertime minimum flows in the Russian River and Dry Creek currently required by Decision 1610 result in high water velocities that reduce the quality and quantity of rearing habitat for coho salmon and steelhead. NMFS' Russian River Biological Opinion concludes that reducing Decision 1610 minimum instream flow requirements will enable alternative flow management scenarios that will increase available rearing habitat in Dry Creek and the upper Russian River, and provide a lower, closer-to-natural inflow to the estuary between late spring and early fall, thereby enhancing the potential for maintaining a seasonal freshwater lagoon that would likely support increased production of juvenile steelhead and salmon.

Changes to Decision 1610 are under the purview of the SWRCB, which retained under Decision 1610 the jurisdiction to modify minimum instream flow requirements if future fisheries studies identified a benefit. NMFS recognized that changing Decision 1610 would require a multi-year

[1] SWRCB water-right permits 12947A, 12949, 12950 and 16596.
[2] Divert – refers to water diverted directly from streamflows into distribution systems for beneficial uses or into storage in reservoirs.
[3] Re-divert – refers to water that has been diverted to storage in a reservoir, then is released and diverted again at a point downstream.

(6 to 8 years) process of petitioning the SWRCB for changes to minimum instream flow requirements, public notice of the petition, compliance with the California Environmental Quality Act (CEQA), and a SWRCB hearing process. To minimize the effects of existing minimum instream flows on listed salmonids during this process, the Russian River Biological Opinion stipulated that the Water Agency "will seek both long term and interim changes to minimum flow requirements stipulated by D1610." The permanent and temporary changes to Decision 1610 minimum instream flow requirements specified by NMFS in the Russian River Biological Opinion are summarized in Figure 3.1.

Permanent Changes

The Russian River Biological Opinion requires the Water Agency to begin the process of changing minimum instream flows by submitting a petition to change Decision 1610 to the SWRCB within one year of the date of issuance of the final Biological Opinion. The Water Agency filed a petition with the SWRCB on September 23, 2009, to permanently change Decision 1610 minimum instream flow requirements. The requested changes are to reduce minimum instream flow requirements in the mainstem Russian River and Dry Creek between late spring and early fall during normal and dry water years and promote the goals of enhancing salmonid rearing habitat in the upper Russian River mainstem, lower river in the vicinity of the Estuary, and Dry Creek downstream of Warm Springs Dam. NMFS' Russian River Biological Opinion concluded that, in addition to providing fishery benefits, the lower instream flow requirements "should promote water conservation and limit effects on in-stream river recreation." NMFS stated that the following changes, based on observations during the 2001 interagency flow-habitat study and the 2007 low flow season, may achieve these goals:

During Normal Years:

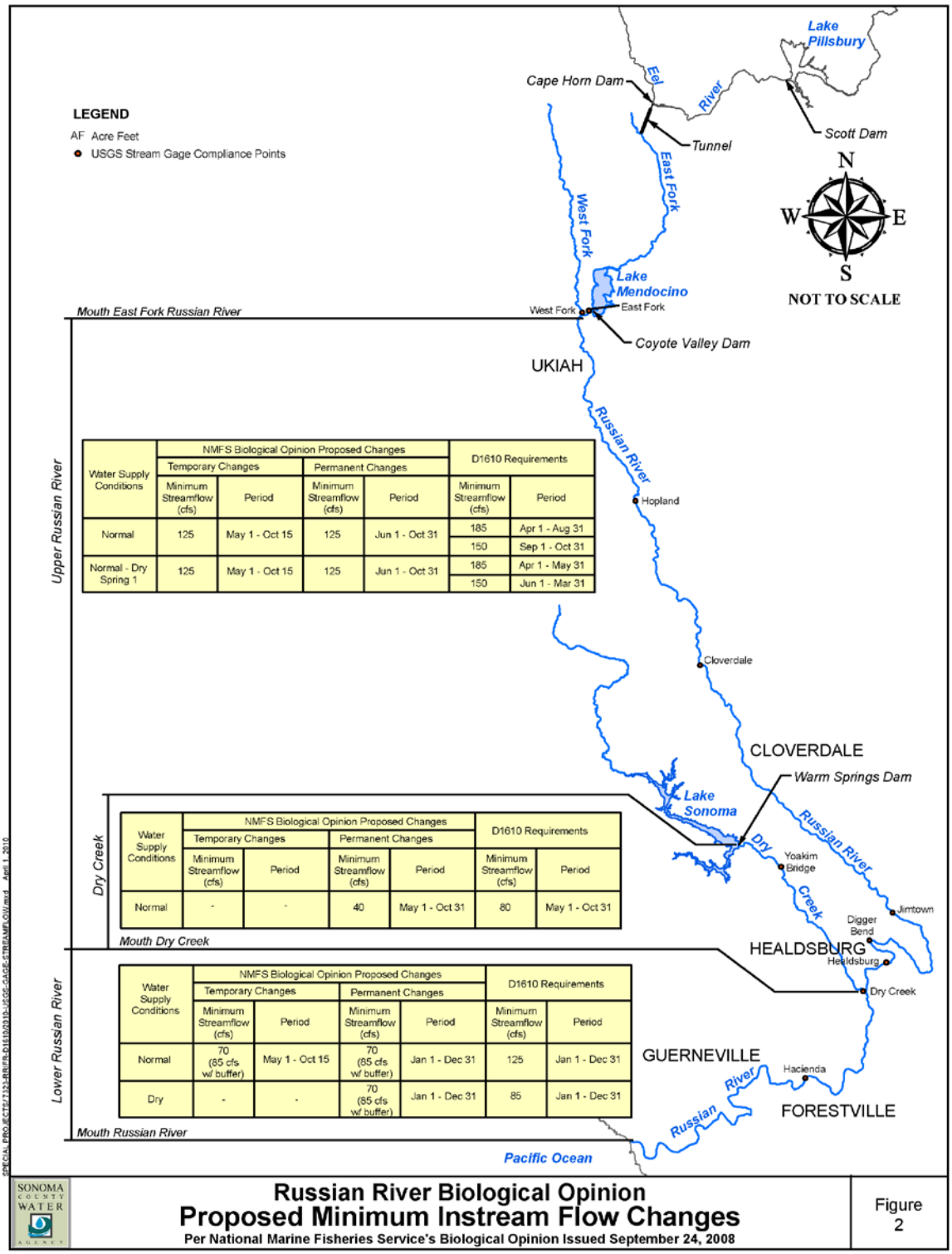
1. Reduce the minimum flow requirement for the Russian River from the East Fork to Dry Creek from 185 cubic-feet per second (cfs) to 125 cfs between June 1 and August 31; and from 150 cfs to 125 cfs between September 1 and October 31.
2. Reduce the minimum flow requirement for the Russian River between the mouth of Dry Creek and the mouth of the Russian River from 125 cfs to 70 cfs.
3. Reduce the minimum flow requirement for Dry Creek from Warm Springs Dam to the Russian River from 80 cfs to 40 cfs from May 1 to October 31.

During Dry Years:

1. Reduce the minimum flow requirement for the Russian River between the mouth of Dry Creek and the mouth of the Russian River from 85 cfs to 70 cfs.

Summary Status

The SWRCB issued a second amended public notice of the Water Agency's petition to modify Decision 1610 for public comment on March 29, 2010 (Appendix A-1). As required by the Russian River Biological Opinion, on September 23, 2010, within 6 months of issuance of the



Water Supply Conditions	NMFS Biological Opinion Proposed Changes				D1610 Requirements	
	Temporary Changes		Permanent Changes			
	Minimum Streamflow (cfs)	Period	Minimum Streamflow (cfs)	Period	Minimum Streamflow (cfs)	Period
Normal	125	May 1 - Oct 15	125	Jun 1 - Oct 31	185	Apr 1 - Aug 31
					150	Sep 1 - Oct 31
Normal - Dry Spring 1	125	May 1 - Oct 15	125	Jun 1 - Oct 31	185	Apr 1 - May 31
					150	Jun 1 - Mar 31

Water Supply Conditions	NMFS Biological Opinion Proposed Changes				D1610 Requirements	
	Temporary Changes		Permanent Changes			
	Minimum Streamflow (cfs)	Period	Minimum Streamflow (cfs)	Period	Minimum Streamflow (cfs)	Period
Normal	-	-	40	May 1 - Oct 31	80	May 1 - Oct 31

Water Supply Conditions	NMFS Biological Opinion Proposed Changes				D1610 Requirements	
	Temporary Changes		Permanent Changes			
	Minimum Streamflow (cfs)	Period	Minimum Streamflow (cfs)	Period	Minimum Streamflow (cfs)	Period
Normal	70 (85 cfs w/ buffer)	May 1 - Oct 15	70 (85 cfs w/ buffer)	Jan 1 - Dec 31	125	Jan 1 - Dec 31
Dry	-	-	70 (85 cfs w/ buffer)	Jan 1 - Dec 31	85	Jan 1 - Dec 31

Figure 3.1. A summary of the permanent and temporary changes to Decision 1610 minimum instream flow requirements specified by NMFS in the Russian River Biological Opinion.

SWRCB's public notice, the Water Agency issued a Notice of Preparation (NOP) of an Environmental Impact Report (EIR) for the Fish Habitat Flows and Water Rights Project (Fish Flow Project). A copy of the NOP is provided in Appendix A-2. In order to provide an opportunity for the public and regulatory agencies to ask questions and submit comments on the scope of the Fish Flow Project EIR, three Scoping Meetings were held during the 45-day NOP review period. Scoping meetings were held in Monte Rio on November 3, 2010; in Windsor on November 8, 2010; and in Ukiah on November 10, 2010. Comments received during the NOP scoping process are being considered during preparation of the Fish Flow Draft EIR.

Temporary Changes

Until the SWRCB issues an order on the petition to permanently modify Decision 1610, the minimum instream flow requirements specified in Decision 1610 (with the resulting adverse impacts to listed salmonids) will remain in effect, unless temporary changes to these requirements are made by the SWRCB. The Russian River Biological Opinion requires that the Water Agency petition the SWRCB for temporary changes to the Decision 1610 minimum instream flow requirements beginning in 2010 and for each year until the SWRCB issues an order on the Water Agency's petition for the permanent changes to these requirements. NMFS' Russian River Biological Opinion only requires that petitions for temporary changes "request that minimum bypass flows of 70 cfs be implemented at the USGS gage at the Hacienda Bridge between May 1 and October 15, with the understanding that for compliance purposes SCWA will typically maintain about 85 cfs at the Hacienda gage. For purposes of enhancing steelhead rearing habitats between the East Branch and Hopland, these petitions will request a minimum bypass flow of 125 cfs at the Healdsburg gage between May 1 and October 15."

Summary Status

The Water Agency petitioned the SWRCB for temporary changes to Decision 1610 on April 4, 2010 (Appendix A-3). Inflow into Lake Mendocino was sufficiently high enough to classify 2010 as a Normal year under Decision 1610 and storage in Lake Mendocino had improved over conditions in 2009. Consequently, the Water Agency filed a Temporary Urgency Change Petition (TUCP) to request that the SWRCB reduce the minimum instream flow requirements for the Russian River in the Water Agency's water-right permits in accordance with the recommendations in the Russian River Biological Opinion.

The Water Agency requested that the SWRCB make the following temporary changes to the Decision 1610 instream flow requirements:

- From May 1 through October 15, 2010, instream flow requirements for the upper Russian River (from the confluence with the East Fork of the Russian River to its Confluence with Dry Creek) be reduced from 185 cfs to 125 cfs
- From May 1 through October 15, 2010 instream flow requirements for the lower Russian River (downstream of its confluence with Dry Creek) be reduced from 125

cfs to 70 cfs with the understanding the Water Agency will typically maintain approximately 85 cfs at the Hacienda Gauge as practicably feasible.

The SWRCB issued Order WR 2010-0018-DWR approving the Water Agency's TUCP on May 24, 2010 (Appendix A-4). The order included several terms and conditions, including requirements for fisheries habitat monitoring (Terms 2 to 6), preparation of a water quality monitoring plan (Term 8), reporting of water conservation measures implemented during the term of the order (Term 11), relevant updates of estimated future water savings (Term 12) and maximum applied water allowance achieved by the Agency's contractors (Term 13). Reports to fulfill Terms 8, 11, 12, and 13 were prepared and submitted to the SWRCB and are provided in Appendices A-5 through A-8.

Provisions 2 through 7 of the Order required the Water Agency to conduct and report on a number of fisheries monitoring projects. The Water Agency and SWRCB consulted with NMFS and the California Department of Fish and Game (DFG) regarding the fisheries monitoring objectives and methods. Projects included monitoring adult Chinook returns at the Mirabel inflatable dam, dive surveys to monitor Chinook in the lower and upper Russian River, dive surveys to measure the relative abundance of juvenile steelhead and native freshwater fish in the upper Russian River, and salmonid downstream migrant trapping operations in Dry Creek, the mainstem of the Russian River at Mirabel Dam and the Russian River estuary near Duncans Mills. Updates of fisheries monitoring data were sent to NMFS and DFG staff on a weekly basis per term 7 of the Order. Detailed results are provided in the *Results of the Fisheries Monitoring Plan to Meet State Water Resources Control Board Order WR 2010 – 0018 Exec* (Water Agency 2011, Appendix A-9).

During the term of the Order, real time water quality data (pH, temperature, dissolved oxygen, specific conductivity, turbidity, and depth) was monitored at 11 surface and 4 groundwater sites along the mainstem Russian River. All samples will be analyzed for nutrients, major ions, trace metals, total and dissolved organic carbon, a broad suite of organic wastewater compounds (polyaromatic hydrocarbons, disinfection -by-products, selected pesticides and herbicides, and personal care and household products such as fragrances and detergents), by laboratories operated by the U.S. Geological Survey (USGS). In addition, water samples collected at surface-water sites located at Russian River near Hopland, Russian River at Digger Bend near Healdsburg, Russian River near Guerneville and at Russian River at Casini Ranch were analyzed for human-use pharmaceuticals; these analyses were also conducted by laboratories operated by the USGS.

In addition to the deployment of continuously recording datasondes in the Russian River estuary, as required by the Russian River Biological Opinion, grab samples were taken and analyzed for nutrients and bacteria. All samples were analyzed for nutrients, chlorophyll *a*, standard bacterial indicators (total and fecal coliform, and *Enterococci*), total and dissolved organic carbon, and turbidity. Monitoring results were posted to the Water Agency website and are provided in Appendix A-10. Water quality monitoring in the Russian River Estuary is further discussed in Chapter 4.

4: Estuary Management

The Russian River estuary (Estuary) is located approximately 97 kilometers (km; 60 miles) northwest of San Francisco in Jenner, Sonoma County, California. The Russian River watershed encompasses 3,847 square kilometers (km) (1,485 square miles) in Sonoma, Mendocino, and Lake counties. The Estuary extends from the mouth of the Russian River upstream approximately 10 to 11 km (6 to 7 miles) between Austin Creek and the community of Duncans Mills (Heckel 1994).

The Estuary may close throughout the year as a result of a barrier beach forming across the mouth of the Russian River. The mouth is located at Goat Rock State Beach (California Department of Parks and Recreation). Although closures may occur at anytime of the year, the mouth usually closes during the spring, summer, and fall (Heckel 1994; Merritt Smith Consulting 1997, 1998, 1999, 2000; Sonoma County Water Agency and Merritt Smith Consulting 2001). Closures result in ponding of the Russian River behind the barrier beach and, as water surface levels rise in the Estuary, flooding may occur. The barrier beach has been artificially breached for decades; first by local citizens, then the County of Sonoma Public Works Department, and, since 1995, by the Water Agency. The Water Agency's artificial breaching activities are conducted in accordance with the Russian River Estuary Management Plan recommended in the Heckel (1994) study. The purpose of artificially breaching the barrier beach is to alleviate potential flooding of low-lying properties along the estuary.

NMFS' Russian River Biological Opinion (NMFS 2008) found that artificially elevated inflows to the Russian River estuary during the low flow season (May through October) and historic artificial breaching practices have significant adverse effects on the Russian River's estuarine rearing habitat for steelhead, coho salmon, and Chinook salmon. The historical method of artificial sandbar breaching, which is done in response to rising water levels behind the barrier beach, adversely affects the estuary's water quality and freshwater depths. The historical artificial breaching practices create a tidal marine environment with shallow depths and high salinity. Salinity stratification contributes to low dissolved oxygen at the bottom in some areas. The Biological Opinion (NMFS 2008) concludes that the combination of high inflows and breaching practices impact rearing habitat because they interfere with natural processes that cause a freshwater lagoon to form behind the barrier beach. Fresh or brackish water lagoons at the mouths of many streams in central and southern California often provide depths and water quality that are highly favorable to the survival of rearing salmon and steelhead.

The Biological Opinion's Reasonable and Prudent Alternative (RPA) 2, Alterations to Estuary Management, (NMFS 2008) requires the Water Agency to collaborate with NMFS and to modify estuary water level management in order to reduce marine influence (high salinity and tidal inflow) and promote a higher water surface elevation in the estuary (formation of a fresh or brackish lagoon) for purposes of enhancing the quality of rearing habitat for young-of-year and age 1+ juvenile (age 0+ and 1+) steelhead from May 15 to October 15 (referred to hereafter as

the "lagoon management period"). A program of potential, incremental steps are prescribed to accomplish this, including adaptive management of a lagoon outlet channel on the barrier beach, study of the existing jetty and its potential influence on beach formation processes and salinity seepage through the barrier beach, and a feasibility study of alternative flood risk measures. RPA 2 also includes provisions for monitoring the response of water quality, invertebrate production, and salmonids in the estuary to the management of water surface elevations during the lagoon management period.

The following section provides a summary of the Water Agency's estuary management actions required under the Russian River Biological Opinion RPA 2 in 2010.

Sandbar Management

RPA 2 requires the Water Agency, in coordination with NMFS, CDFG, and the USACE, to annually prepare barrier beach outlet channel design plans. Each year after coordinating with the agencies, the Water Agency is to provide a draft plan to NMFS, CDFG, and the USACE by April 1 for their review and input. The initial plan was to entail the design of a lagoon outlet channel cut diagonally to the northwest. Sediment transport equations shall be used by Water Agency as channel design criteria to minimize channel scour at the anticipated rate of Russian River discharge. This general channel design will be used instead of traditional mechanical breaching whenever the barrier beach closes and it is safe for personnel and equipment to work on the barrier beach. Alternate methods may include 1) use of a channel cut to the south if prolonged south west swells occur, and 2) use of the current jetty as a channel grade control structure (as described below) for maintaining water surface elevations up to 7-9 feet NGVD (NMFS 2008).

The Water Agency contracted with Philip Williams and Associates (PWA) to prepare the Russian River Estuary Outlet Channel Adaptive Management Plan Year 2 (PWA 2010, Appendix B-1). The approach of the Year 2 plan was to meet the objective of RPA 2 to the greatest extent feasible while staying within the constraints of existing regulatory permits and minimizing the impact to aesthetic and recreational resources of the site. It was recognized that the measures developed in the Year 2 management plan, when implemented, potentially could not fully meet the objectives established by the RPA due to the permitting constraints. The concept of this approach was developed in coordination with NMFS.

A monthly topographic survey of the beach at the mouth of the Russian River is also required under RPA 2. As a Marine Mammal Protection Act permit was required for all beach management activities, the Water Agency was unable to perform beach topographic surveys in January, February, and March 2010 (see Permitting below). The presence of harbor seal pups and weather conditions prohibited beach surveys in April and May 2010. A topographic survey was not completed in December 2010 due to wet weather conditions. The beach topographic maps are provided in Appendix B-2.

There were 6 barrier beach formations (sandbar closures) in 2010 (Table 4.1). Two closures were followed by natural breaching. Implementation of the *2010 Lagoon Outlet Channel*

Adaptive Management Plan occurred once on July 8, 2010. The outlet channel closed during high tide on the same day and the barrier beach naturally breached on July 11, 2010. The Water Agency artificially breached the sandbar at the mouth of the Russian River 3 times in 2010. Two of the artificial breaching events occurred during the Lagoon Management Period (May 15 to October 15) mandated by the Russian River Biological Opinion (NMFS 2008) following consultation with the National Marine Fisheries Service and California Department of Fish and Game regarding potential flood risk associated with high wave events and inflows into the Russian River estuary. The timing of the closures late in the Lagoon Management Period would provide little or no habitat benefit to juvenile steelhead and the potential for flooding was high due to the limited beach access due to high wave events breaking across the beach.

Table 4.1. Summary of Russian River Estuary Sandbar Closures and Management Events in 2010.

Closure No.	Approximate Sandbar Closure Date	Approx. No. Days Closed	Event Type and Date	Jenner Gage Level at Breach (feet)
1	01/08/2010	3	Artificial Breach - 01/11/2010	7.5
2	07/04/2010	4	Lagoon outlet implementation- 07/08/2010a	5.6
	07/08/2010	3	Natural Breach – 07/11/2010	7.2
3	09/21/2010	10	Artificial Breach - 10/1/2010b	7.7
4	10/4/2010	8	Artificial Breach – 10/12/2010c	6.9
5	10/21/2010	3	Natural Breach – 10/24/2010	8.7
6	11/2/2010	1	Natural Breach – 11/2/2010	6.7

[a] SCWA implemented the 2010 lagoon outlet channel adaptive management plan on July 8,2010. The outlet channel closed during a high tide event on the same day. The barrier beach naturally breached July 11, 2010.

[b] SCWA consulted with National Marine Fisheries Service and California Department of Fish and Game regarding the potential flood risk posed by high surf activity and inflows making access to the beach difficult. Consensus was that artificial breaching should be done to minimize flood risk. Attempted to breach on September 30, 2010, but high wave activity reformed the barrier beach. Successfully breached the barrier beach on October 1, 2010.

[c] SCWA consulted with National Marine Fisheries Service and California Department of Fish and Game regarding the potential flood risk posed by high surf activity and inflows making access to the beach difficult. Consensus was that artificial breaching should be done to minimize flood risk. Attempted to breach on October 11, 2010, but high wave activity reformed the barrier beach. Successfully breached the barrier beach on October 12, 2010.

Lagoon Outlet Channel Implementation – July 8, 2010

The July 8, 2010,lagoon outlet channel implementation event was the only one in 2010. The barrier beach formed, closing the mouth of the Russian River, on July 4, 2010. Prior to the

closure, the river channel had been flowing to the northwest in an orientation similar to the target orientation for the lagoon outlet channel (Figure 4.1).The outlet channel naturally established itself for about one week at the end of June, and was then closed by ocean waves. After this closure, the Water Agency mechanically re-created the outlet channel, following consultation with NMFS, CDFG, and State Parks, in accordance with the *2010 Lagoon Outlet Channel Adaptive Management Plan* (Appendix B-1). However, waves closed the outlet channel during high tide on the day of implementation. Before the outlet channel could be re-established by the Water Agency, the lagoon breached naturally, returning the estuary to tidal conditions for the remainder of the summer. Pinniped monitoring occurred prior to, during, and following outlet channel creation as required by the Marine Mammal Protection Act permit (see Permitting below).

Jetty

RPA 2 includes a second step if adaptive management of the outlet channel as described, "is not able to reliably achieve the targeted annual and seasonal estuary management water surface elevations by the end of 2010, Water Agency will draft a study plan for analyzing the effects and role of the Russian River jetty at Jenner on beach permeability, seasonal sand storage and transport, seasonal flood risk, and seasonal water surface elevations in the Russian River estuary. That study will also evaluate alternatives for achieving targeted estuarine management water surface elevations via jetty removal, partial removal of the jetty, jetty notching, and potential use of the jetty as a tool in maintaining the estuary water surface elevations described above."

No additional work on the jetty study plan was performed or required in 2010.

Flood Risk Management

RPA 2 also includes a Flood Risk Reduction step if it proves difficult to reliably achieve raised water surface elevation targets based on implementation of a lagoon outlet channel or modification of the existing jetty. Should those actions be unsuccessful in meeting estuarine water surface elevation goals, RPA 2 states that the Water Agency "will evaluate, in coordination with NMFS and other appropriate public agencies, the feasibility of actions to avoid or mitigate damages to structures in the town of Jenner and low-lying properties along the estuary that are currently threatened with flooding and prolonged inundation when the barrier beach closes and the estuary's water surface elevation rises above 9 feet. Such actions may include, but are not limited to, elevating structures to avoid flooding or inundation."

The first effort to address flood risk management feasibility was compilation of a preliminary list of structures, properties, and infrastructure that would be subject to flooding/inundation as the result of sandbar formation and if the estuary were allowed to naturally breach. As required by Reasonable and Prudent Alternative (RPA) 2 in the Russian River Biological Opinion (NMFS 2008), the Water Agency submitted a preliminary list of properties, structures, and infrastructure that may be subject to inundation if the barrier beach at the mouth of the Russian River was allowed to naturally breach (Appendix B-3). Allowing Estuary water surface

July 1, 2010 Natural Open Channel. Photo from Highway 1 Overlook.

July 7, 2010 Channel Closed by Tidal Action. Photo from Highway 1 Overlook.

July 8, 2010 Created Outlet Channel. Photo from Highway 1 Overlook.

Figure 4.1. Russian River Estuary: Natural outlet channel closed and created outlet channel conditions, July 2010

elevations to rise to between 10 and 12 feet NGVD (the estimated water surface elevation if the barrier beach was allowed to naturally breach per consultation with NMFS) may potentially inundate portions of up to 96 properties.

The Water Agency created a Geographic Information System (GIS) tool specifically for evaluating inundation risk to properties along the Estuary. An aerial photograph was overlaid with a digital elevation map created during the bathymetric survey of the Russian River estuary in 2008 and 2009. A County of Sonoma parcel permit tool was used by matching the APN number to the parcel to determine the type of structures on the property. These data sources provided the parcel location, and the approximate elevation and location of structures on the property. The information was entered into a spreadsheet by Assessor's Parcel Number (APN), potential inundation elevation, and type of property, structure, and infrastructure. The number of structures and type are also included. Structures include houses, garages, sheds, and boat docks. Also included is the type of infrastructure including: wells, septic, roads, bridges, and telephone poles. The information provided is considered preliminary and will be revised as the Water Agency moves forward with the flood risk management feasibility requirements of RPA 2.

Permitting

In addition to compliance with the federal and California Endangered Species Acts, water level and beach management activities in the Estuary require compliance with numerous other federal and state regulations, as well as leases from several state agencies to perform management activities at Goat Rock State Beach and in the Russian River estuary. At the time of issuance of the Russian River Biological Opinion,[4] the Water Agency held permits for artificial breaching from California State Parks, California State Lands Commission, California Coastal Commission, North Coast Regional Water Quality Control Board, California Department of Fish and Game, and the U.S. Army Corps of Engineers. Beginning in late 2008, the Water Agency began working with these state and federal agencies to either modify or receive clarification regarding the scope of activities allowed under existing permits to allow for creation of the lagoon outlet channel and compliance with RPA 2 of the Russian River Biological Opinion. Existing permits were either modified or clarification received to allow creation of the lagoon outlet channel, with the exception of the California Coastal Commission's Coastal Development Permit, which was modified in 2010. Applications for new permits were submitted to the State Lands Commission, Coastal Commission, North Coast Regional Water Quality Control Board, California Department of Fish and Game, and the U.S. Army Corps of Engineers in December 2010. Completion of the permitting processes is pending the certification of a new California Environmental Quality Act (CEQA) document. Beach management activities in 2011 would be conducted under extensions of the existing permits.

The Water Agency began a CEQA process to obtain new regulatory permits that would allow for a change in the volume of sand excavated for creation of the lagoon outlet channel and to

[4] The previous NMFS biological opinion specific to estuary breaching activities was replaced with the Russian River Biological Opinion.

replace expiring permits. The Notice of Preparation (NOP) was released to local, state, and federal agencies, and to other interested parties on May 7, 2010. The NOP was circulated for a 45-day public review period, which ended on June 21, 2010. During the NOP review period, the Water Agency held two scoping meetings, in May at the Jenner Community Center and the Sonoma County Permit and Resource Management Department in Santa Rosa, to discuss the project and to solicit public input as to the scope and content of the EIR. On December 15, 2010, the Water Agency released the Draft EIR for public review. A 60-day public review and comment period on the Draft EIR ended February 14, 2011. A public hearing on the Draft EIR was held during the public review period on January 18, 2010 from 6:00 p.m. to 9:00 p.m. at the Jenner Community Center.

Following issuance of the Russian River Biological Opinion, the Water Agency was informed that a permit was also required under the Marine Mammal Protection Act (MMPA) as beach management activities occurred in the vicinity of a harbor seal haulout at the mouth of the Russian River. The Water Agency applied to NMFS for an Incidental Harassment Authorization (IHA) under the MMPA in 2009. The final IHA was issued in March 2010. As this permit was required for all beach management activities, the Water Agency was unable to perform beach topographic surveys prior to its issuance in 2010.

4.1 Water Quality Monitoring

Water quality monitoring was conducted in the lower, middle, and upper reaches of the Russian River Estuary between the mouth of the river at Jenner and Monte Rio, including two tributaries. Water Agency staff continued to collect data to establish baseline information on water quality in the Estuary, gain a better understanding of the longitudinal and vertical water quality profile during the ebb and flow of the tide, and track changes to the water quality profile that may occur during periods of barrier beach closure and reopening.

Saline water is denser than freshwater and a salinity “wedge” forms as freshwater outflow passes over the denser tidal inflow. During the lagoon management period (May 15 to October 15), the lower and middle reaches of the Estuary up to Sheephouse Creek are predominantly saline environments with a thin freshwater layer that flows over the denser saltwater. The upper reach of the Estuary transitions to a predominantly freshwater environment, which is periodically underlain by a denser, saltwater layer that migrates upstream to Duncans Mills during summer low flow conditions and barrier beach closure. Additionally, river flows, tides, topography, and wind action affect the amount of mixing of the water column at various longitudinal and vertical positions within the Estuary.

In 2010, the Estuary experienced three closures during the lagoon management period. The barrier beach formed and the Estuary closed for a period of 7 days from 4 July to 11 July, 10 days from 21 September to 1 October, and 9 days from 3 October to 12 October. During these closures, the Water Agency was able to monitor the partial development of a freshwater lagoon system as freshwater inflows increased the depth of the surface layer and the volume of denser

saltwater in the lower layer of the water column began to decline, presumably as it seeped through the barrier beach.

Methods

Continuous Multi-Parameter Monitoring

Water quality was monitored using YSI Series 6600 multi-parameter datasondes. Hourly salinity (parts per thousand, ppt), water temperature (degrees Celsius), dissolved oxygen (milligrams per liter, mg/L), and pH (hydrogen ion) data were collected. Datasondes were cleaned and recalibrated periodically following the YSI User Manual procedures, and data was downloaded during each calibration event.

Nine stations were established for continuous water quality monitoring, including seven stations in the mainstem and two tributary stations (Figure 4.1.1). One mainstem station was located in the lower reach at the mouth of the Russian River at Goat Rock State Beach (Mouth Station). Three mainstem stations were placed in the middle reach: Patty's Rock upstream of Penny Island (Patty's Rock Station); Bridgehaven just downstream from the Highway 1 Bridge (Bridgehaven Station); and in the pool downstream of Sheephouse Creek (Sheephouse Creek Station). One tributary station was located in the mouth of Willow Creek, which flows into the middle reach of the estuary (Willow Creek Station). Two mainstem stations were located in the upper reach; a pool next to an area known as Heron Rookery located halfway between Sheephouse Creek and Duncans Mills (Heron Rookery Station), and downstream of Freezeout Creek in Duncans Mills (Freezeout Creek Station). The other tributary station was located downstream of the first steel bridge in lower Austin Creek, which flows into the mainstem above Duncans Mills (Austin Creek Station). The furthest upstream mainstem station was located in Monte Rio, outside of the influence of saline water, but within the upper extent of inundation and backwatering during lagoon formation (Monte Rio Station).

The rationale for choosing Estuary sites was to locate the deepest holes at various points throughout the Estuary to obtain the fullest vertical profiles possible, and to monitor hypoxic and/or anoxic events and temperature or salinity stratification. Sondes were located in the mouths of Willow and Austin Creeks to collect baseline water quality conditions and monitor potential changes to water quality, including salinity intrusion, during estuary closure and inundation. The Monte Rio station was established to monitor potential changes to water quality conditions in the upstream extent of the river that can become inundated during barrier beach closure, also referred to as the maximum backwater area (Figure 4.1.1).

Mainstem estuary monitoring stations were comprised of a concrete anchor attached to a steel cable suspended from the surface by a large buoy (Figure 4.1.2). All mainstem estuary stations had a vertical array of two datasondes to collect water quality profiles. Stations in the lower and middle reaches of the Estuary that are predominantly saline had sondes placed at the surface (~1m) and mid-depth (~3m) portions of the water column.

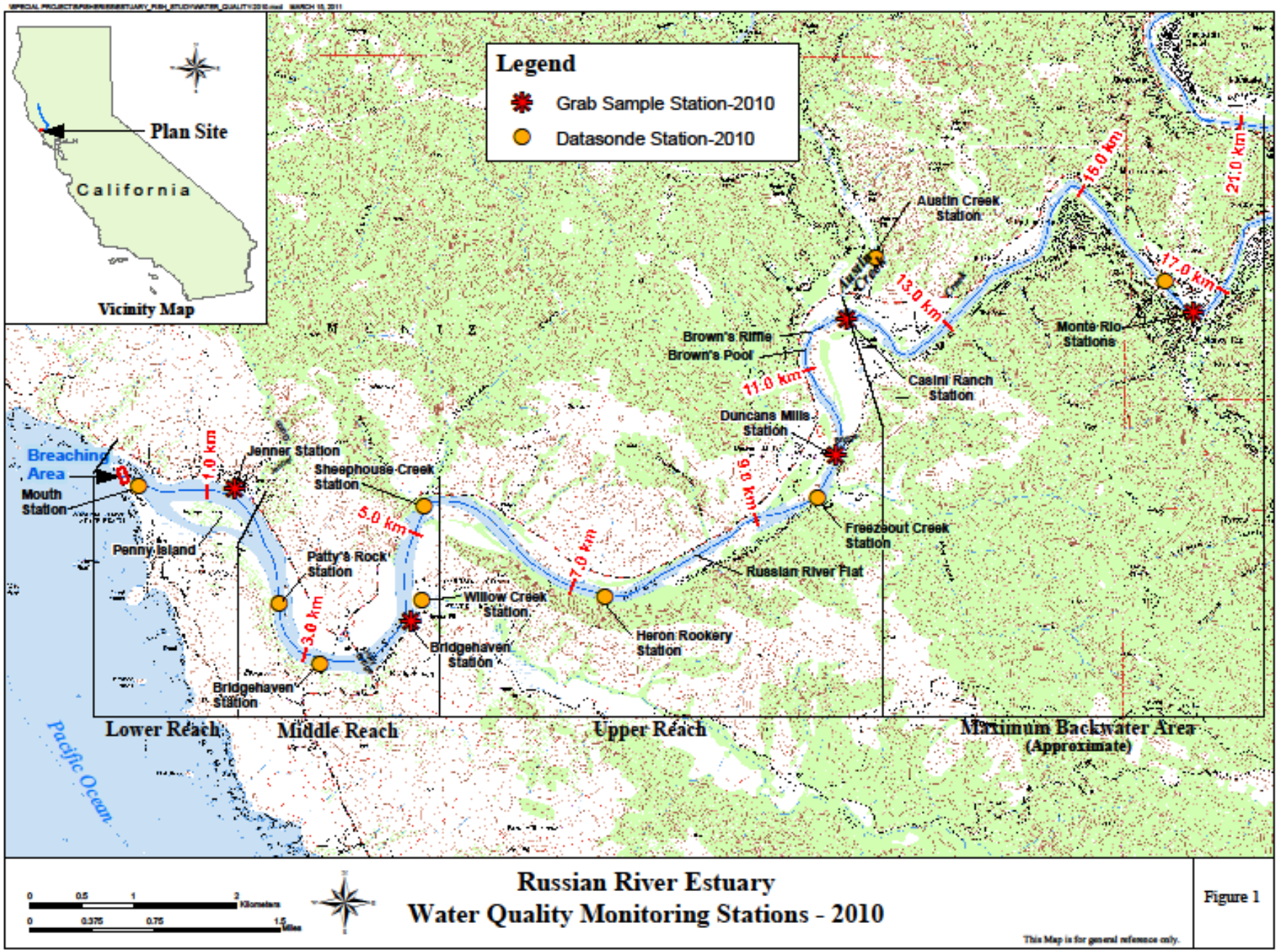


Figure 4.1.1. 2010 Russian River Estuary Water Quality Monitoring Stations

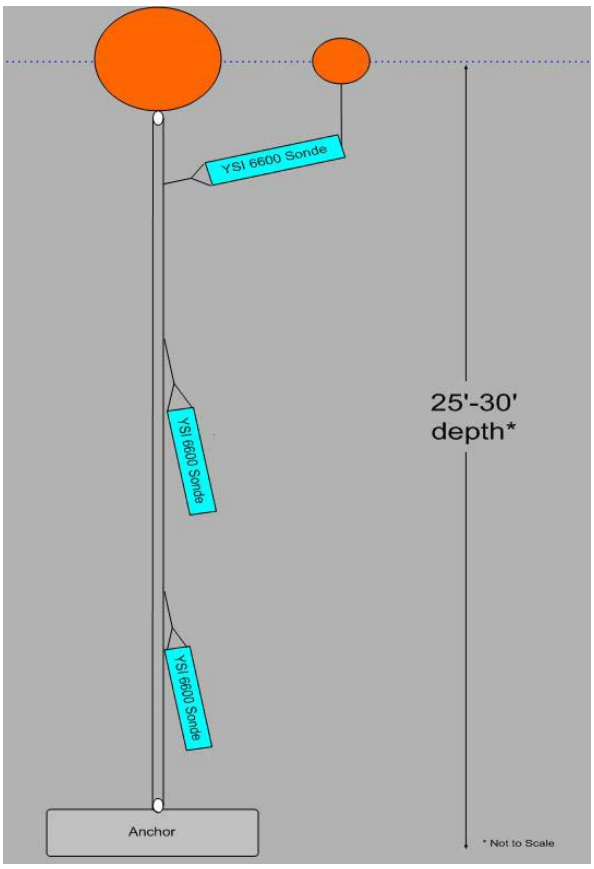


Figure 4.1.2. Typical Russian River Estuary monitoring station datasonde array.

The two stations in the upper reach of the Estuary, where water is predominantly fresh to brackish, were located in the lower half of the water column at mid-depth (~3-4m) and the bottom (~6-8m). Sondes were located in this manner to track vertical and longitudinal changes in water quality characteristics, including periods of barrier beach closure and reopening.

Monitoring stations in the tributaries and at Monte Rio consisted of one datasonde suspended at approximately mid-depth (during open conditions) in the thalweg at each respective site.

Monitoring stations at the Mouth, Patty's Rock, Bridgehaven, Sheephouse Creek, Heron Rookery, and Freezeout Creek stations were deployed from the end of April to the end of October. The Willow Creek and Austin Creek stations were deployed from the first week of May to the end of October, and the Monte Rio Station was deployed from the first week of June to the end of October. All stations were retrieved earlier than typical years due to strong storm events and resultant high flows that occurred in late October.

Grab Sample Collection

Five stations were established in 2010 for nutrient and indicator bacteria grab sampling: the Jenner Boat Ramp (Jenner Station); Bridgehaven at the mouth of Willow Creek (Bridgehaven Station); Moscow Road Bridge in Duncans Mills (Duncans Mills Station); Casini Ranch across from the mouth of Austin Creek (Casini Ranch Station); and just downstream of the Monte Rio Bridge (Monte Rio Station). This sampling was included in the *Russian River Water Quality Monitoring Plan for the Sonoma County Water Agency2010 Temporary Urgency Change (TUC)* (Appendix A-5). Refer to Figure 4.1.1 for grab sampling locations.

Water Agency staff collected grab samples once every two weeks from 22 June to 14 October. Additional focused sampling (collecting three samples over a ten-day period), was conducted following or during specific river management and operational events including: removal of Vacation Beach dam, sandbar breaching, and lagoon outlet channel implementation. All grab samples were analyzed at Alpha Analytical Labs in Ukiah.

Nutrient sampling was conducted for total organic nitrogen, ammonia, unionized ammonia, nitrate, nitrite, total Kjeldahl nitrogen, total nitrogen (calculated), and total phosphorus, as well as for *chlorophyll a*, which is a measurable parameter of algal growth that can be tied to excessive nutrient concentrations. Grab samples were collected for presence of indicator bacteria including total coliforms, fecal coliforms, and *Enterococcus*. These bacteria are considered indicators of water quality conditions that may be a concern for water contact recreation and public health. The results of sampling conducted for total orthophosphate, dissolved organic carbon, total organic carbon, total dissolved solids, and turbidity are included as an appendix; however, an analysis and discussion of these constituents is not included in this report. Temperature and pH were recorded during grab sampling events and are included in the appendix.

Results

Water quality conditions in 2010 were similar to trends observed in sampling from 2004 to 2009. The lower and middle reaches are predominantly saline environments with a thin freshwater layer that flows over the denser saltwater layer. The upper reach transitions to a predominantly freshwater environment, which is periodically underlain by a denser, saltwater layer that migrates up and downstream and appears to be affected in part by freshwater inflow rates, tidal inundation, barrier beach closure, and subsequent tidal cycles following reopening of the barrier beach. The lower and middle reaches of the Estuary are subject to tidally-influenced fluctuations in water depth and inundation during barrier beach closure, as is the upper reach to a lesser degree. The river upstream of Duncans Mills is considered freshwater habitat that is subject to inundation and backwatering during barrier beach closure.

Table 4.1.1 presents a summary of minimum, mean, and maximum values for temperature, depth, dissolved oxygen (DO), pH, and salinity recorded at the various datasonde monitoring stations. Data associated with malfunctioning datasonde equipment has been removed from

Table 4.1.1. Russian River Estuary 2010 water quality monitoring results. Minimum, mean, and maximum temperature (degrees C), depth (m), dissolved oxygen (mg/L), hydrogen ion (pH), and salinity (ppt).

Monitoring Station *Sonde*	**Temperature** (°C)	**Depth** (m)	**Dissolved Oxygen** (%) saturation	**Dissolved Oxygen** (mg/L)	**Hydrogen Ion** (pH)	**Salinity** (ppt)
Mouth						
Surface						
April 23 - October 22						
Min	9.7	0.5	58.7	5.4	7.5	0.1
Mean	16.8	0.9	104.7	9.4	8.2	10.5
Max	**23.0**	**1.0**	**192.4**	**16.8**	**9.0**	**33.9**
Mid-Depth						
April 23 - October 22						
Min	9.3	2.8	51.3	4.5	7.3	0.2
Mean	13.7	3.0	102.1	9.1	7.9	24.9
Max	**20.8**	**3.1**	**294.6**	**25.3**	**8.9**	**34.2**
Patty's Rock						
Surface						
April 28 - October 24						
Min	11.5	0.6	62.6	5.7	7.3	0.1
Mean	17.1	0.8	103.3	9.8	8.2	4.1
Max	**23.0**	**0.9**	**248.5**	**24.2**	**9.1**	**31.1**
Mid-Depth						
April 28 - October 20						
Min	10.0	2.3	51.0	4.3	7.4	0.1
Mean	14.1	2.7	96.3	8.4	8.0	25.9
Max	**20.9**	**2.8**	**229.7**	**18.8**	**8.7**	**33.5**
Bridgehaven						
Surface						
April 28 - October 26						
Min	12.4	0.6	40.3	3.7	7.2	0.1
Mean	18.0	0.8	101.3	9.2	8.1	6.7
Max	**23.2**	**1.1**	**345.4**	**34.7**	**9.0**	**31.0**
Mid-Depth						
April 28 - October 26						
Min	10.5	2.4	1.3	0.1	7.1	0.1
Mean	14.4	3.4	99.6	8.7	7.9	25.2
Max	**20.6**	**5.9**	**164.5**	**14.0**	**8.7**	**32.8**
Willow Creek						
Mid-Depth						
May 3 - October 27						
Min	8.7	0.4	0.0	0.0	6.5	0.1
Mean	16.5	1.1	75.8	7.4	7.6	3.5
Max	**24.3**	**2.9**	**198.3**	**16.1**	**9.3**	**24.6**
Sheephouse Creek						
Surface						
April 23 - October 26						
Min	12.6	0.8	39.9	3.4	6.8	0.1
Mean	19.2	0.9	97.9	9.1	8.0	2.3
Max	**23.9**	**1.0**	**233.3**	**22.9**	**9.4**	**30.2**
Mid-Depth						
April 23 - October 26						
Min						
Mean						
Max						

Table 4.1.1. (cont.)

Monitoring Station *Sonde*	Temperature (°C)	Depth (m)	Dissolved Oxygen (%) saturation	Dissolved Oxygen (mg/L)	Hydrogen Ion (pH)	Salinity (ppt)
Heron Rookery						
Mid-Depth						
April 29 - October 24						
Min	12.0	2.7	42.3	3.6	7.3	0.1
Mean	18.5	3.4	88.0	8.1	8.1	3.3
Max	**23.6**	**4.8**	**167.6**	**15.9**	**8.9**	**28.3**
Bottom						
April 29 - October 24						
Min	12.6	7.6	0.5	0.1	5.5	0.1
Mean	17.3	8.6	56.6	5.2	7.1	15.2
Max	**23.1**	**9.4**	**163.3**	**15.3**	**8.7**	**26.5**
Freezeout Creek						
Mid-Depth						
April 29 - October 26						
Min	12.7	3.5	57.0	5.2	7.3	0.2
Mean	19.8	3.8	95.0	8.7	8.1	0.7
Max	**24.2**	**7.8**	**151.3**	**14.1**	**8.8**	**9.0**
Bottom						
April 29 - October 26						
Min	12.6	4.6	0.0	0.0	5.5	0.1
Mean	19.6	6.3	74.6	6.8	7.7	2.5
Max	**23.7**	**8.4**	**169.4**	**14.8**	**8.7**	**11.0**
Austin Creek						
Mid-Depth						
May 5 - October 27						
Min	11.0	0.3	29.4	3.0	7.3	0.0
Mean	16.4	0.7	84.4	8.3	7.8	0.1
Max	**21.3**	**2.7**	**120.9**	**11.6**	**8.3**	**0.2**
Monte Rio						
Mid-Depth						
June 7 - October 28						
Min	10.6	0.8	66.3	6.2	7.2	0.1
Mean	17.8	1.1	100.3	9.5	7.9	0.1
Max	**22.1**	**2.7**	**231.3**	**21.2**	**9.1**	**0.2**

the data sets, resulting in the data gaps observed in the graphs presented as Figures 4.1.3 through 4.1.38. These data gaps may affect minimum, mean, and maximum values of the various monitored constituents, including at the Patty's Rock Surface Sonde in July and September, the Bridgehaven Mid-Depth Sonde in October, the Willow Creek Sonde in May, the Sheephouse Creek Surface Sonde for the entire monitoring season, the Heron Rookery Bottom Sonde from late July to early August and late August to late September, the Freezeout Creek Bottom Sonde from mid- to late May, and the Austin Creek Sonde in May and early to mid-August.

Although gaps exist in the 2010 data that affect sample statistics, long time-series data has been collected on an hourly frequency for several years at most of these stations, and it is unlikely that the missing data appreciably affected the broader understanding of water quality conditions within the estuary. The following sections provide a brief discussion of the results observed for each parameter monitored.

Salinity

Full strength seawater has a salinity of approximately 35 ppt, with salinity decreasing from the ocean to the upstream limit of the Estuary, which is considered freshwater at approximately 0.5 ppt (Horne 1994). All of the mid-depth sondes in the lower and middle reaches were located in a predominantly saline environment, whereas the surface sondes were located at the saltwater-freshwater interface (halocline or salt wedge) and recorded both freshwater and saltwater conditions. In the middle reach of the Estuary, salinities can range as high as 30 ppt in the saltwater layer, with brackish conditions prevailing at the upper end of the salt wedge, to less than 1 ppt in the freshwater layer on the surface. The Willow Creek sonde was located just upstream of the confluence with the Russian River, where predominantly freshwater conditions observed during higher springtime flows transitioned to a brackish environment during lower dry season flows.

In the upper reach, the Estuary begins to transition to a predominantly brackish and freshwater environment in the Heron Rookery area. The Freezeout Creek station is located in a predominantly freshwater environment; however, saltwater does occur in the lower half of the water column during open estuary conditions with lower instream flows, as well as during barrier beach closure.

The Austin Creek and Monte Rio stations are located in freshwater habitat above the upper reach of the Estuary (in the maximum backwater area) that becomes partially inundated during barrier beach closure. Salinity was not observed at these stations during either open or closed conditions.

Lower and Middle Reach Salinity

The surface sondes at the Mouth, Patty's Rock, Bridgehaven, and Sheephouse Creek stations were suspended at a depth of approximately 1 meter, and experienced frequent hourly fluctuations in salinity during open conditions after springtime flows receded in early July. These fluctuations are caused by tidal movement and expansion and contraction of the salt wedge. The freshwater layer was persistent at the surface sondes before spring flows receded. The surface sondes at the Mouth, Patty's Rock, Bridgehaven, and Sheephouse Creek had mean salinity values of 10.5, 4.1, 6.7, and 2.3 ppt, respectively (Table 4.1.1).

Salinity concentrations were observed to decrease at the surface sondes in response to barrier beach closure (Figures 4.1.3 through 4.1.6). This is due to a combination of freshwater inflows

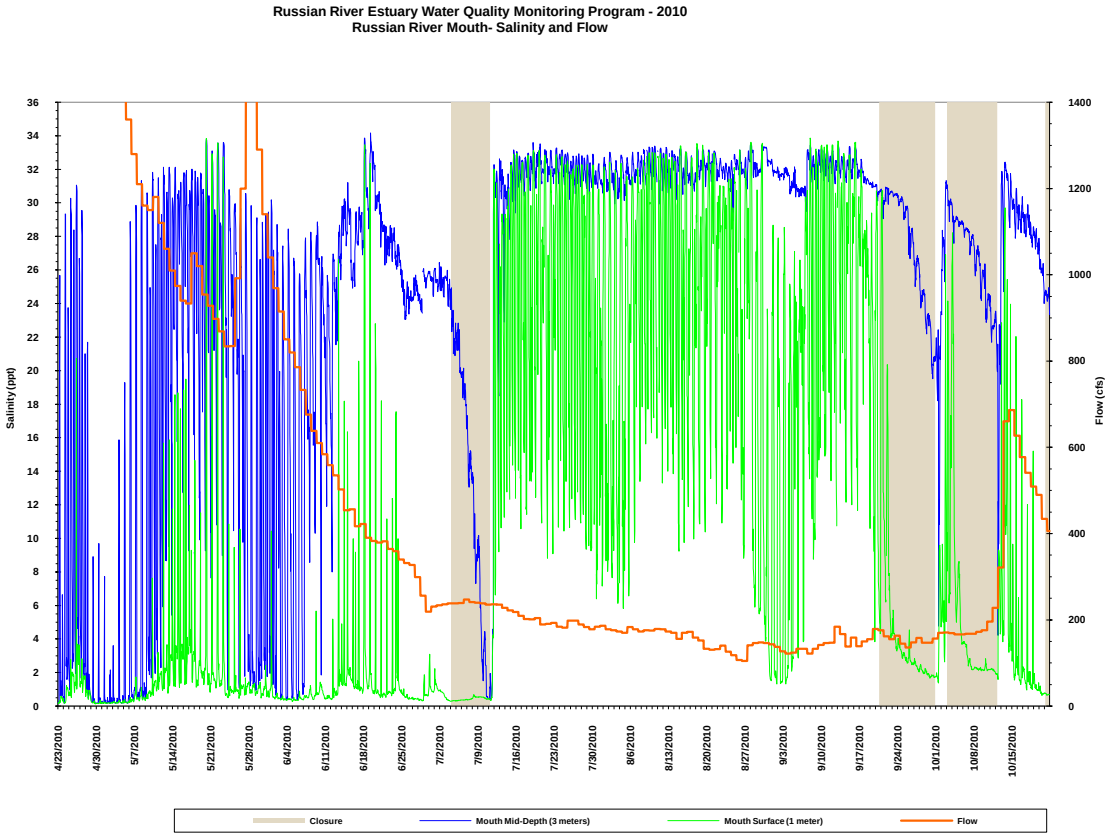


Figure 4.1.3. 2010 Russian River Mouth Salinity and Flow Graph

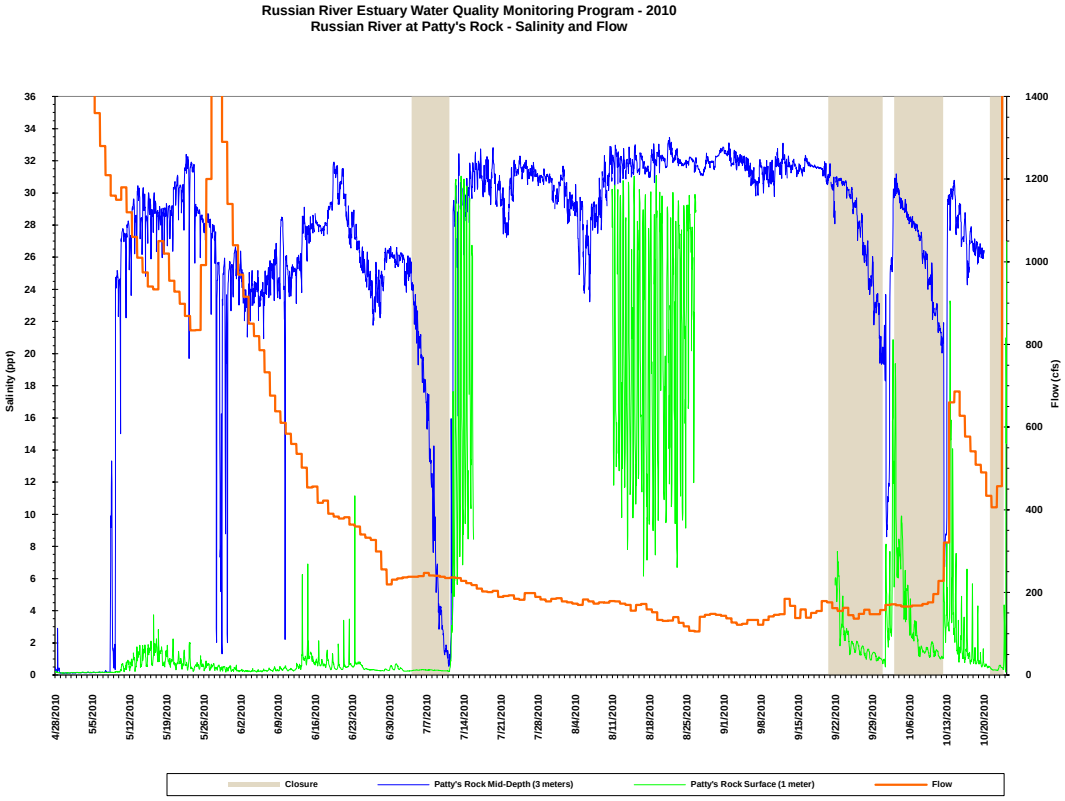


Figure 4.1.4. 2010 Russian River at Patty's Rock Salinity and Flow Graph

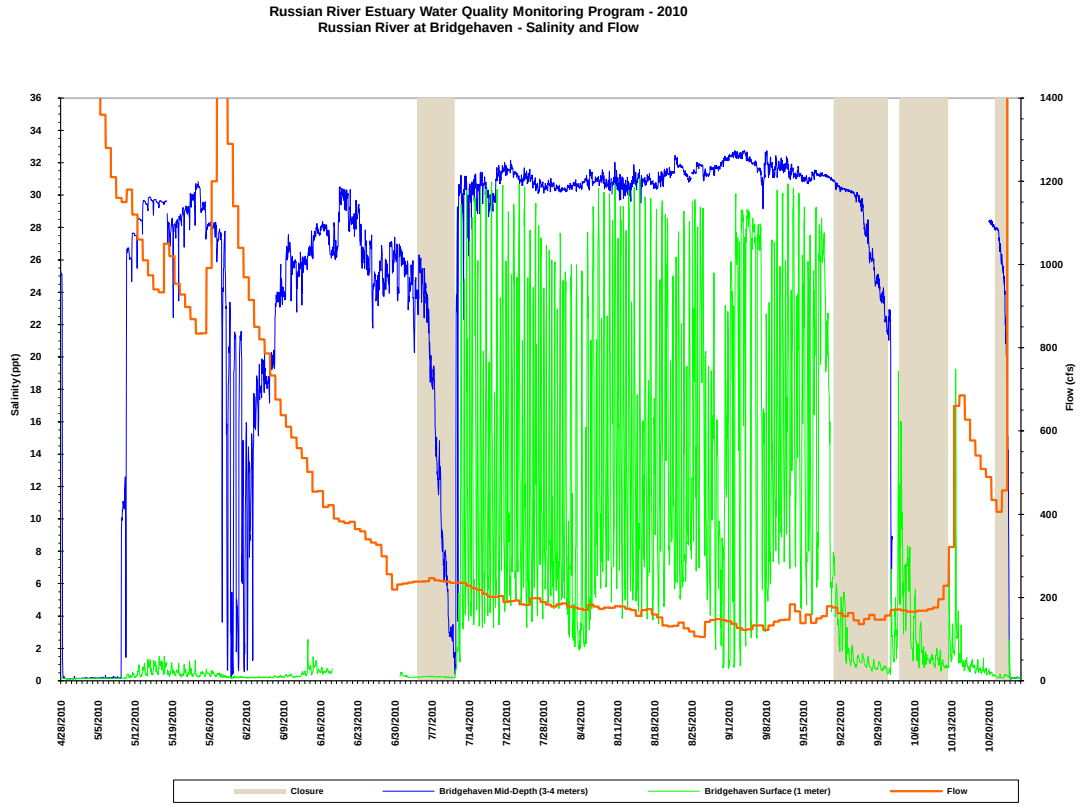


Figure 4.1.5. 2010 Russian River at Bridgehaven Salinity and Flow Graph

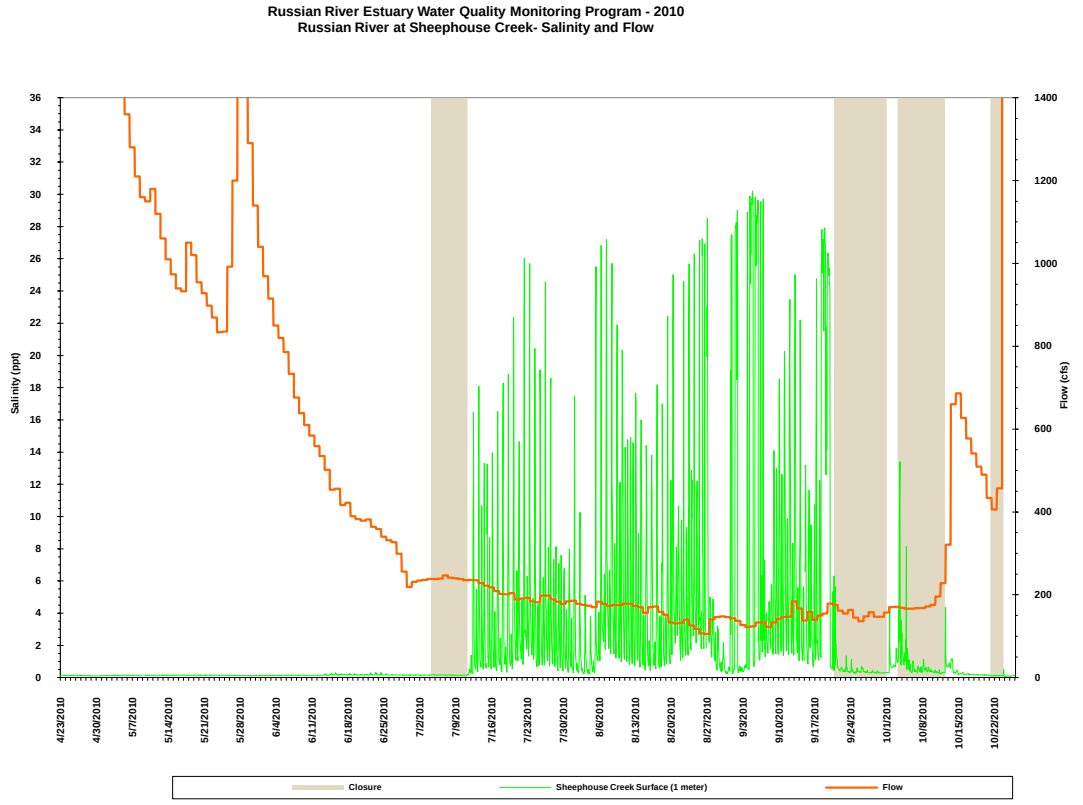


Figure 4.1.6. 2010 Russian River at Sheephouse Creek Salinity and Flow Graph

increasing the depth of the freshwater layer over the salt layer, the resulting compression and leveling out of the salt layer during stratification, and seepage of saline water through the barrier beach. Salinity returned to pre-closure levels after the mouth was breached, although the time required to return to pre-breach conditions varied at each site and differed between closure events. This variability was related to the strength of subsequent tidal cycles, freshwater inflow rates, topography, relative location within the Estuary, and to a lesser degree, wind mixing.

The Sheephouse Creek mid-depth sonde experienced an equipment malfunction during the entire monitoring period and no data were collected for this station in 2010. The mid-depth sondes at the Mouth, Patty's Rock, and Bridgehaven had mean salinity values near 25 ppt (Table 4.1.1). Minimum values at the Mouth mid-depth sonde were observed to occur with hourly fluctuations during high springtime flows, similar to what is observed at the surface sondes during open conditions later the monitoring period (Figure 4.1.3). Minimum salinity values were also observed at all mid-depth stations in the lower and middle reaches when freshwater flows temporarily displaced the saltwater at these stations during: spring storm events in late-April and May, barrier beach closure, and flushing events after the barrier beach was breached (Figures 4.1.3 through 4.1.6).

The Willow Creek sonde was located in a predominantly freshwater habitat during higher mainstem flows that persisted through June. Freshwater conditions remained at the station during and immediately following the 4 July to 11 July closure, however saline water migrated to this location on a high tide on 13 July and remained for the rest of the season (Figure 4.1.7). Once present, salinity at this site varied over the season, but remained primarily brackish in concentration (Table 4.1.1).

Upper Reach Salinity

Two stations were monitored in the upper reach in 2010: Heron Rookery and Freezeout Creek. Both stations included a bottom sonde and a mid-depth sonde. Sondes were located in this manner to track changes in concentration of salinity in the water column.

The Heron Rookery station is located approximately 7.5 km upstream from the mouth of the river in a deep pool. This station is situated where the Estuary begins to transition from predominantly saline conditions to brackish and freshwater conditions. The bottom and mid-depth sondes at Heron Rookery had mean salinity concentrations of 15.2 ppt and 3.3 ppt, respectively (Table 4.1.1). The high value at the mid-depth sonde was associated with a spike in concentration that occurred during barrier beach closure on 23 September (Figure 4.1.8).

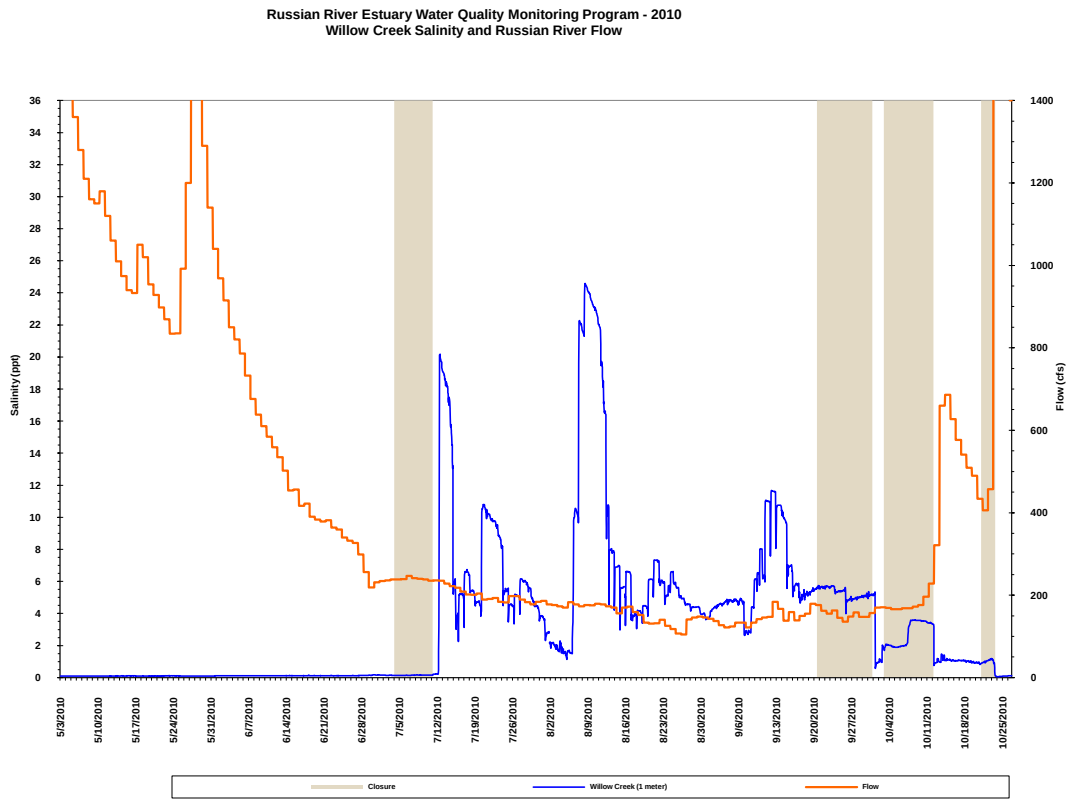


Figure 4.1.7. 2010 Willow Creek Salinity and Russian River Flow Graph

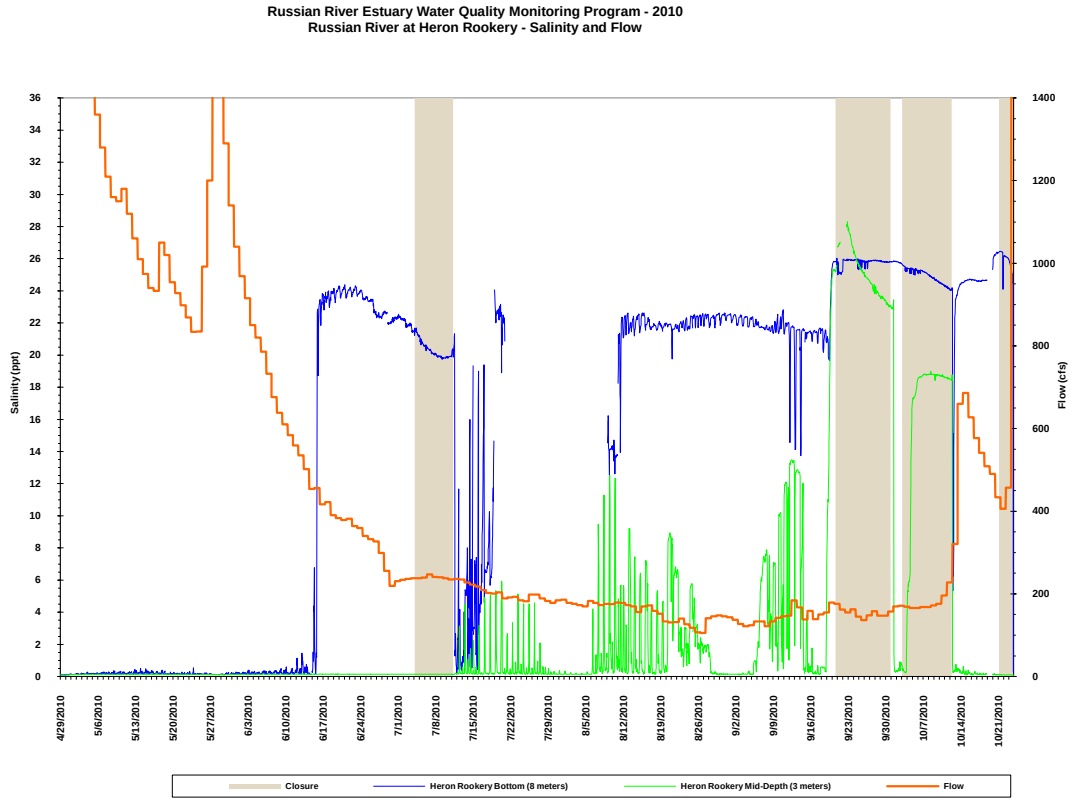


Figure 4.1.8. 2010 Russian River at Heron Rookery Salinity and Flow Graph

The Freezeout Creek station is located in a predominantly freshwater habitat that was occasionally subject to elevated salinity levels as the salt wedge migrated up the Estuary during both open and closed conditions (Figure 4.1.9). The bottom and mid-depth sondes at Freezeout Creek had mean salinity concentrations of 2.5 and 0.7 ppt (Table 4.1.1).

The salt wedge migrated to the Heron Rookery station during open conditions in mid-June when freshwater inflows decreased below 500 cfs (Figures 4.1.8). The salt wedge was not observed at the Freezeout Creek station until mid-July when freshwater inflows decreased to approximately 200 cfs (Figures 4.1.9). However, concentrations varied during open conditions due to tidal cycles and changes in freshwater inflow. Additionally, saline conditions increased and persisted at the mid-depth and bottom sondes at Heron Rookery and Freezeout Creek during barrier beach closures in September and early October as the salt layer stratified and flattened out underneath the deepening freshwater layer. Salinity was generally observed to decrease after the mouth was breached, although the time required to return to pre-breach conditions varied at each site and differed between closure events. This variability was related to the strength of subsequent tidal cycles, freshwater inflow rates, topography, relative location within the Estuary, and to a lesser degree, wind mixing.

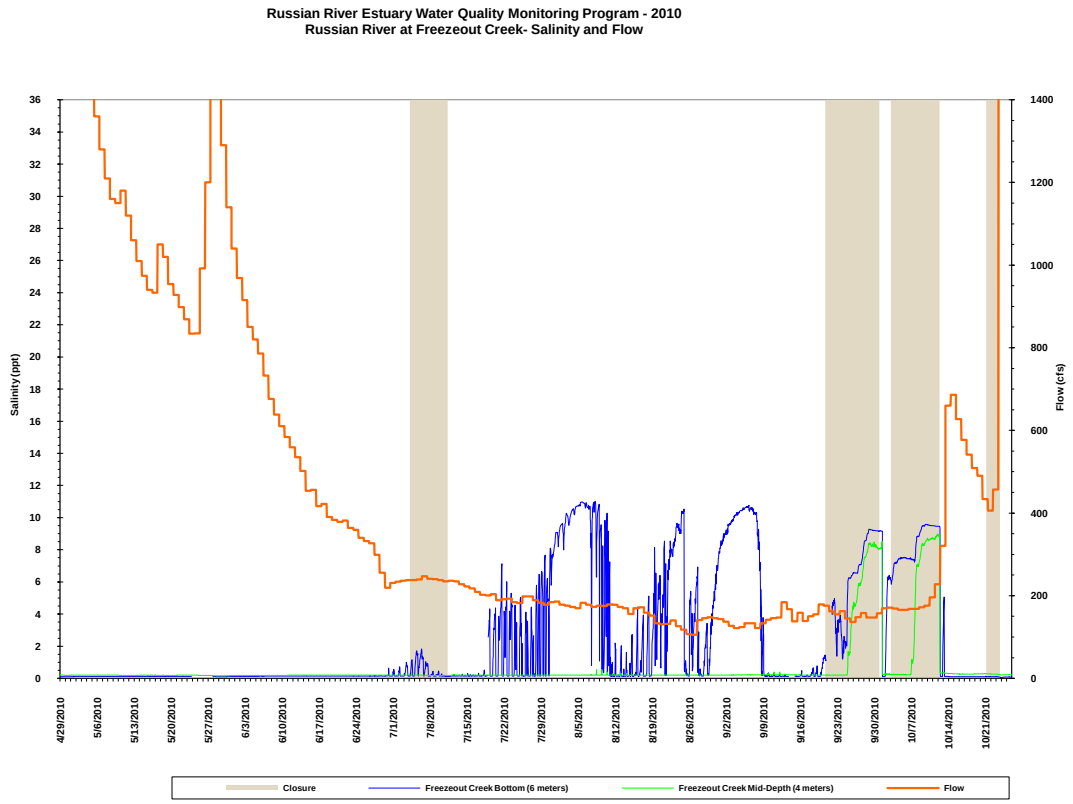


Figure 4.1.9. 2010 Russian River at Freezeout Creek Salinity and Flow Graph

The Freezeout Creek station and mid-depth sonde at Heron Rookery transitioned to a predominantly freshwater habitat following early season storms that produced flows over 600 cfs on 14 October; however salinity persisted at the Heron Rookery bottom sonde until another storm produced inflows over 3,000 cfs on 24 October (Figures 4.1.8 and 4.1.9). Consequently, both storm events coincided with the breaching of the barrier beach, first by the Water Agency on 12 October and then naturally on 24 October. The natural breach on 24 October appeared to be a result of the high storm flows.

Maximum Backwater Area Salinity

Two stations were located in the maximum backwater area including one tributary station located in lower Austin Creek, and one mainstem Russian River station located in Monte Rio Figure 4.1.1). The Austin Creek station was located approximately 0.6 km upstream from the confluence with the Russian River. The Monte Rio station was located approximately 0.5 km downstream of the Monte Rio Bridge.

Neither station was observed to have salinity levels above normal background conditions expected in freshwater habitat, during both open and closed barrier beach conditions (Figures 4.1.10 and 4.1.11). Both stations had mean salinity concentrations of 0.1 ppt, with concentrations ranging from 0.1 to 0.2 ppt at Monte Rio, and 0.0 to 0.2 ppt at Austin Creek (Table 4.1.1).

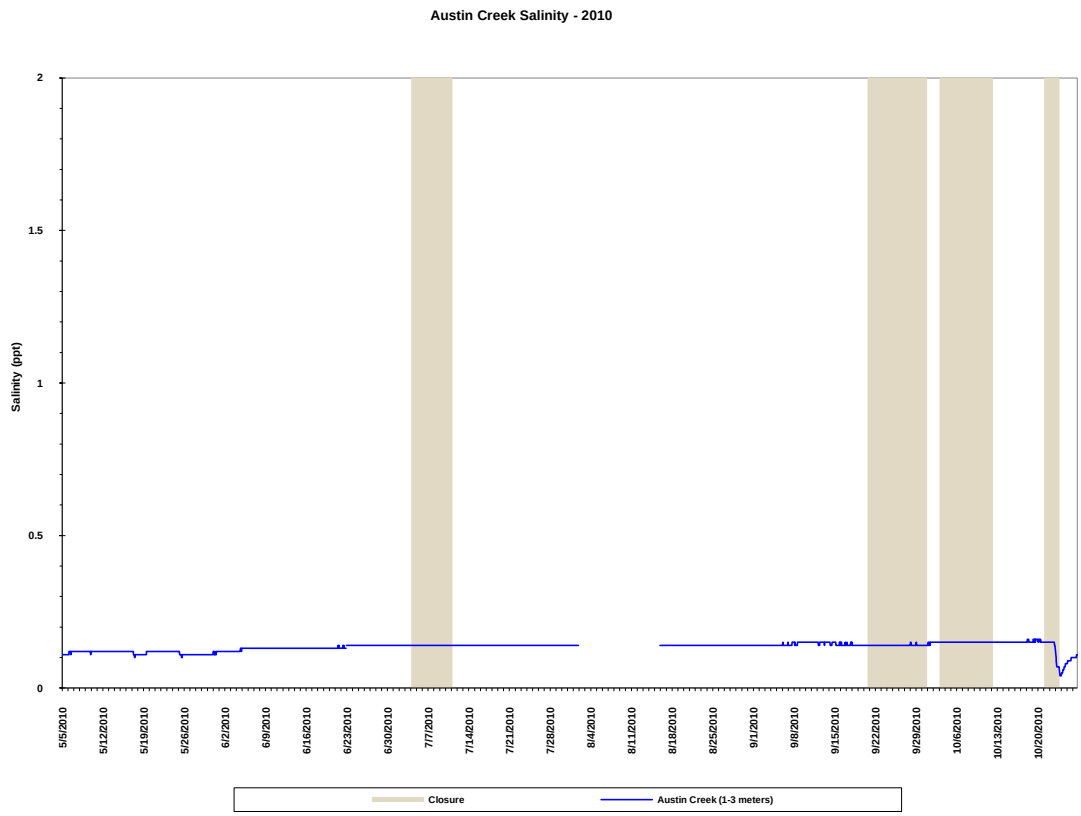


Figure 4.1.10. 2010 Austin Creek Salinity Graph

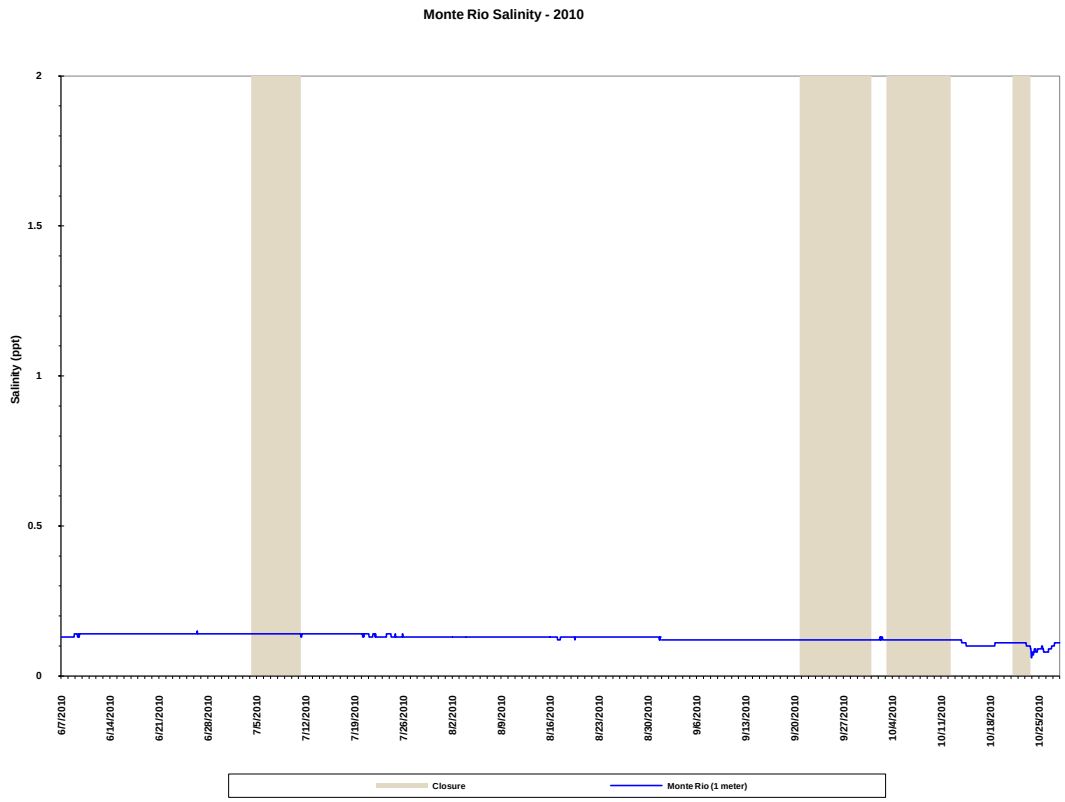


Figure 4.1.11. 2010 Russian River at Monte Rio Salinity Graph

Temperature

During open estuary conditions, water temperatures were reflective of the halocline[5], with lower mean and maximum temperatures typically being observed in the saline layer at the bottom and mid-depth sondes compared to temperatures recorded in the freshwater layer at the mid-depth and surface sondes (Figures 4.1.12 through 4.1.17). The differences in maximum temperatures between the underlying saline layer and the overlying freshwater layer can be attributed in part to the source of saline and fresh water. During open estuary conditions, the saline water from the Pacific Ocean, with temperatures typically around 10 degrees C, enters the Estuary. Whereas, the mainstem Russian River, with temperatures reaching as high as 25 degrees C in the interior valleys, is the primary source of freshwater into the Estuary.

However, during barrier beach closure, fresh/salt water stratification occurred. Density and temperature gradients between freshwater and saltwater play a role in stratification and serve to prevent/minimize mixing of the freshwater and saline layers. Over time, solar radiation heats the mid-depth saline layer, and the overlying surface freshwater layer restricts the release of heat. This often resulted in higher water temperatures in the mid-depth saline layer than in the overlying surface freshwater layer and underlying bottom saline layer located below the effects of solar heating (Figures 4.1.12 through 4.1.18). This stratification-based heating also

[5] A vertical salinity gradient in a body of water.

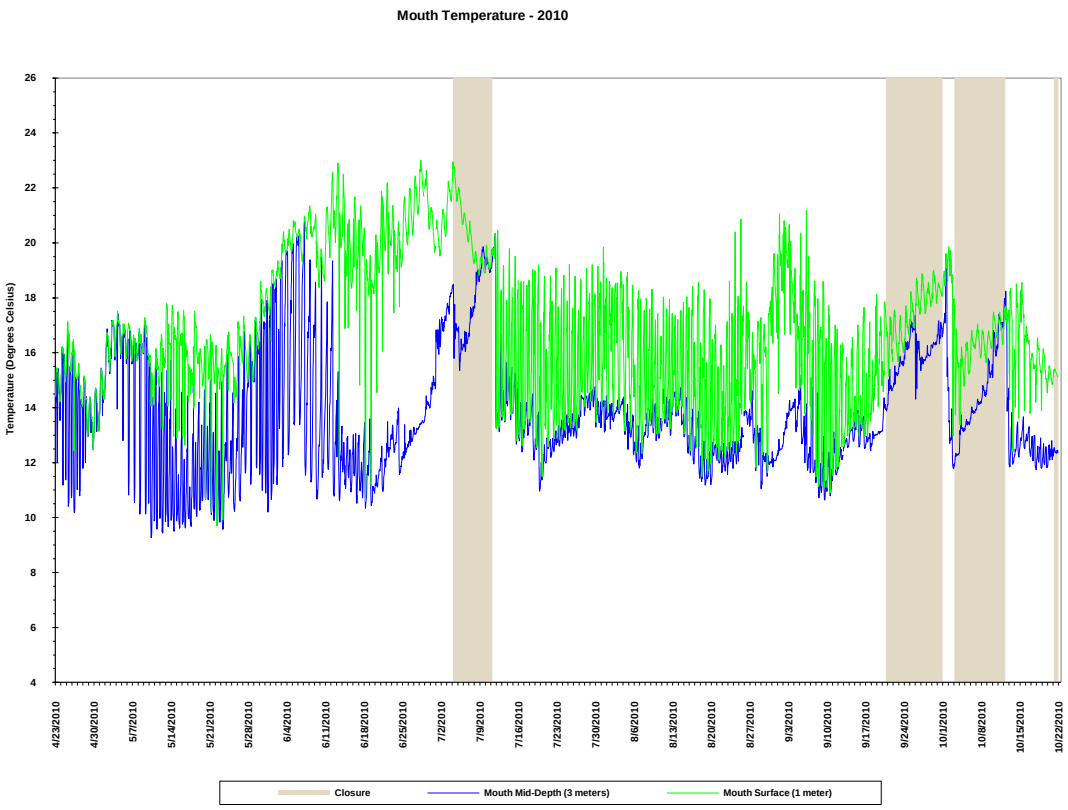


Figure 4.1.12. 2010 Russian River Mouth Temperature Graph

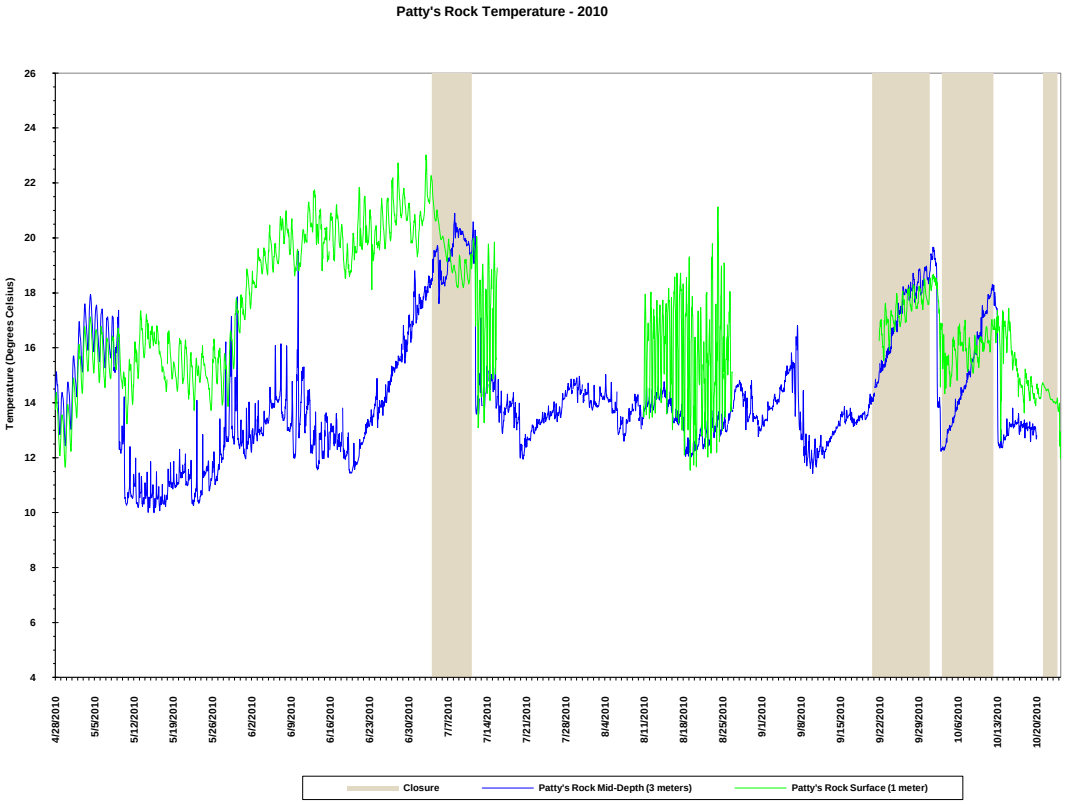


Figure 4.1.13. 2010 Russian River at Patty's Rock Temperature Graph

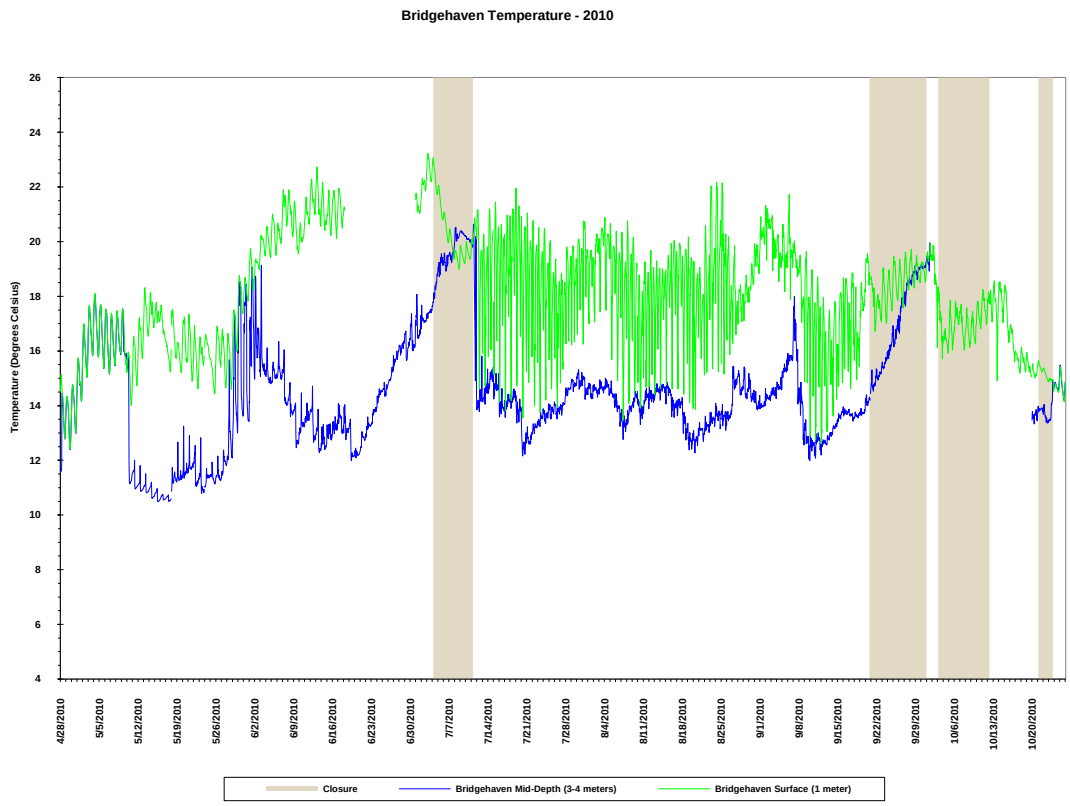


Figure 4.1.14. 2010 Russian River at Bridgehaven Temperature Graph

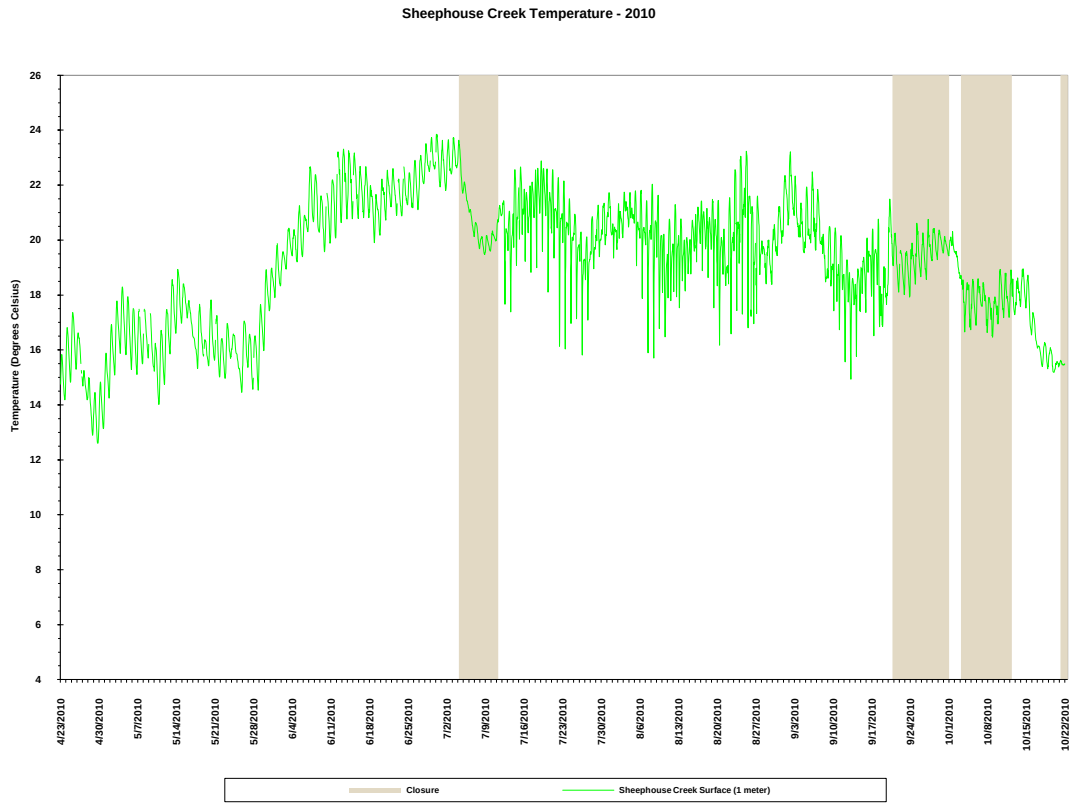


Figure 4.1.15. 2010 Russian River at Sheephouse Creek Temperature Graph

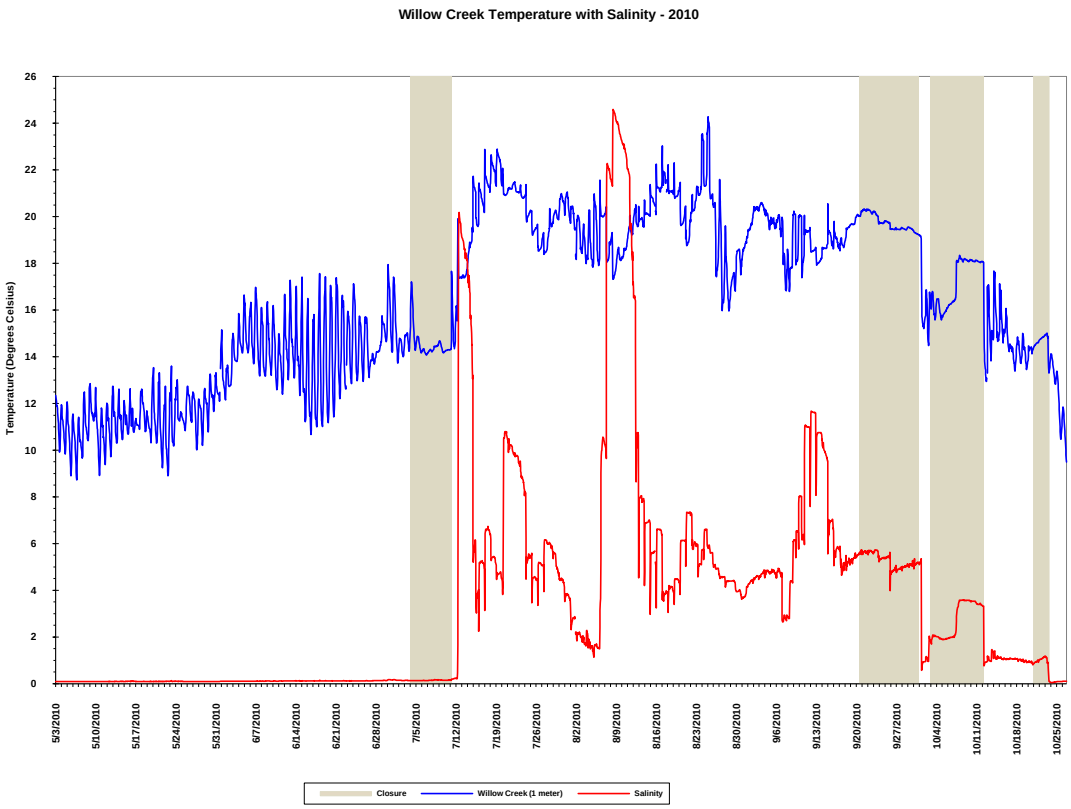


Figure 4.1.16. 2010 Willow Creek Temperature with Salinity Graph

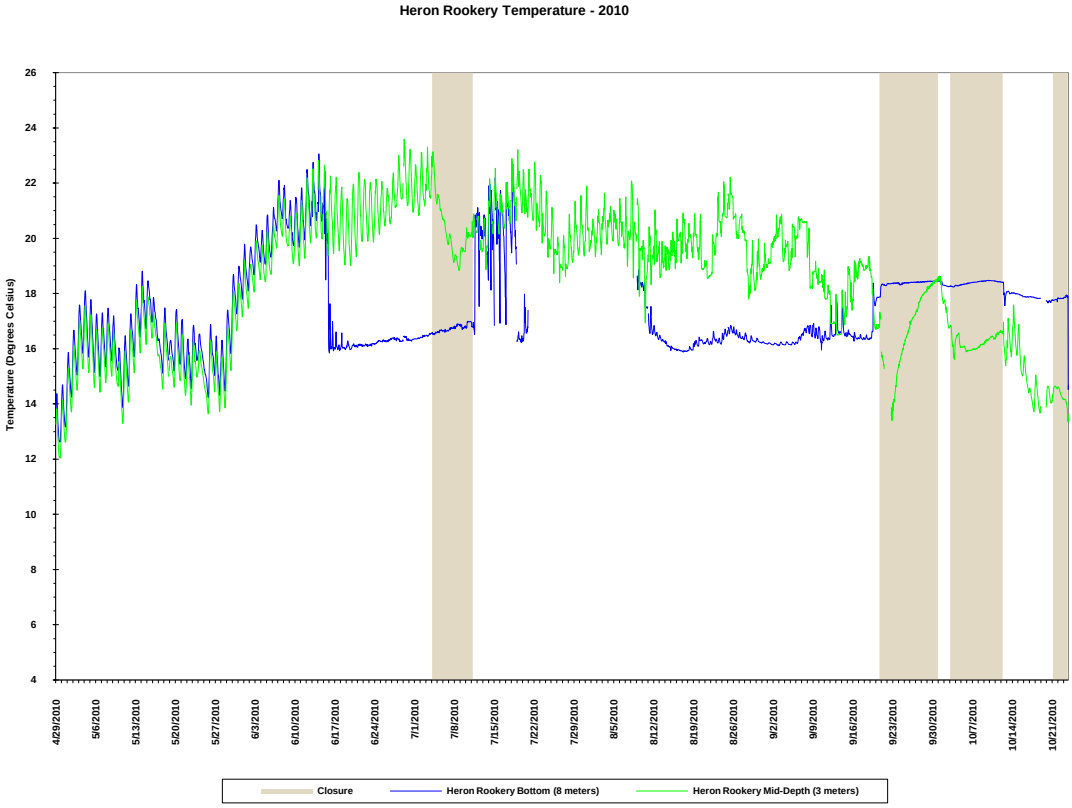


Figure 4.1.17. 2010 Russian River at Heron Rookery Temperature Graph

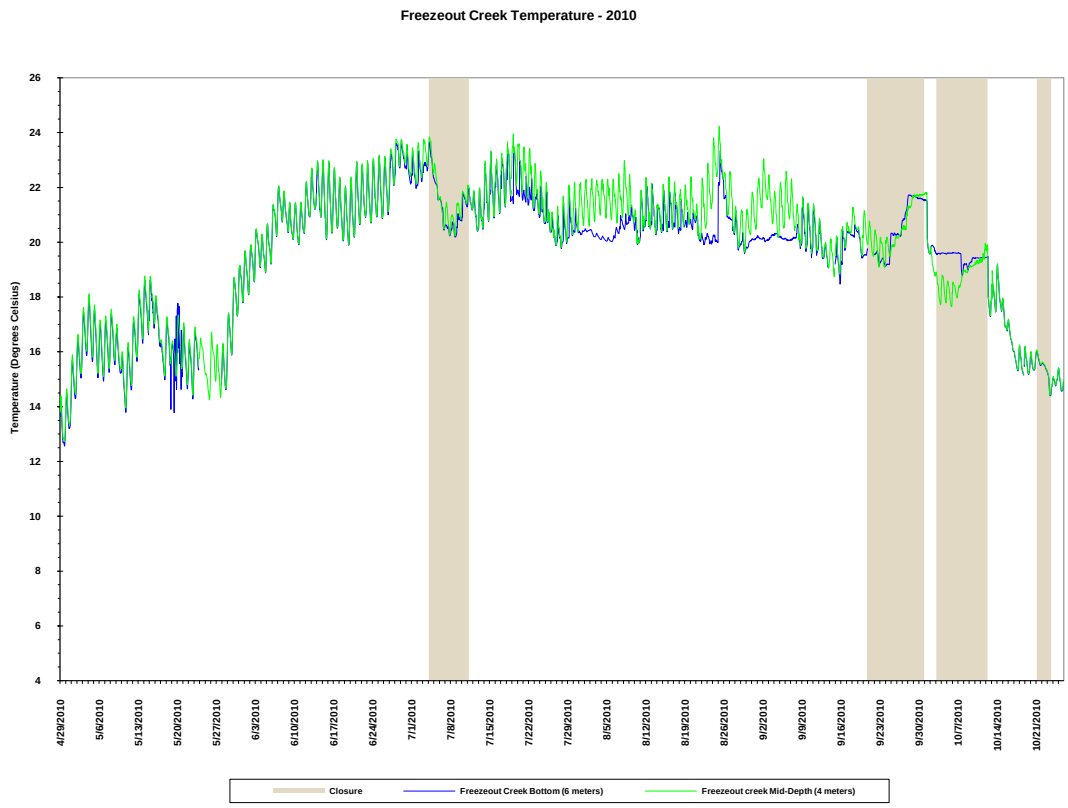


Figure 4.1.18. 2010 Russian River at Freezeout Creek Temperature Graph

contributed to higher seasonal mean and maximum temperatures in the mid-depth saline layer than would be expected to occur under open conditions.

Lower and Middle Reach Temperature

The surface sondes were located at the freshwater/saltwater interface. The Sheephouse Creek surface sonde tends to have the highest temperatures (Table 4.1.1), given that it is the furthest upstream of the lower and middle reach stations, where the freshwater layer has the least amount of cooling time as the river leaves the warmer canyons around Guerneville and Monte Rio and enters the cooler climate near the coastline. The Sheephouse Creek station is approximately 5.1 km (3.2 mi) upstream from the Mouth Station, 2.7 km (1.7 mi) inland from the coastline, and behind two ridgelines to the west and south that provide additional protection from the influences of marine fog and wind.

The mid-depth sondes were located primarily in saltwater and had maximum temperatures of approximately 20 degrees C at the Mouth, Patty's Rock, and Bridgehaven, respectively (Table 4.1.1).

The Sheephouse Creek mid-depth sonde experienced an equipment malfunction during the entire monitoring period and no valid data were collected at this station in 2010 (Figure 4.1.15).

The Willow Creek sonde was located in primarily freshwater habitat until after the first barrier beach closure and reopening in July. At this point, the station transitioned to a brackish system and temperatures were observed to increase, on average, until storm-related flows at the end

of October flushed out the brackish water (Figure 4.1.16). Minimum temperatures were observed at the beginning and the end of the monitoring period during periods of cooler weather and storm related flow events that contributed cooler freshwater into the system. Maximum temperatures were observed mid-season in brackish water. Temperature response to barrier beach closure was variable, cooling slightly during the July closure, heating and then cooling during the September closure, and heating considerably during the October closure. It should be noted that the July closure occurred under freshwater conditions and the September and October closure occurred during brackish conditions, with an increase in salinity corresponding with the temperature increase during the October closure.

Upper Reach Temperature

Overall temperatures in both the saline layer and freshwater layer were typically hottest at the furthest upstream stations, as recorded at Heron Rookery and Freezeout Creek, and became progressively cooler as the water flows downstream, closer to the cooling effects of the coast and ocean. For example, during open conditions on 24 June, a maximum freshwater temperature of 23.1 degrees C was observed at the Freezeout Creek station (Figure 4.1.18); whereas a maximum freshwater temperature of 20.8 degrees C was observed at the Mouth station (Figure 4.1.12).

The bottom sondes at Heron Rookery and Freezeout Creek had mean temperatures of 17.3 and 19.6 degrees C, respectively (Table 4.1.1). The lower mean temperature can be partially attributed to the presence of cooler tidally-mixed saline water for a longer time period at Heron Rookery than at Freezeout Creek (Figures 4.1.8 and 4.1.9).

The mid-depth sondes at Heron Rookery and Freezeout Creek had mean temperatures of 18.5 and 19.8 degrees C, respectively (Table 4.1.1). The lower mean and minimum temperatures at Heron Rookery were also due to the presence of cooler saline water that was not present at the Freezeout Creek station with as much frequency.

During open estuary conditions in the lagoon management period, water temperatures in the upper reach of the Estuary were cooler in the saline layer than the overlying freshwater layer (Figures 4.1.17 and 4.1.18). Upon closure of the barrier beach, stratification-related heating of the saline layer was observed in the upper reach similar to that observed in the lower and middle reaches (Figures 4.1.12 through 4.1.14). While temperatures initially decreased during several closures at both stations, this was usually associated with freshwater conditions, whereas temperature increases corresponded with the presence of salinity (Figures 4.1.8 and 4.1.9).

Temperatures generally decreased after the barrier beach was breached, although the time required to return to pre-breach conditions varied at each site and differed between closure events. This variability was related to the presence of salinity, strength of subsequent tidal cycles, freshwater inflow rates, topography, relative location within the Estuary, and to a lesser degree, wind mixing.

Maximum Backwater Area Temperature

Austin Creek had a maximum temperature of 21.3 degrees C, a mean temperature of 16.4 degrees C, and a minimum temperature of 11.0 degrees C. Temperatures at this station did not appear to be affected by barrier beach closure during the July closure. The diurnal cycle of heating and cooling appeared to increase during the September and October closures, when freshwater inflows from Austin Creek were at their lowest point (<5cfs) for the season; however the diurnal cycle was not as large as was observed earlier in the season during open conditions (Figure 4.1.19).

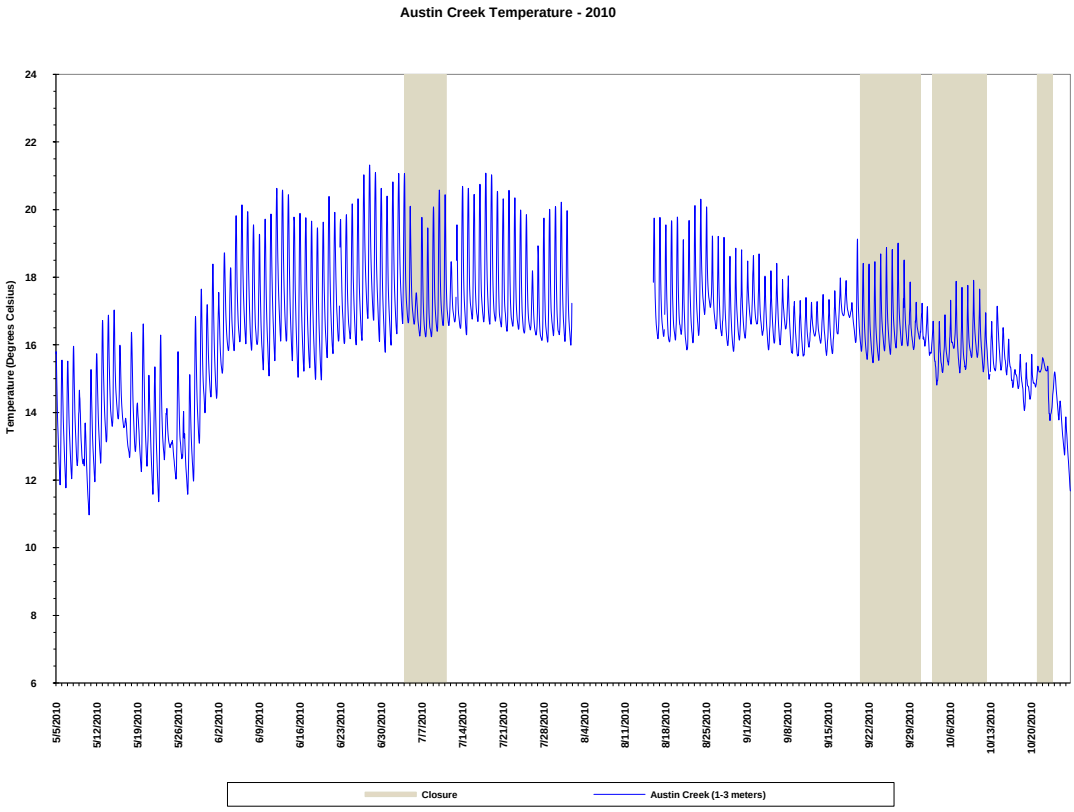


Figure 4.1.19. 2010 Austin Creek Temperature Graph

The Monte Rio station had a maximum temperature of 22.1 degrees C, a mean temperature of 17.8 degrees C, and a minimum temperature of 10.6 degrees C (Table 4.1.1). The highest temperatures were observed to occur during open conditions. The affect of barrier beach closure on temperature was insignificant and variable, with minor increases and decreases observed to occur during barrier beach closure and reopening (Figure 4.1.20). This variability was likely related to differences in air temperatures and freshwater inflow rates, and to a lesser degree, wind mixing.

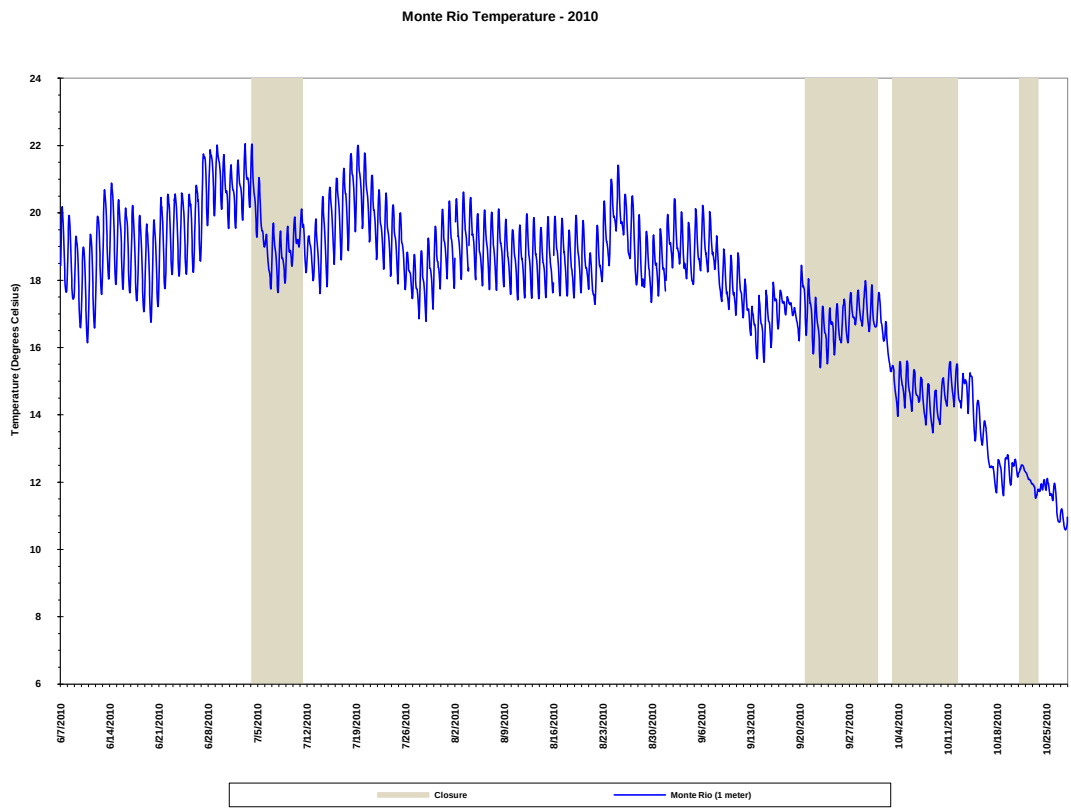


Figure 4.1.20. 2010 Russian River at Monte Rio Temperature Graph

Dissolved Oxygen

Dissolved oxygen (DO) levels in the Estuary, including the maximum backwater area, depend upon factors such as the extent of diffusion from surrounding air and water movement, including freshwater inflow. DO is affected by salinity and temperature stratification, tidal and wind mixing, abundance of aquatic plants, and presence of decomposing organic matter. DO affects fish growth rates, embryonic development, metabolic activity, and under severe conditions, stress and mortality. Cold water has a higher saturation point than warmer water; therefore cold water is capable of carrying higher levels of oxygen.

DO levels are also a function of nutrients, which can accumulate in water and promote plant and algal growth that both consume and produce DO during respiration and photosynthesis. Estuaries tend to be naturally eutrophic because land-derived nutrients are concentrated where runoff enters the marine environment in a confined channel.[6] Upwelling in coastal systems also promotes increased productivity by conveying deep, nutrient-rich waters to the surface, where the nutrients can be assimilated by algae. Excessive nutrient concentrations and plant and algal growth can overwhelm eutrophic systems and lead to a reduction in DO levels that can affect the overall ecological health of the Estuary.

[6] *National Estuarine Eutrophication Assessment* by NOAA National Centers for Coastal Ocean Science (NCCOS) and the Integration and Application Network (IAN), 1999.

Dissolved oxygen concentrations in the lower and middle reaches were generally higher at the surface sondes compared to the mid-depth sondes at a given sampling station (Figures 4.1.21 through 4.1.24). The surface sondes typically had the highest mean DO concentrations, as well as the highest maximum and minimum concentrations, when compared with the mid-depth sondes (Table 4.1.1). Supersaturation conditions observed at the surface sondes contributed to the higher maximum and mean DO concentrations, with the most significant events occurring at Patty's Rock and Bridgehaven during open estuary conditions (Figures 4.1.22 and 4.1.23).

However, supersaturation events were also observed at the mid-depth sondes, with the most significant events occurring at the Mouth (Figure 4.1.21). Supersaturation events at the mid-depth sondes were typically less significant and occurred less frequently than events at the corresponding surface sondes, except during the September and October closures, when they were observed to exceed DO concentrations at the corresponding surface sondes (Figures 4.1.21 through 4.1.23). However, these values did not exceed the season high values observed at the corresponding surface sondes, except at the Mouth station, where a data gap at the surface station during a supersaturation event in late-June may have contributed to this exception (Figure 4.1.21).

Dissolved oxygen concentrations in Willow Creek were reflective of the presence of salinity, with higher values being observed in freshwater habitat and lower values being observed in brackish conditions. However, the lowest DO concentrations were observed during estuary closure, in both freshwater and brackish conditions, with hypoxic to anoxic conditions being observed in brackish water during the September closure (Figure 4.1.25).

The upper reach DO concentrations at the mid-depth sondes were fairly consistent with conditions at the mid-depth sondes in the lower and middle reaches. However, it should be noted that the mid-depth sondes in the upper reach were located in predominantly freshwater habitat, whereas the mid-depth sondes in the lower and middle reaches were located in predominantly brackish to saline habitat. Upper reach DO concentrations were typically lower in the saline layer, as observed at the bottom sondes during both open and closed Estuary conditions, than DO concentrations observed in the saline layer in the lower and middle reaches. This can partially be attributed to the location of these sondes at the bottom of deep holes where the saline layer becomes trapped. There is less mixing of the saline layer in these deep holes, especially further up in the estuary where the influence of the tidal cycle is reduced, resulting in recurring hypoxic and anoxic conditions.

Lower and Middle Reach DO

The Surface Sondes had fairly consistent mean DO concentrations in the lower and middle reaches (Table 4.1.1). Mean DO concentrations at the mid-depth sondes were also fairly consistent from station to station, with mean DO concentrations of 9.1, 8.4, and 8.7 mg/L at the Mouth, Patty's Rock, and Bridgehaven, respectively (Table 4.1.1). The Sheephouse Creek mid-depth sonde experienced an equipment malfunction during the entire monitoring period and no valid data were collected at this station in 2010 (Figure 4.1.24).

Significant fluctuations in DO concentrations were observed at all stations in the lower and middle reaches during open Estuary conditions, with more pronounced events occurring during

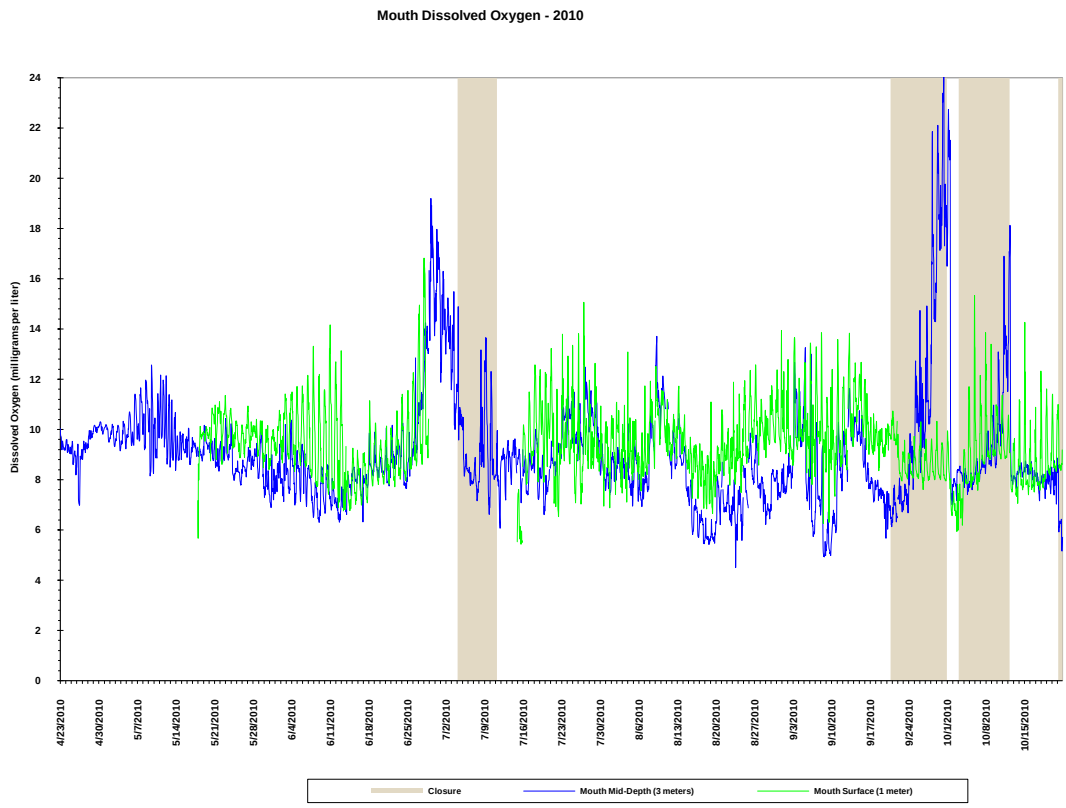


Figure 4.1.21. 2010 Russian River Mouth Dissolved Oxygen Graph

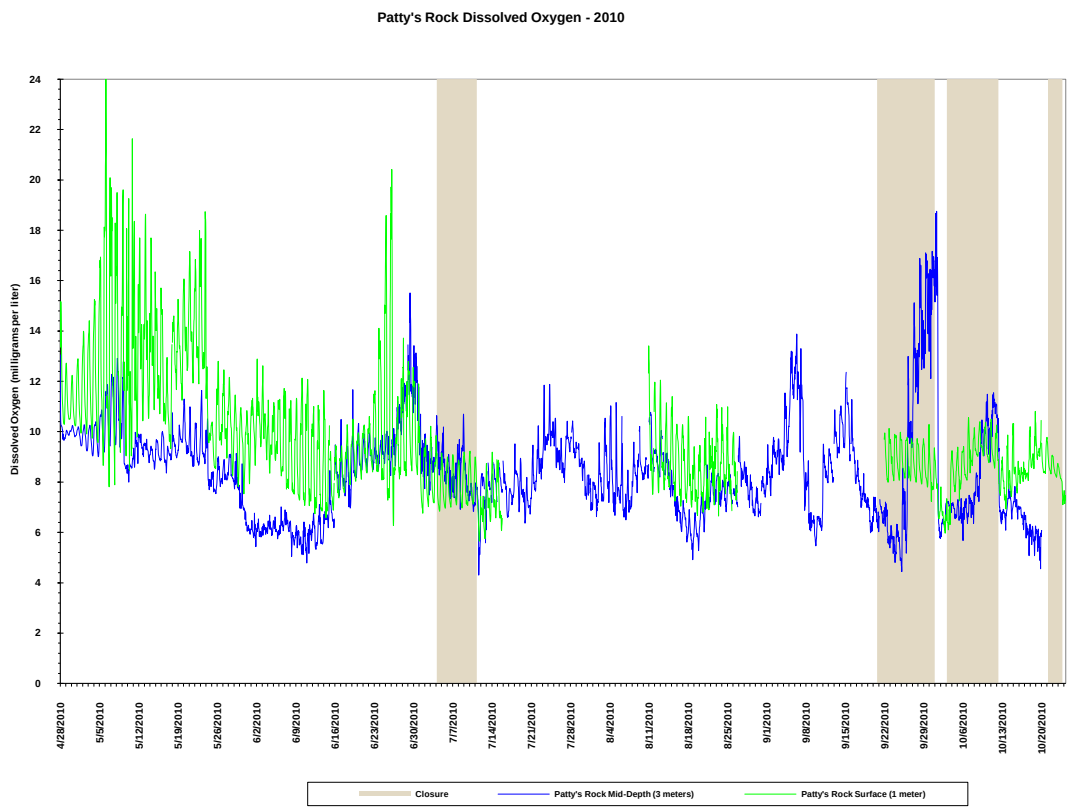


Figure 4.1.22. 2010 Russian River at Patty's Rock Dissolved Oxygen Graph

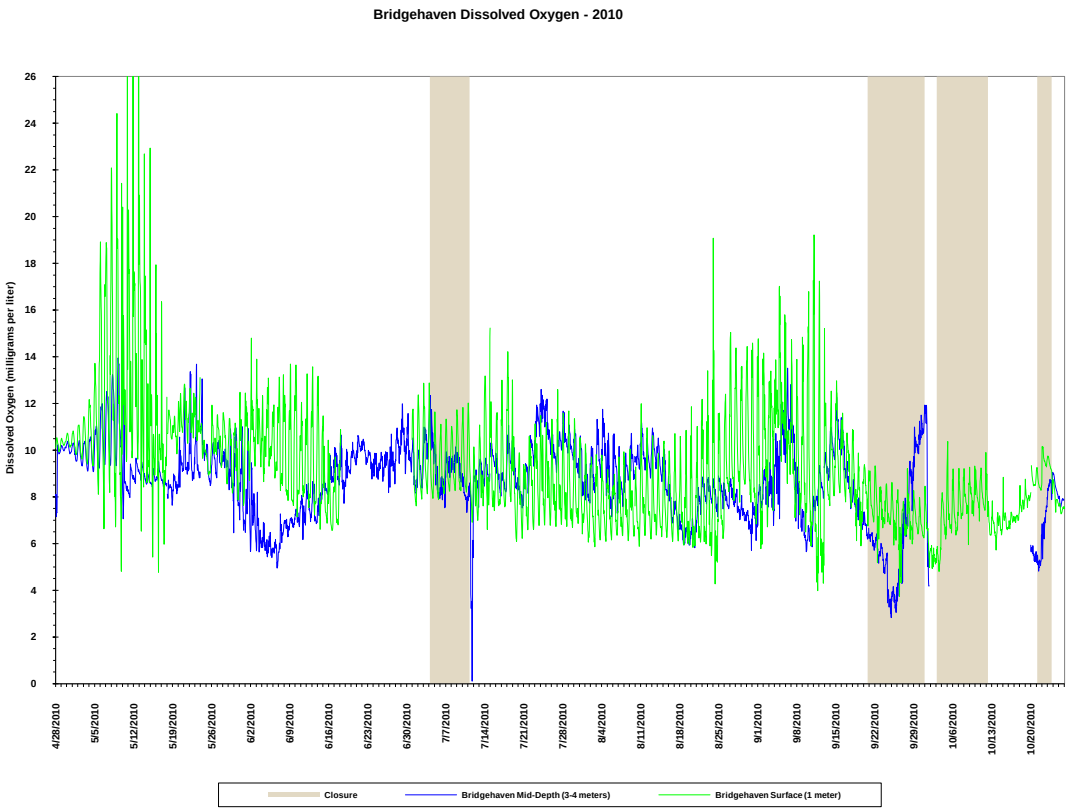


Figure 4.1.23. 2010 Russian River at Bridgehaven Dissolved Oxygen Graph

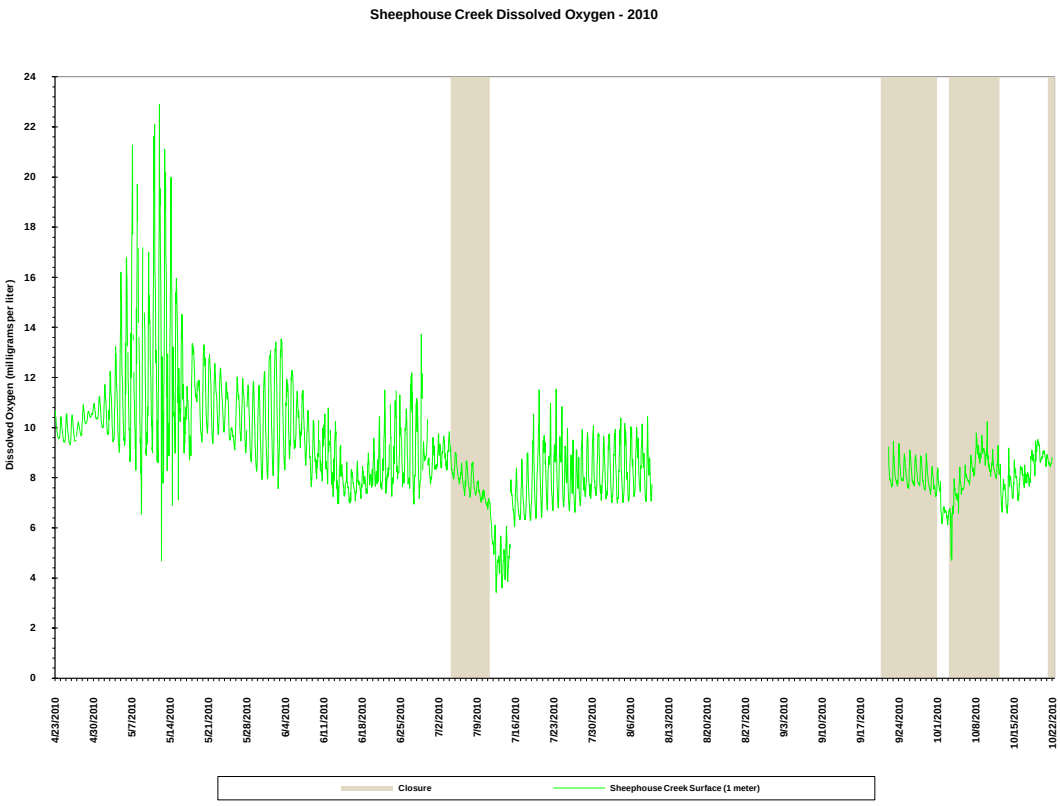


Figure 4.1.24. 2010 Russian River at Sheephouse Creek Dissolved Oxygen Graph

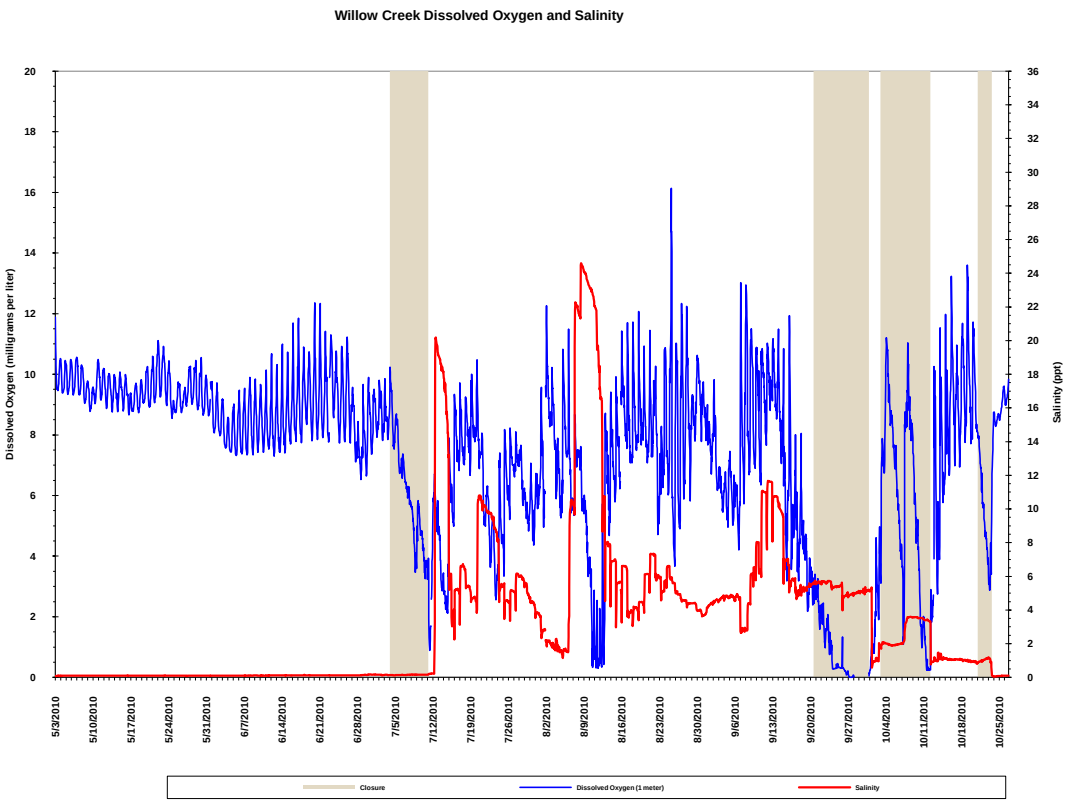


Figure 4.1.25. 2010 Willow Creek Dissolved Oxygen and Salinity Graph

periods of barrier beach closure. Short-term hypoxic and/or anoxic events observed at some of the mid-depth sondes in 2009 were not observed during 2010. DO concentrations at the mid-depth sondes declined during estuary closure, but not to hypoxic or anoxic levels. However, DO concentrations became temporarily anoxic at the Bridgehaven mid-depth sonde immediately following the breaching of the barrier beach in July (Figure 4.1. 23) and may have been affected by the downstream migration of hypoxic to anoxic water from Willow Creek, which is located about 1km upstream of the Bridgehaven station (Figure 4.1.25). Minimum DO concentrations occurred either during or immediately following barrier beach closure and were observed to be 4.5, 4.3, and 0.1 mg/L at the Mouth, Patty's Rock, and Bridgehaven mid-depth sondes, respectively.

Consequently, all sondes at all depths experienced some degree of fluctuating DO concentrations, especially during periods of barrier beach closure. However, the effect of barrier beach closure was variable as DO concentrations at the surface sondes remained unaffected, slightly decline, or increase in some instances. Although the surface sondes at the Mouth, Patty's Rock, Bridgehaven, and Sheephouse Creek had minimum seasonal DO concentrations of 5.4, 5.7, 3.7 and 3.4 mg/L, most of these values did not coincide with any of the barrier beach closures (Table 4.1.1). However, temporary decreases in DO concentrations were observed at the stations immediately following reopening of the barrier beach. These decreases in DO concentration may have also been affected by the downstream migration of hypoxic and/or anoxic water from Willow Creek and/or the upper reach of the estuary (Figures 4.1.25 through 4.1 27).

Recovery of DO concentrations following reopening of the barrier beach was variable in timing and relative concentration among stations and sondes, but typically occurred within several days of the barrier beach being opened.

Again, differences between stations can be partially attributed to data gaps associated with equipment malfunctions, as well as different monitoring periods. Additional data collection and analysis would be needed to further explore whether any of these conditions represent trends.

The surface sondes, and mid-depth sondes to a lesser degree, also experienced hourly fluctuating supersaturation events. At times when oxygen production exceeds the diffusion of oxygen out of the system, supersaturation may occur (Horne, 1994). DO concentrations exceeding 100% saturation in the water column are considered supersaturated conditions. Because the ability of water to hold oxygen changes with temperature, there are a range of concentration values that correspond to 100% saturation. For instance, at sea level, 100% saturation is equivalent to approximately 11 mg/L at 10 degrees C, but only 8.2 mg/L at 24 degrees C. Consequently, these two temperature values roughly represent the range of temperatures observed in the Estuary during the 2009 monitoring season.

The most significant supersaturation event was observed at the Bridgehaven surface sonde (Figure 4.1.23). The maximum DO concentration at the Bridgehaven surface sonde was approximately 34.7 mg/L (345%), compared to 16.8 mg/L (192%), 24.2 mg/L (249%) , and 22.9 mg/L (233%) at the Mouth, Patty's Rock, and Sheephouse Creek surface sondes, respectively (Table 4.1.1). Maximum DO concentrations at the Mid-Depth sondes were approximately 25.3 mg/L (295%) at the Mouth, 18.8 mg/L (230%) at Patty's Rock, and 14.0 mg/L (164.5%) at Bridgehaven.

The Willow Creek sonde had a mean DO concentration of 7.4 mg/L, a maximum DO concentration of 16.1 mg/L, and a minimum DO concentration of 0.0 mg/L (Table 4.1.1). Minimum values were observed to occur during and/or following barrier beach closure, with more pronounced hypoxic to anoxic conditions being observed during closure in the presence of saline water. However, low DO values were also observed during open conditions in the presence of saline water (Figure 4.1.25).

Upper Reach DO

Dissolved oxygen concentrations at the mid-depth sondes in the upper reach were slightly lower overall compared to concentrations in the lower and middle reaches (Table 4.1.1), with less significant supersaturation events contributing to this difference. The mid-depth sondes at Heron Rookery and Freezeout Creek had mean DO concentrations of 8.1 and 8.7 mg/L (Table 4.1.1).

The bottom sondes at Heron Rookery and Freezeout Creek had mean DO concentrations of 5.2 and 6.8 mg/L, maximum concentrations of 15.3 and 14.8 mg/L, and minimum concentrations of 0.1 and 0.0 mg/L, respectively (Table 4.1.1). However, the Heron Rookery bottom sonde experienced equipment malfunctions that produced data gaps in July and September, which may have affected minimum, mean, and maximum DO values (Figure 4.1.26).

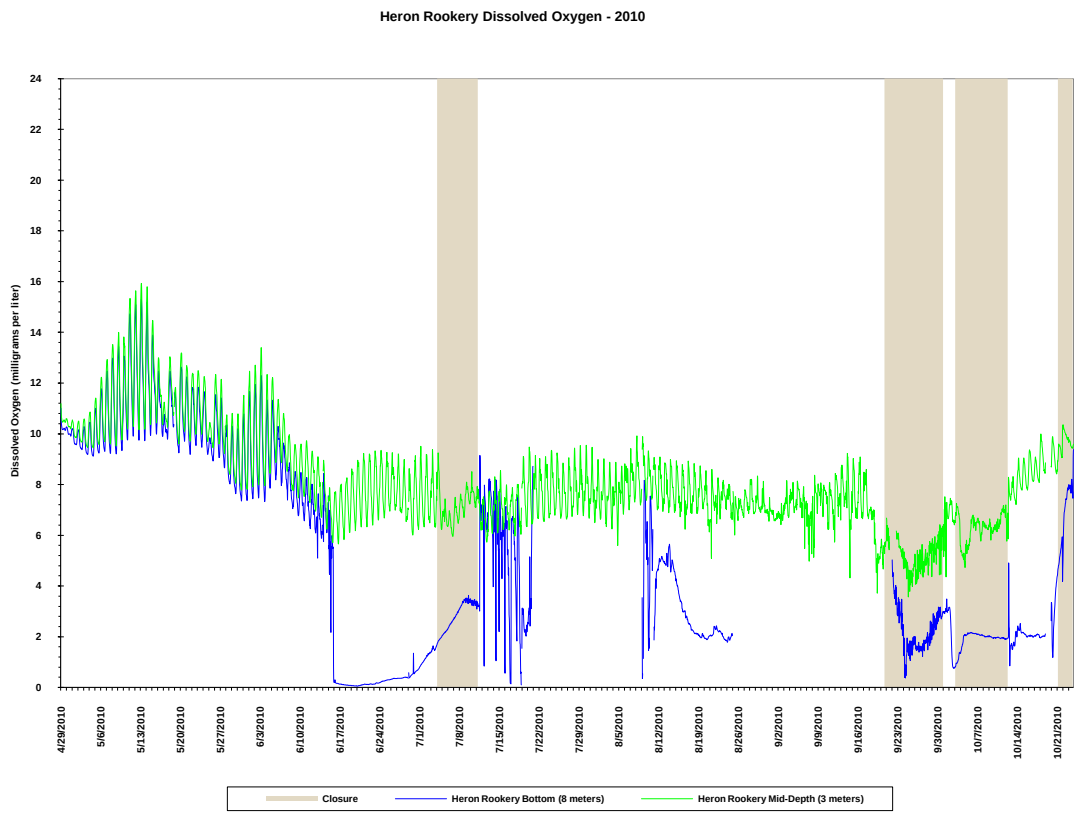


Figure 4.1.26. 2010 Russian River at Heron Rookery Dissolved Oxygen Graph

The salt wedge migrated upstream in mid-June and displaced the freshwater in the lower portion of the water column at the Heron Rookery station when late-spring storm flows dropped below approximately 500 cfs (Figures 4.1.26). This was not observed until late July at the Freezeout Creek station when flows dropped to approximately 200 cfs (Figure 4.1.27). The salt wedge then became persistent in the deep pools during open conditions from early July to early October; however, salinity concentrations continued to fluctuate at the two stations with changes to freshwater inflow rates, tidal inundation and mixing.

During open conditions, DO levels periodically became hypoxic in the saline layer at the bottom sondes. Whereas, DO levels at the mid-depth sondes remained at acceptable levels for salmonids during open conditions (Figures 4.1.26 and 4.1.27).

DO response to barrier beach closure and reopening was also variable throughout the season and dependent on the presence of salinity, the length of time of the closure, the timing of subsequent closure events, freshwater inflow rates and subsequent tidal inundation and mixing. During the July closure, DO levels at the bottom sondes became hypoxic to anoxic, while DO levels at the mid-depth sondes remained at acceptable levels (Figures 4.1.26 and 4.1.27). During this closure, the bottom sondes were located in the saline layer and the mid-depth sondes were located in the freshwater layer.

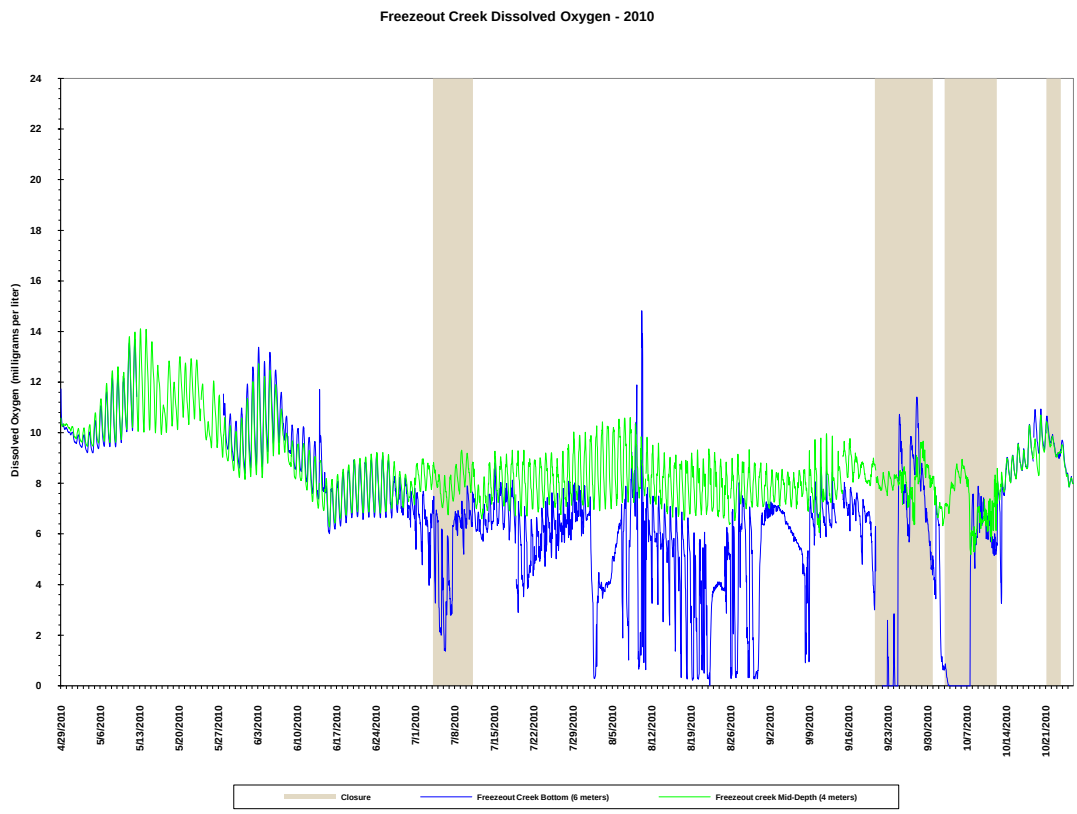


Figure 4.1.27. 2010 Russian River at Freezeout Creek Dissolved Oxygen Graph

Whereas, during the closures in September and October, the salt wedge had migrated further upstream placing the mid-depth sondes within the salt layer and DO levels decreased slightly, with concentrations becoming temporarily hypoxic at Heron Rookery during the September closure and at Freezeout Creek during the first October closure. Low DO concentrations persisted at the bottom of the Freezeout Creek and Heron Rookery stations until mid-October, when increased freshwater storm flows began to push the saline layer out of these stations.

The presence of salinity would typically coincide with the presence of depressed DO levels, but not always, suggesting that variability is dependent on changes in the length of time of closures, the timing of subsequent closure events, freshwater inflow rates and subsequent tidal inundation and mixing.

It is important to note that highly anoxic conditions observed at the Freezeout Creek bottom sonde, and to a lesser degree at the Heron Rookery bottom sonde, included the release of hydrogen sulfide (H_2S) into the water column, whereby equipment was observed with staining and odors consistent with releases of H_2S. According to the manufacturer, H_2S releases can be read by the YSI dissolved oxygen sensor as a false positive for dissolved oxygen. These H_2S releases were directly observed by staff during maintenance and calibration efforts and also recorded in the data set, where DO levels were observed to spike from hypoxic and/or anoxic conditions to fully saturated and supersaturated conditions during the same time that these observations were made (Figures 4.1.26 and 4.1.27).

Maximum Backwater Area DO

The Austin Creek station had a mean DO concentration of 8.3 mg/L, a maximum concentration of 11.6 mg/L, and a minimum concentration of 3.0 mg/L (Table 4.1.1). Minimum values were observed in mid-October during open estuary conditions when flow became intermittent (measured at less than 2 cfs at the upstream USGS gauging station) and several pools in lower Austin Creek (including the station pool) became isolated from one another, with only subsurface flow occurring between pools (Figure 4.1.28).

Dissolved oxygen concentrations were observed to increase at the Austin Creek station during a subsequent short closure event that began on 21 October, and continued to increase to approximately 10 mg/L during storm flows that began on 23 October and peaked at approximately 1,700 cfs on 24 October (Figure 4.1.28). Consequently, the river mouth reopened on 24 October during these high flows.

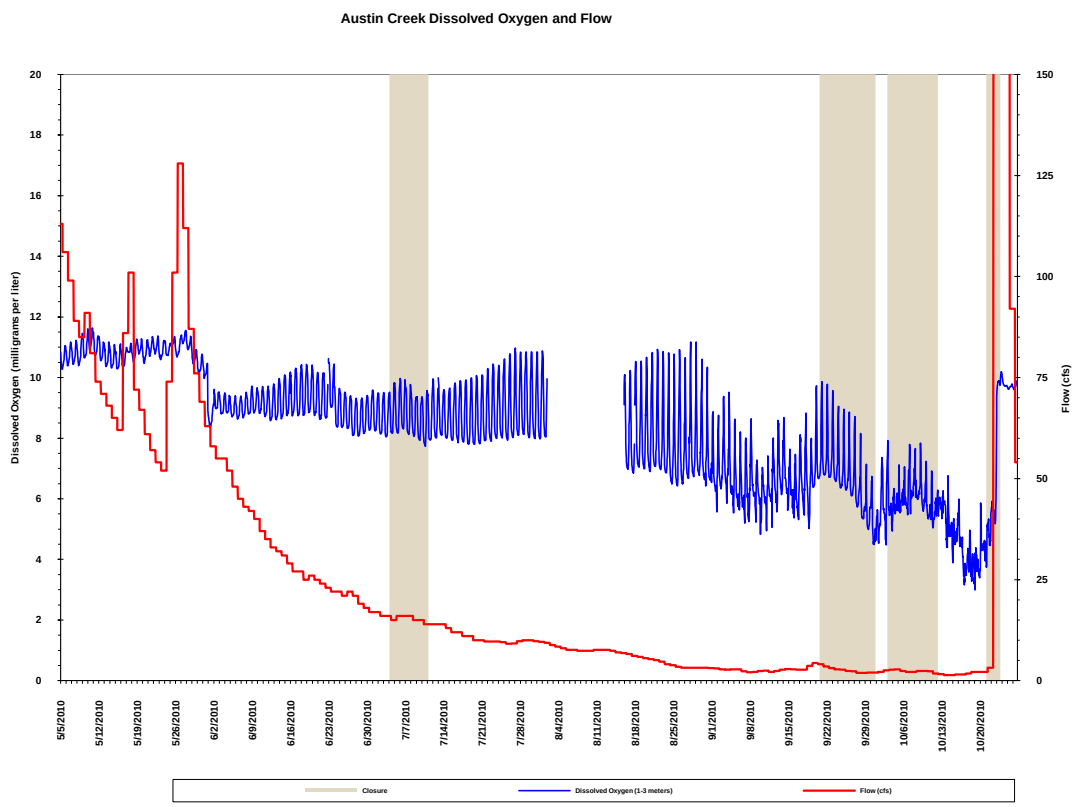


Figure 4.1.28. 2010 Austin Creek Dissolved Oxygen and Flow Graph

The Monte Rio Station had a mean DO concentration of 9.5 mg/L, a maximum concentration of 21.2 mg/L, and a minimum concentration of 6.2 mg/L (Table 4.1.1). Dissolved oxygen concentrations were observed to initially increase and then decrease slightly during estuary closure or reopening events. However, concentrations remained above 8 mg/L, on average, during both closed and open estuary summer flow conditions (Figure 4.1.29).

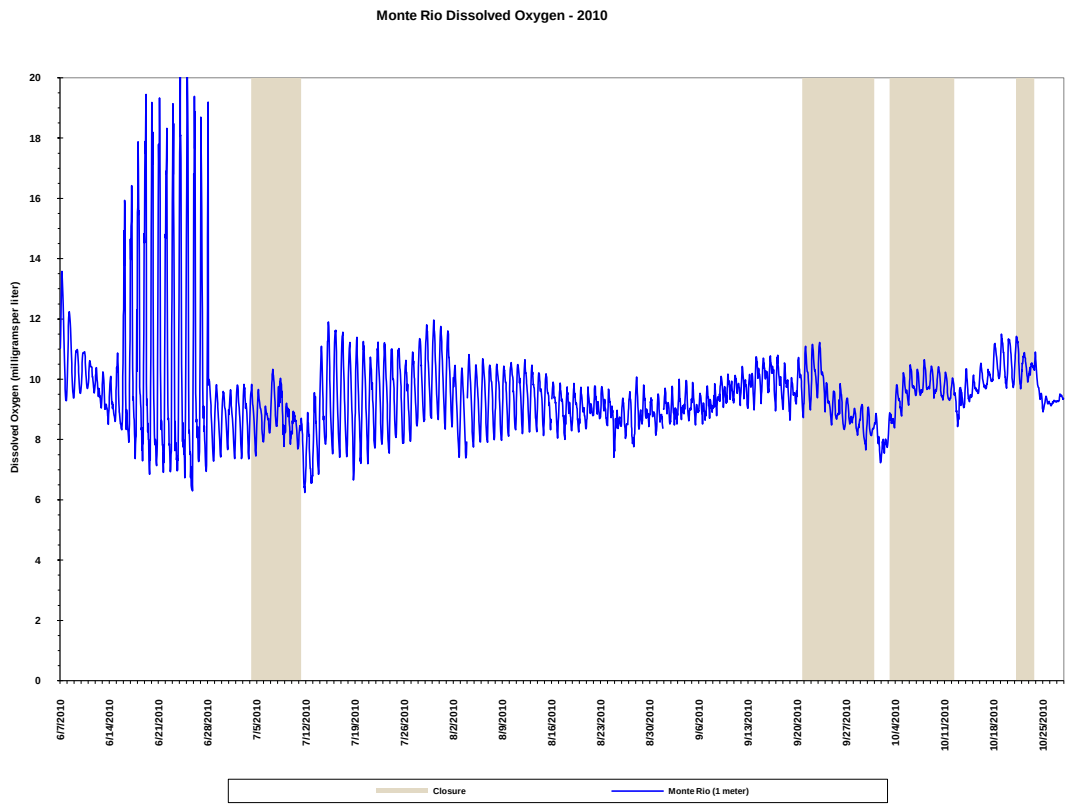


Figure 4.1.29. 2010 Russian River at Monte Rio Dissolved Oxygen Graph

Hydrogen Ion (pH)

The acidity or alkalinity of water is measured in units called pH, an exponential scale of 1 to 14 (Horne, 1994).[7] A pH value of 7 is considered neutral, freshwater streams generally remain at a pH between 6 and 9, and ocean-derived salt water is usually at a pH between 8 and 9. When the pH falls below 6 over the long term, there is a noticeable reduction in the abundance of many species, including snails, amphibians, crustacean zooplankton, and fish such as salmon and some trout species (Horne, 1994).

Lower and Middle Reach pH

Hydrogen ion (pH) values were fairly consistent among all stations at all depths in the lower and middle reaches, with mean values ranging from 7.9 pH at the Mouth and Bridgehaven mid-depth sondes to 8.2 pH at the Mouth and Patty's Rock surface sondes (Table 4.1.1). Values generally increased slightly at the surface sondes during closed estuary conditions, with the exception of the Sheephouse Creek station (Figures 4.1.30 through 4.1.33). The Sheephouse Creek surface sonde became more variable in response to barrier beach closures, with decreases and increases appearing to reflect similar decreases and increases of DO concentrations (see Figures 4.1.24 and 4.1.33). Similarly, pH values varied at the mid-depth sondes during closures, with decreases and increases appearing to reflect similar decreases and increases of DO concentrations at these stations (see Figures 4.1.20 and 4.1.29 for example).

[7] Acidity is controlled by the hydrogen ion H^+, and pH is defined as the negative log of the hydrogen ion concentration.

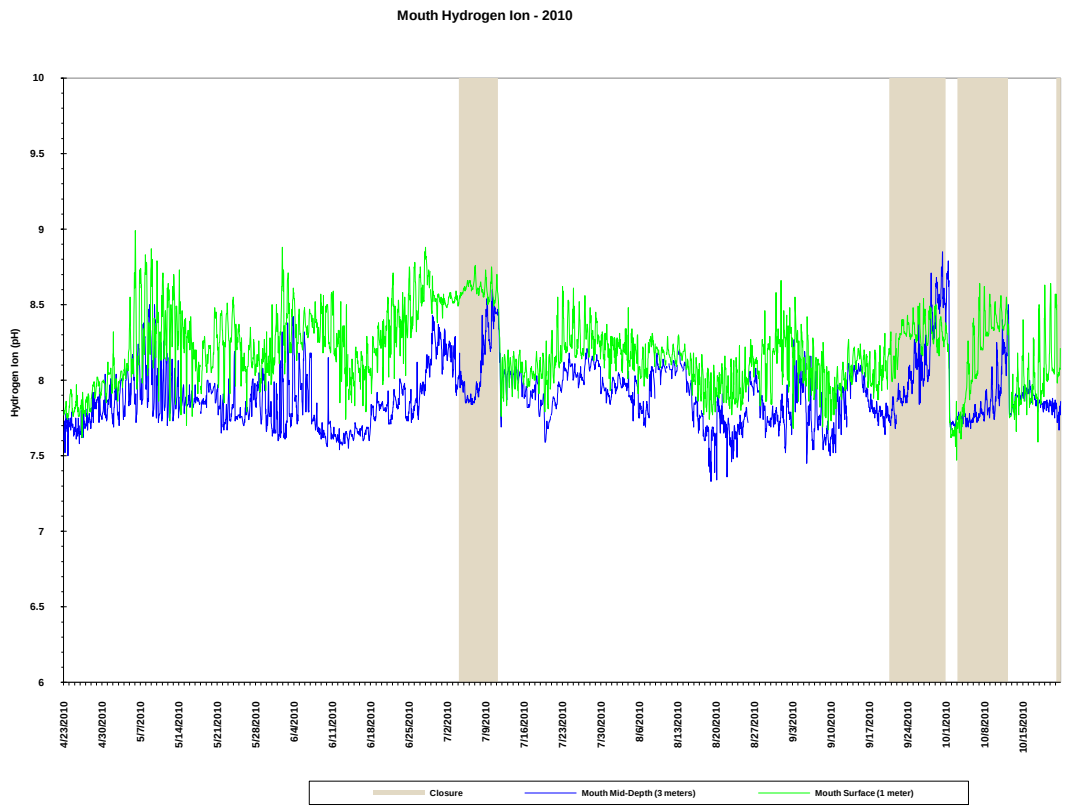


Figure 4.1.30. 2010 Russian River Mouth Hydrogen Ion Graph

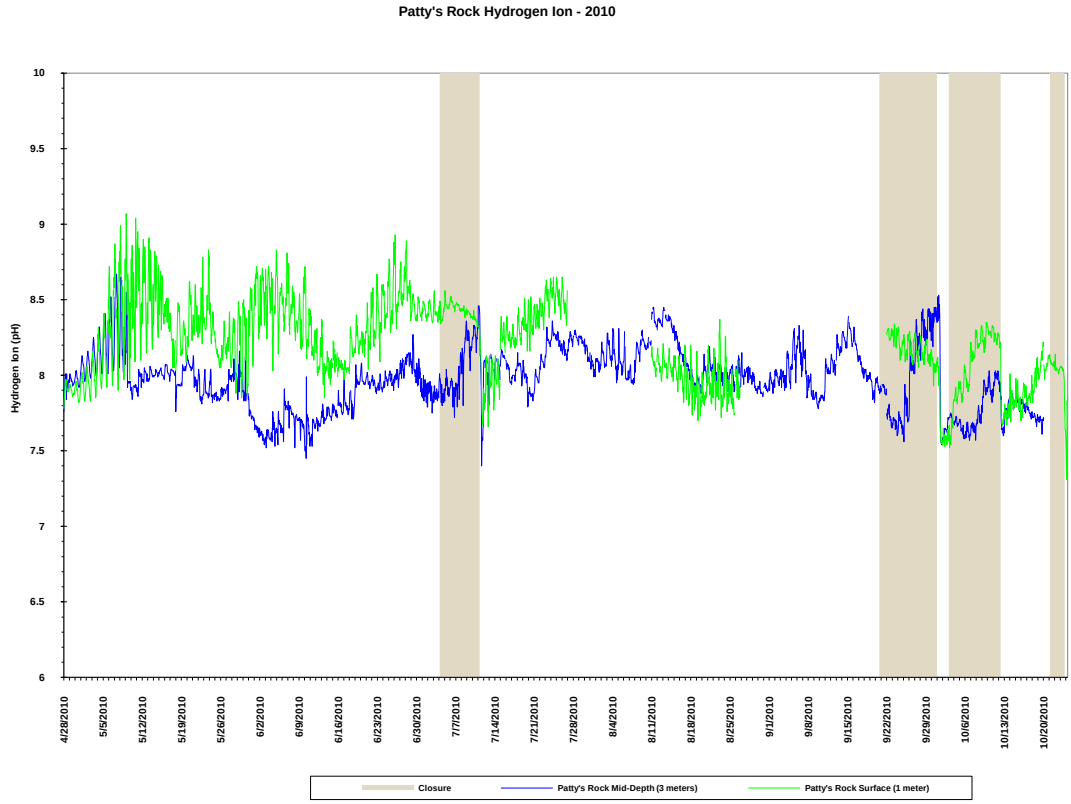


Figure 4.1.31. 2010 Russian River at Patty's Rock Hydrogen Ion Graph

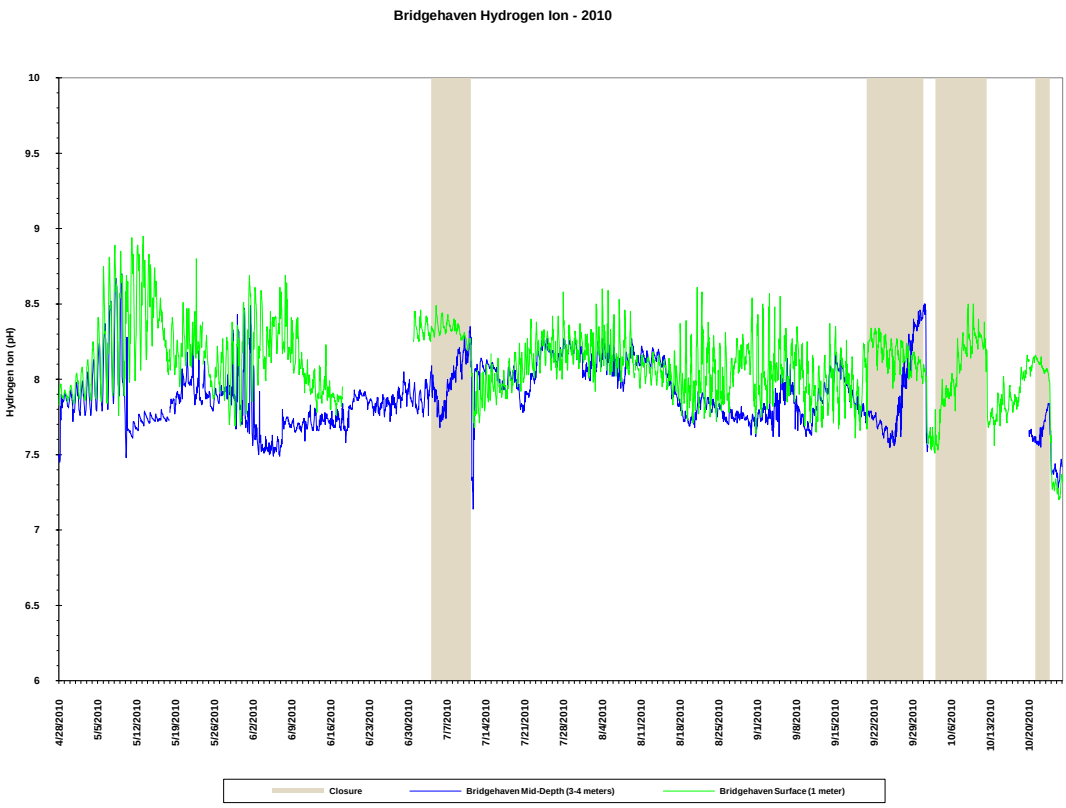


Figure 4.1.32. 2010 Russian River at Bridgehaven Hydrogen Ion Graph

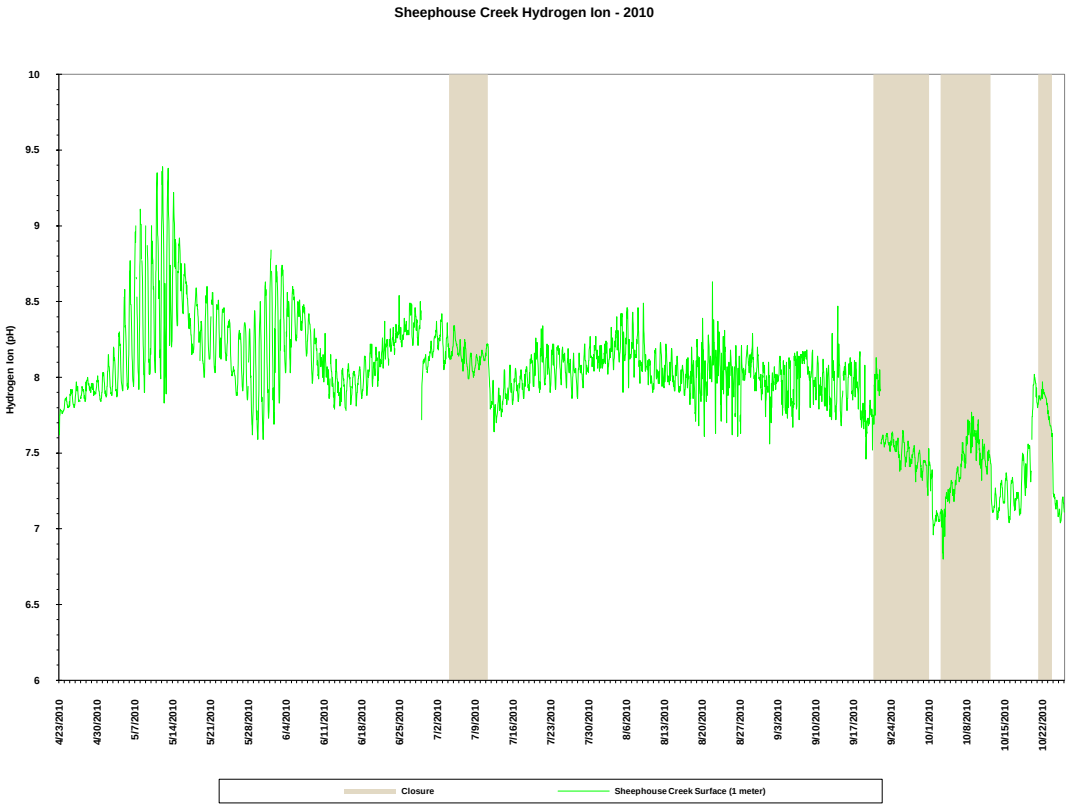


Figure 4.1.33. 2010 Russian River at Sheephouse Creek Hydrogen Ion Graph

The Willow Creek station had a mean pH value of 7.6, a maximum pH value of 9.3, and a minimum pH value of 6.5 (Table 4.1.1). Values were generally higher in saline water than in freshwater. However, the lowest values occurred after the barrier beach was breached on 1 October, as hypoxic brackish water of approximately 6 ppt was flushed out of the system and replaced with water containing less than 1 ppt of salt. The river mouth closed again on 4 October, and pH values increased as oxygenated brackish water moved back into the system (Figure 4.1.34).

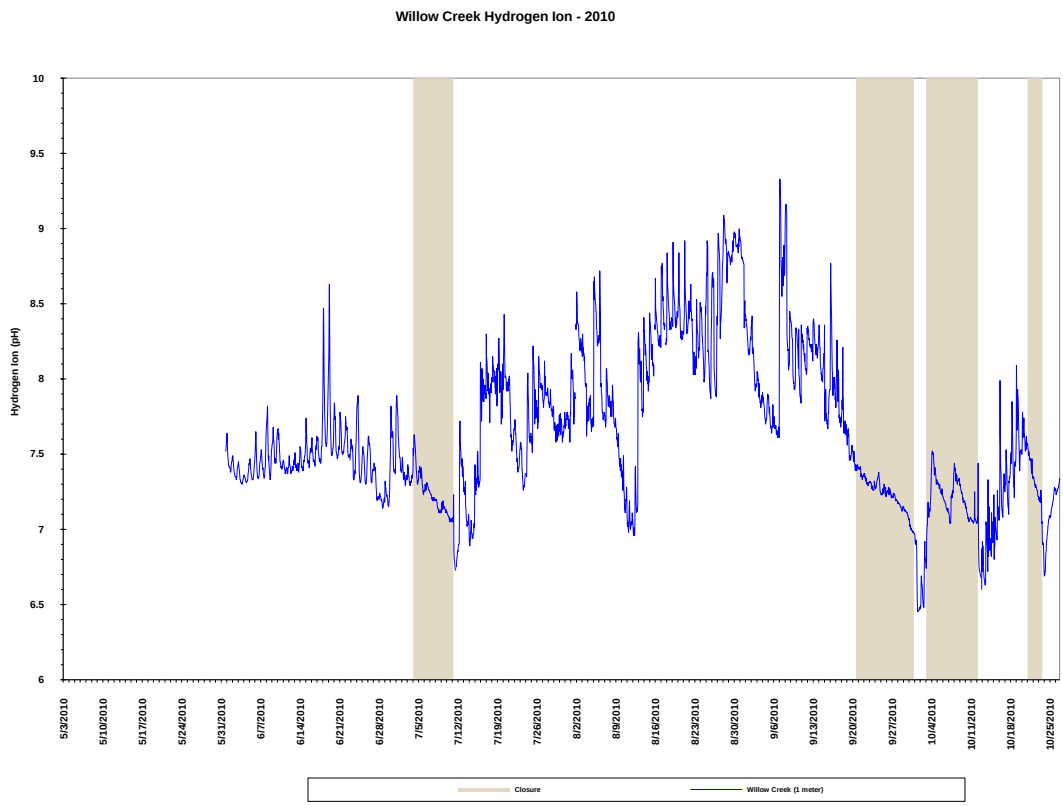


Figure 4.1.34. 2010 Willow Creek Hydrogen Ion Graph

Upper Reach pH

Minimum, mean, and maximum pH values at the Heron Rookery and Freezeout Creek mid-depth sondes were consistent with each other and with pH values observed in the lower and middle reaches of the estuary (Table 4.1.1). Whereas, pH values at the bottom sondes at Heron Rookery and Freezeout Creek were generally lower than those observed at the mid-depth sondes, including significantly lower minimum pH values (Figures 4.1.35 and 4.1.36).

Mean pH values were 8.1 at both mid-depth sondes, and 7.1 and 7.7 at the Heron Rookery and Freezeout Creek bottom sondes, respectively (Table 4.1.1). Maximum pH values were 8.9 at the Heron Rookery mid-depth sonde, 8.8 at the Freezeout Creek Mid-depth sonde, and 8.7 at both bottom sondes. Minimum pH values were observed to be 7.3 at both mid-depth sondes, and 5.5 at both bottom sondes.

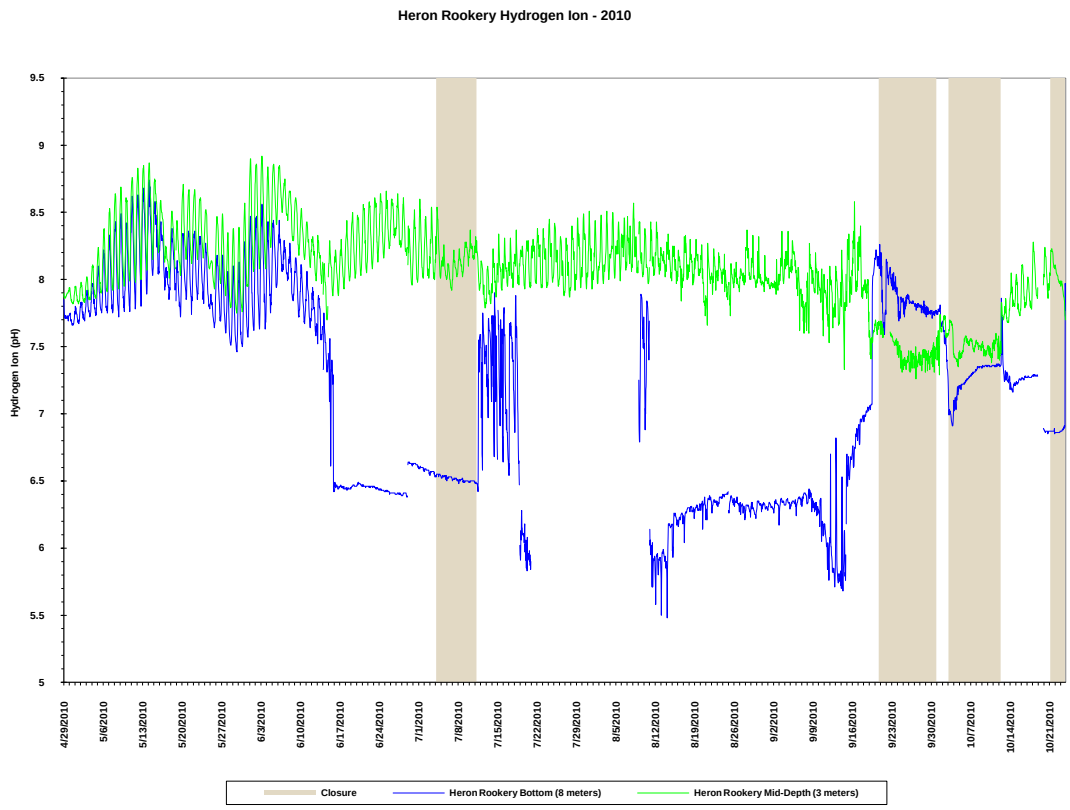


Figure 4.1.35. 2010 Russian River at Heron Rookery Hydrogen Ion Graph

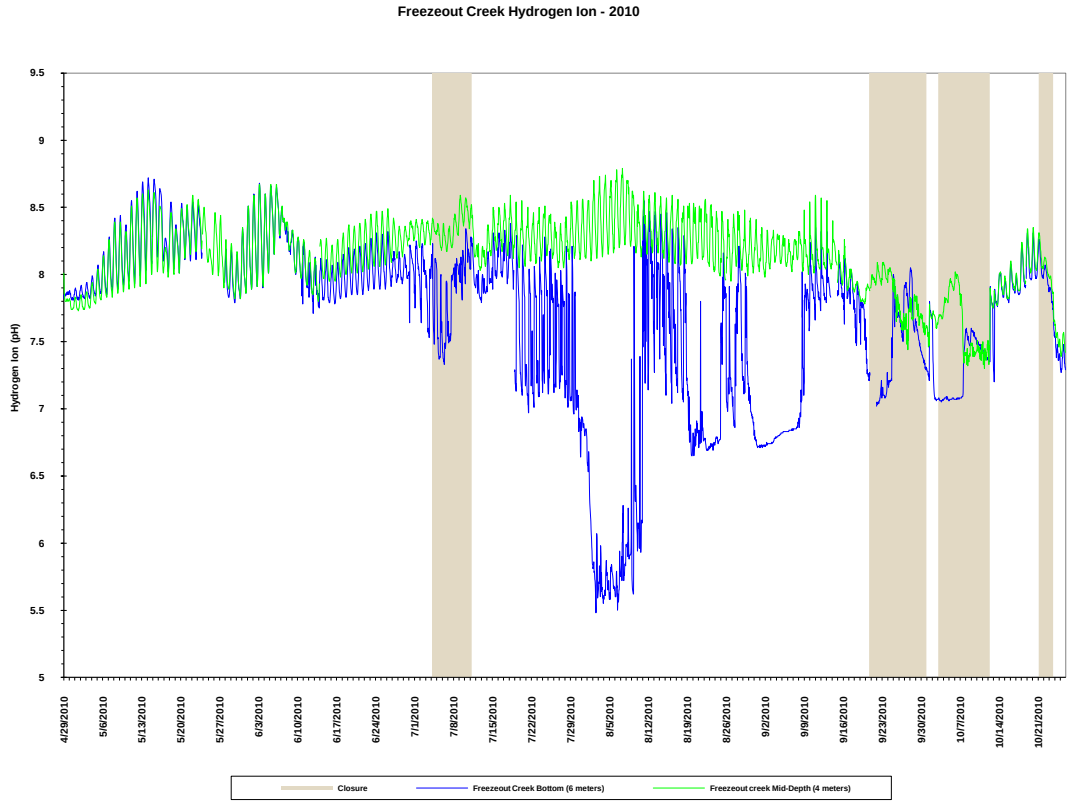


Figure 4.1.36. 2010 Russian River at Freezeout Creek Hydrogen Ion Graph

Both bottom sondes had minimum pH values of 5.5 that were observed to occur during periods of salinity intrusion and hypoxic to anoxic DO concentrations. During these anoxic events, H_2S was often released into the water column (as evidenced by large swings in DO concentrations and/or false DO supersaturation values shown in Figures 4.1.26 and 4.1.27) and likely contributed to the resulting low pH values (Figures 4.1.35 and 4.1.36).

Maximum Backwater Area pH

The Austin Creek station had a mean pH value of 7.8, a maximum pH value of 8.3, and a minimum pH value of 7.3 (Table 4.1.1). Values increased slightly during estuary closures in September and October; however response was variable during the first estuary closure in July. Although response observed during estuary closure was variable over the season, pH values continued to remain within the range of values observed during open conditions (Figure 4.1.37).

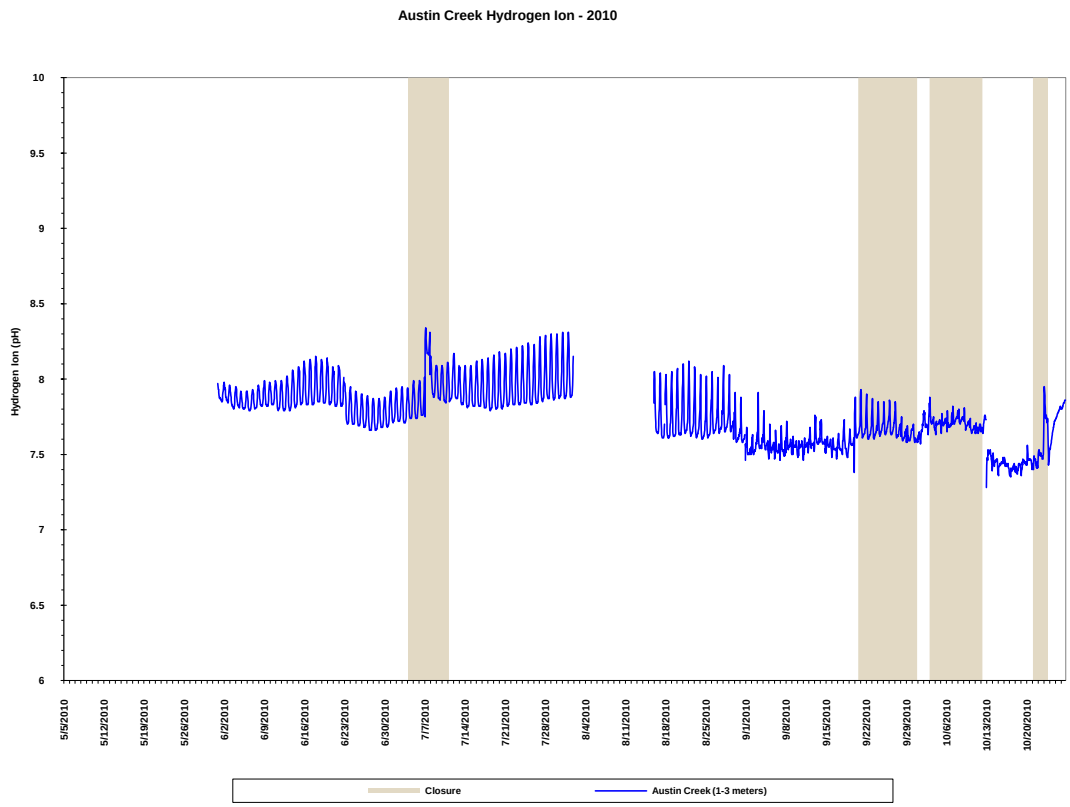


Figure 4.1.37. 2010 Austin Creek Hydrogen Ion Graph

The Monte Rio station had a mean pH value of 7.9, a maximum pH value of 9.1, and a minimum pH value of 7.2 (Table 4.1.1). Response to estuary closure was variable and fairly insignificant, with values observed to increase and decrease during closure but remain within the range of pH values observed throughout the rest of the monitoring season (Figure 4.1.38). High values coincided with high DO concentrations that occurred in June (Figure 4.1.29). Low values coincided with a storm event and increasing stream flows at the end of October.

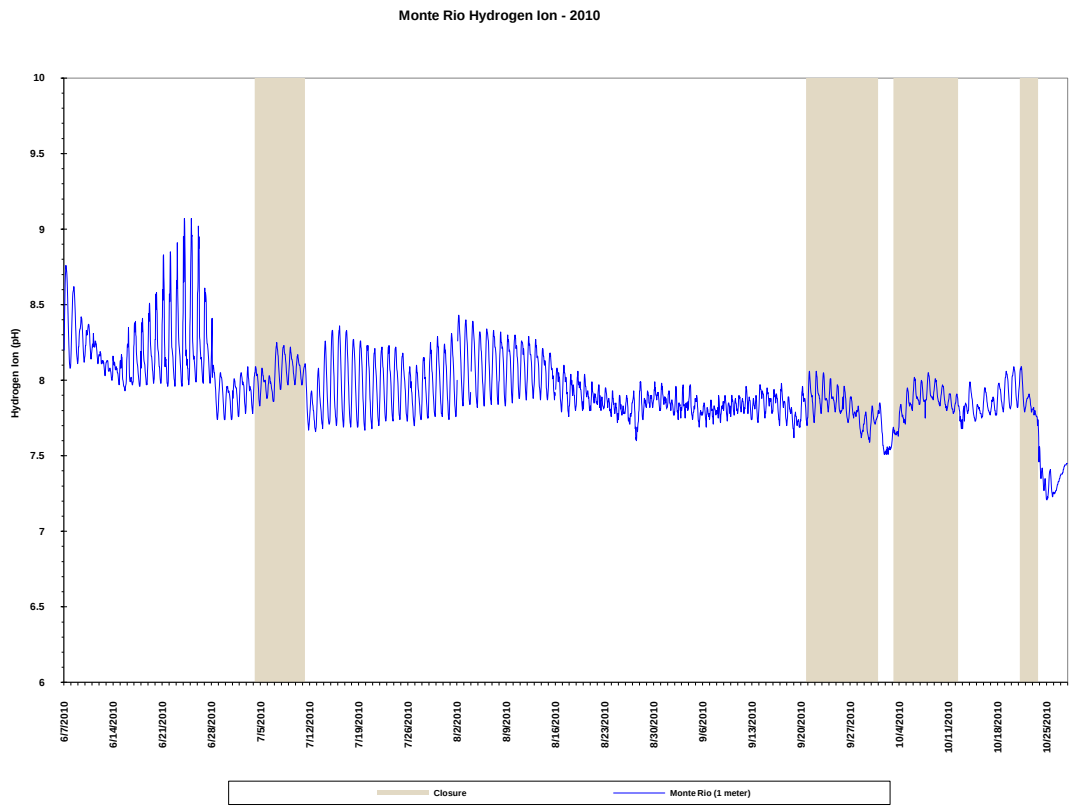


Figure 4.1.38. 2010 Russian River at Monte Rio Hydrogen Ion Graph

Grab Sampling

Grab sampling was conducted at five mainstem stations from Jenner to Monte Rio (Figure 4.1.1). Sampling was generally conducted every two weeks from 22 June to 14 October, when flows were above 125 cfs and the estuary was open. Sampling would have increased to every week if flows dropped below 125 cfs, but they remained above that level throughout the lagoon management period. Additional sampling was conducted twice weekly during estuary closure events and summer dam removal in late-September and October (Figures 4.1.2 through 4.1.6). Samples collected and analyzed for nutrients, chlorophyll *a*, and indicator bacteria are discussed below. Other sample results including organic carbon, dissolved solids, and turbidity are not analyzed, but are included as an appendix to the report.

Nutrients

The United States Environmental Protection Agency (USEPA) established section 304(a) nutrient criteria across 14 major ecoregions of the United States. The Russian River was designated in Aggregate Ecoregion III (USEPA, 2011). USEPA's section 304(a) criteria are intended to provide for the protection of aquatic life and human health (USEPA, 2011). The following discussion of nutrients compares sampling results to these USEPA criteria. However, it is important to note that these criteria are established for freshwater systems, and as such, are only applicable to the freshwater portions of the Estuary. Currently, there are no numeric nutrient criteria established specifically for estuaries.

Total nitrogen concentrations were generally below levels recommended for the protection of aquatic habitats; however total phosphorus concentrations were predominantly above recommended levels. The USEPA desired goal for total nitrogen in Aggregate Ecoregion III is 0.38 mg/L for rivers and streams not discharging into lakes or reservoirs (USEPA, 2000). Calculating total nitrogen values requires the summation of the different components of total nitrogen; organic and ammoniacal nitrogen (together referred to as Total Kjeldahl Nitrogen or TKN), and nitrate/nitrite nitrogen. Often times, nitrogen constituent results were reported as less than the Method Detection Limit (MDL). In these instances, the MDL is used for the purposes of calculating total nitrogen estimates, and the total nitrogen value is considered less than the estimate (Tables 4.1.2 – 4.1.6). Estimated total nitrogen concentrations were observed to remain below the USEPA criteria of 0.38 mg/L a majority of the time at all stations, however there were exceedances observed at each station. Most of these exceedances occurred during sampling events in June and early July, however there were a few exceedances at various stations in September and October (Tables 4.1.2 – 4.1.6). Interestingly, there were no exceedances at any stations during sampling events in August. Exceedances occurred during open and closed conditions, with the most exceedances at the Jenner Boat Ramp station. Total nitrogen concentrations that exceeded the criteria were generally observed to be 0.5 mg/L or less, but there were some instances where higher concentrations were observed, including two total nitrogen concentrations of <0.83 mg/L, recorded at the Duncans Mills station on 5 October, and at the Monte Rio station on 12 October. Both of these values were observed during closed estuary conditions; however the next highest value of 0.75 mg/L was observed during open estuary conditions at the Jenner Boat Ramp station on 14 September.

The USEPA's goal for total phosphates as phosphorus in Aggregate Ecoregion III is 21.88 micrograms per liter (µg/L), or approximately 0.022 mg/L, for rivers and streams not discharging into lakes or reservoirs (USEPA, 2000). Total phosphorus concentrations exceeded the USEPA criteria a majority of the time during both open and closed conditions at all five stations in the Estuary. Measureable levels of total phosphorus ranged from a high of 0.077 mg/L at the Bridgehaven Station on 14 October during open conditions and elevated storm flows, to a low of >0.21 mg/L at the Monte Rio Station on 12 October during closed conditions as storm flows were just starting to increase, and was the only sample collected at Monte Rio that did not exceed the USEPA criteria. The other stations also had season low values below the 0.02 mg/L MDL (<0.02) and recorded as non-detect (ND) on 12 October, and the Duncans Mills station had an ND sample result on 14 October as well. Total phosphorus concentrations were generally higher in June and July at all stations during both open and closed Estuary conditions, when late springs flows were still elevated, and tended to decrease through the rest of the season. However, total phosphorus concentrations increased during the last sampling event on 14 October compared to 12 October, except at the Duncans Mills station, which had ND sample results on both events. Samples were collected on 12 October during closed conditions and stream flows of approximately 228 cfs as measured at the Hacienda gaging station, whereas samples were collected on 14 October during open conditions and stream flows of approximately 660 cfs.

Table 4.1.2. 2010 Jenner Station Grab Sample Results

Jenner Boat Ramp*	Total Organic Nitrogen	Ammonia as N	Ammonia as N Unionized	Nitrate as N (NO_3^-)	Nitrite as N	Total Kjeldahl Nitrogen	Total Nitrogen (calculated)	Phosphorus, Total	Chlorophyll-a	Total Coliforms	Fecal Coliforms	Enterococcus	
MDL**	0.200	0.10	0.00010	0.030	0.020	0.10		0.020	0.000050	2.0	2.0	2.0	Estuary
Unit of Measure	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	MPN/100mL	MPN/100mL	MPN/100mL	Condition
6/22/2010	0.35	ND	--	0.15	ND	0.35	0.50	0.05	0.001	110	23	8.0	open
7/6/2010	0.273	ND	0.0086	0.13	ND	0.28	0.41	0.035	0.0033	500	240	50	closed
7/20/2010	ND	ND	ND	0.13	ND	0.40	0.53	0.041	0.00023	170	30	4.0	open
8/3/2010	0.210	ND	ND	ND	ND	0.21	0.21	0.043	0.0017	220	50	4.0	open
8/17/2010	ND	ND	ND	ND	ND	0.18	0.18	0.032	0.00071				open
8/19/2010										70	22	ND	open
8/31/2010	0.203	ND	0.0036	0.097	ND	0.24	0.34	0.039	0.0014	27	11	ND	open
9/14/2010	0.224	ND	ND	0.53	ND	0.22	0.75	0.029	0.0013	140	13	6.0	open
9/28/2010	0.231	ND	0.0032	0.081	ND	0.27	0.35	0.031	0.0015	>1600	80	500	closed
9/30/2010	ND	ND	0.0037	ND	ND	0.20	0.20	0.027	0.00097	>1600	240	1600	closed
10/5/2010	ND	ND	0.0015	ND	ND	0.18	0.18	0.033	0.00028	>1600	500	1600	closed
10/7/2010	0.217	ND	0.0010	0.084	ND	0.25	0.33	0.036	0.0017	>1600	300	1600	closed
10/12/2010	ND	ND	0.0034	0.13	ND	0.18	0.31	ND	0.0015	>1600	70	130	closed
10/14/2010	ND	ND	0.00062	0.22	ND	0.18	0.40	0.024	0.00046	300	23	8.0	open

* results are preliminary and subject to final revision.
** Method Detection Limit

Recommended EPA Criteria based on Aggregate Ecoregion III:
Total Phosporus: 0.02188 mg/L (21.88 ug/L)
Total Nitrogen: 0.38 mg/L
Chlorophyll *a* : 0.00178 mg/L (1.78 ug/L)
Turbidity: 2.34 FTU/NTU

Single Sample Values
Beach posting is recommended when indicator organisms exceed any of the following levels:
Total coliforms: 10,000 per 100 ml
Fecal coliforms: 400 per 100 ml
Enterococcus: 61 per 100 ml

Table 4.1.3. 2010 Bridgehaven Station Grab Sample Results

Bridgehaven*	Total Organic Nitrogen	Ammonia as N	Ammonia as N Unionized	Nitrate as N (NO_3^-)	Nitrite as N	Total Kjeldahl Nitrogen	Total Nitrogen (calculated)	Phosphorus, Total	Chlorophyll-a	Total Coliforms	Fecal Coliforms	Enterococcus	
MDL**	0.200	0.10	0.00010	0.030	0.020	0.10		0.020	0.000050	2.0	2.0	2.0	Estuary
Unit of Measure	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	MPN/100mL	MPN/100mL	MPN/100mL	Condition
6/22/2010	0.238	ND	--	0.14	ND	0.24	0.38	0.044	0.0002	900	22	110	open
7/6/2010	ND	ND	0.0032	0.12	ND	0.21	0.33	0.042	0.0036	500	23	80	closed
7/20/2010	ND	0.10	0.0062	0.13	ND	0.28	0.41	0.054	0.0083	>1600	170	30	open
8/3/2010	ND	ND	0.00057	0.088	ND	0.14	0.23	0.042	0.0017	23	8.0	22	open
8/17/2010	ND	ND	0.0023	ND	ND	0.21	0.21	0.040	0.0057				open
8/19/2010										110	13	4.0	open
8/31/2010	ND	ND	0.0027	0.094	ND	0.24	0.33	0.036	0.0032	50	8.0	4.0	open
9/14/2010	ND	ND	0.00019	0.40	ND	0.18	0.58	0.039	0.0043	140	17	13	open
9/28/2010	0.301	ND	ND	0.093	ND	0.30	0.39	0.027	0.00097	>1600	50	50	closed
9/30/2010	ND	ND	0.0058	0.077	ND	0.15	0.23	0.031	0.00087	900	90	300	closed
10/5/2010	ND	ND	0.0014	ND	ND	0.21	0.21	0.038	0.00047	>1600	900	>1600	closed
10/7/2010	ND	0.10	0.0036	0.098	ND	0.21	0.31	0.057	0.00055	>1600	70	240	closed
10/12/2010	ND	ND	0.00065	ND	ND	0.18	0.18	ND	0.0015	>1600	70	130	closed
10/14/2010	ND	ND	0.00044	0.11	ND	0.10	0.21	0.077	0.0023	900	240	14	open

* results are preliminary and subject to final revision.
** Method Detection Limit

Recommended EPA Criteria based on Aggregate Ecoregion III:
Total Phosporus: 0.02188 mg/L (21.88 ug/L)
Total Nitrogen: 0.38 mg/L
Chlorophyll *a* : 0.00178 mg/L (1.78 ug/L)
Turbidity: 2.34 FTU/NTU

Single Sample Values
Beach posting is recommended when indicator organisms exceed any of the following levels:
Total coliforms: 10,000 per 100 ml
Fecal coliforms: 400 per 100 ml
Enterococcus: 61 per 100 ml

Table 4.1.4. 2010 Duncans Mills Station Grab Sample Results

Duncans Mills*	Total Organic Nitrogen	Ammonia as N	Ammonia as N Unionized	Nitrate as N (NO_3^-)	Nitrite as N	Total Kjeldahl Nitrogen	Total Nitrogen (calculated)	Phosphorus, Total	Chlorophyll-a	Total Coliforms	Fecal Coliforms	Enterococcus	
MDL**	0.200	0.10	0.00010	0.030	0.020	0.10		0.020	0.000050	2.0	2.0	2.0	Estuary
Unit of Measure	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	MPN/100mL	MPN/100mL	MPN/100mL	Condition
6/22/2010	ND	ND	--	0.18	ND	0.21	0.39	0.047	0.0005	300	8.0	4.0	open
7/6/2010	ND	ND	0.0018	0.14	ND	0.20	0.34	0.038	0.0027	50	50	30	closed
7/20/2010	ND	0.14	0.020	0.14	ND	0.14	0.28	0.041	0.00092	300	8.0	6.0	open
8/3/2010	ND	ND	0.0034	0.096	ND	0.14	0.24	0.032	0.00059	50	13	2.0	open
8/17/2010	ND	ND	0.0082	0.078	ND	0.14	0.22	0.023	0.00059				open
8/19/2010										140	13	4.0	open
8/31/2010	ND	ND	ND	0.077	ND	0.17	0.25	0.030	0.00028	47	32	4.0	open
9/14/2010	0.245	ND	ND	0.082	ND	0.24	0.32	0.034	0.0013	170	23	14	open
9/28/2010	ND	ND	0.0046	0.10	ND	0.16	0.26	0.034	0.00087	430	140	80	closed
9/30/2010	ND	ND	0.0056	0.075	ND	0.16	0.24	ND	0.0011	>1600	500	240	closed
10/5/2010	0.683	ND	0.0031	0.075	ND	0.75	0.83	0.025	0.00056	500	30	22	closed
10/7/2010	ND	ND	0.0023	0.076	ND	0.25	0.33	0.032	0.00027	130	23	17	closed
10/12/2010	ND	ND	0.0024	0.15	ND	0.21	0.36	ND	0.00055	1600	23	17	closed
10/14/2010	ND	ND	0.00089	0.12	ND	0.11	0.23	ND	0.0037	170	23	23	open

* results are preliminary and subject to final revision.
** Method Detection Limit

Recommended EPA Criteria based on Aggregate Ecoregion III:
Total Phosporus: 0.02188 mg/L (21.88 ug/L)
Total Nitrogen: 0.38 mg/L
Chlorophyll *a* : 0.00178 mg/L (1.78 ug/L)
Turbidity: 2.34 FTU/NTU

Single Sample Values
Beach posting is recommended when indicator organisms exceed any of the following levels:
Total coliforms: 10,000 per 100 ml
Fecal coliforms: 400 per 100 ml
Enterococcus: 61 per 100 ml

Table 4.1.5. 2010 Casini Ranch Station Grab Sample Results

Casini Ranch*	Total Organic Nitrogen	Ammonia as N	Ammonia as N Unionized	Nitrate as N (NO_3^-)	Nitrite as N	Total Kjeldahl Nitrogen	Total Nitrogen (calculated)	Phosphorus, Total	Chlorophyll-a	Total Coliforms	Fecal Coliforms	Enterococcus	
MDL**	0.200	0.10	0.00010	0.030	0.020	0.10		0.020	0.000050	2.0	2.0	2.0	Estuary
Unit of Measure	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	MPN/100mL	MPN/100mL	MPN/100mL	Condition
6/22/2010	0.35	ND	--	0.15	ND	0.35	0.50	0.05	0.001	110	23	8.0	open
7/6/2010	0.273	ND	0.0086	0.13	ND	0.28	0.41	0.035	0.0033	500	240	50	closed
7/20/2010	ND	ND	ND	0.13	ND	0.40	0.53	0.041	0.00023	170	30	4.0	open
8/3/2010	0.210	ND	ND	ND	ND	0.21	0.21	0.043	0.0017	220	50	4.0	open
8/17/2010	ND	ND	ND	ND	ND	0.18	0.18	0.032	0.00071				open
8/19/2010										70	22	ND	open
8/31/2010	0.203	ND	0.0036	0.097	ND	0.24	0.34	0.039	0.0014	27	11	ND	open
9/14/2010	0.224	ND	ND	0.53	ND	0.22	0.75	0.029	0.0013	140	13	6.0	open
9/28/2010	0.231	ND	0.0032	0.081	ND	0.27	0.35	0.031	0.0015	>1600	80	500	closed
9/30/2010	ND	ND	0.0037	ND	ND	0.20	0.20	0.027	0.00097	>1600	240	1600	closed
10/5/2010	ND	ND	0.0015	ND	ND	0.18	0.18	0.033	0.00028	>1600	500	1600	closed
10/7/2010	0.217	ND	0.0010	0.084	ND	0.25	0.33	0.036	0.0017	>1600	300	1600	closed
10/12/2010	ND	ND	0.0034	0.13	ND	0.18	0.31	ND	0.0015	>1600	70	130	closed
10/14/2010	ND	ND	0.00062	0.22	ND	0.18	0.40	0.024	0.00046	300	23	8.0	open

* results are preliminary and subject to final revision.
** Method Detection Limit

Recommended EPA Criteria based on Aggregate Ecoregion III:
Total Phosporus: 0.02188 mg/L (21.88 ug/L)
Total Nitrogen: 0.38 mg/L
Chlorophyll *a* : 0.00178 mg/L (1.78 ug/L)
Turbidity: 2.34 FTU/NTU

Single Sample Values
Beach posting is recommended when indicator organisms exceed any of the following levels:
Total coliforms: 10,000 per 100 ml
Fecal coliforms: 400 per 100 ml
Enterococcus: 61 per 100 ml

Table 4.1.6. 2010 Monte Rio Station Grab Sample Results

Monte Rio*	Total Organic Nitrogen	Ammonia as N	Ammonia as N Unionized	Nitrate as N (NO_3^-)	Nitrite as N	Total Kjeldahl Nitrogen	Total Nitrogen (calculated)	Phosphorus, Total	Chlorophyll-a	Total Coliforms	Fecal Coliforms	Enterococcus	
MDL**	0.200	0.10	0.00010	0.030	0.020	0.10		0.020	0.000050	2.0	2.0	2.0	Estuary
Unit of Measure	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	MPN/100mL	MPN/100mL	MPN/100mL	Condition
6/22/2010	0.203	ND	--	0.20	ND	0.21	0.41	0.047	0.0012	130	8.0	30	open
7/6/2010	ND	ND	0.0029	0.13	ND	0.16	0.29	0.035	0.0025	900	170	130	closed
7/20/2010	ND	ND	0.0024	0.13	ND	ND	0.13	0.042	0.0018	30	23	7.0	open
8/3/2010	ND	ND	0.0019	0.073	ND	0.14	0.21	0.026	0.00099	170	50	9.0	open
8/17/2010	ND	ND	ND	0.074	ND	0.18	0.25	0.024	0.00071				open
8/19/2010										170	13	13	open
8/31/2010	ND	ND	ND	0.076	ND	0.17	0.25	0.030	0.00019	140	17	8.0	open
9/14/2010	ND	ND	0.00096	0.073	ND	0.18	0.25	0.028	0.00025	280	90	33	open
9/28/2010	ND	ND	0.0015	0.081	ND	0.16	0.24	0.027	0.00019	300	130	130	closed
9/30/2010	ND	ND	0.0018	0.075	ND	0.20	0.28	0.027	0.000097	>1600	350	210	closed
10/5/2010	ND	ND	0.0016	0.076	ND	0.18	0.26	0.025	ND	80	17	30	closed
10/7/2010	ND	0.14	0.0046	0.076	ND	0.25	0.33	0.029	0.00037	240	50	240	closed
10/12/2010	0.520	0.18	0.0048	0.13	ND	0.70	0.83	0.021	0.00027	300	80	300	closed
10/14/2010	ND	ND	0.0011	0.12	ND	0.20	0.32	0.027	0.0015	500	240	240	open

* results are preliminary and subject to final revision.
** Method Detection Limit

Recommended EPA Criteria based on Aggregate Ecoregion III:
Total Phosporus: 0.02188 mg/L (21.88 ug/L)
Total Nitrogen: 0.38 mg/L
Chlorophyll *a* : 0.00178 mg/L (1.78 ug/L)
Turbidity: 2.34 FTU/NTU

Single Sample Values
Beach posting is recommended when indicator organisms exceed any of the following levels:
Total coliforms: 10,000 per 100 ml
Fecal coliforms: 400 per 100 ml
Enterococcus: 61 per 100 ml

It is highly likely that phosphorus in the river substrate was re-suspended into the water column from the increasing storm flows and the flushing effects of breaching the barrier beach, leading to the increased concentrations observed at most stations on 14 October.

Chlorophyll *a*

In the process of photosynthesis, chlorophyll *a* - a green pigment in plants, absorbs sunlight and combines carbon dioxide and water to produce sugar and oxygen. Chlorophyll *a* can therefore serve as a measureable parameter of algal growth. Qualitative assessment of primary production on water quality can be based on chlorophyll *a* concentrations. A U.C. Davis report on the Klamath River (1999) assessing potential water quality and quantity regulations for restoration and protection of anadromous fish includes a discussion of chlorophyll *a* and how it can affect water quality. The report characterizes the effects of chlorophyll *a* in terms of different levels of discoloration (e.g., no discoloration to some, deep, or very deep discoloration). The report indicated that less than 10 µg/L (or 0.01 mg/L) of chlorophyll *a* exhibits no discoloration (Deas and Orlob, 1999). Additionally, the USEPA criterion for chlorophyll *a* in Aggregate Ecoregion III is 1.78 µg/L, or approximately 0.0018 mg/L for rivers and streams not discharging into lakes or reservoirs (USEPA, 2000). However, it is important to note that the EPA criterion is established for freshwater systems, and as such, is only applicable to the freshwater portions of the Estuary. Currently, there are no numeric chlorophyll *a* criteria established specifically for estuaries.

Chlorophyll *a* concentrations were less than 0.01 mg/L at all stations during all sampling events; the level recommended to prevent discoloration of surface waters (Tables 4.1.2 – 4.1.4). Estimated chlorophyll *a* concentrations were also observed to remain below the USEPA criteria of 0.0018 mg/L a majority of the time at all stations, however there were exceedances observed at each station (Tables 4.1.2 – 4.1.6). The grab sampling stations typically experienced only one or two exceedances during the entire season; however the Bridgehaven Station exceeded the criteria six times. These exceedances generally occurred during sampling events in June and early July, with all stations exceeding the criteria on the 6 July sampling event. Exceedances occurred during open and closed estuary conditions early in the season; however there were no exceedances at any station during closed estuary conditions in September and October. The Bridgehaven Station had the highest chlorophyll *a* concentration of the season, with a value of 0.0083 mg/L recorded during open conditions on 20 July, whereas the Monte Rio Station had a season low value below the 0.000050 mg/L MDL (<0.000050) and recorded as non-detect (ND) on 5 October during closed estuary conditions (Figures 4.1.3 and 4.1.6). There were also exceedances at the Casini Ranch, Duncans Mills, and Bridgehaven stations during the last sampling event on 14 October, two days after the estuary had been re-opened (Tables 4.1.3 – 4.1.5).

Indicator Bacteria

The California Department of Public Health (CDPH) developed the "Draft Guidance for Fresh Water Beaches," which describes bacteria levels that, if exceeded, may require posted warning signs in order to protect public health (CDPH, 2011). The CDPH draft guideline for total coliform is 10,000 most probable numbers (MPN) per 100 milliliters (ml), and 400 MPN per 100 ml for fecal coliforms. The MPN for *Enterococcus* is 61 per 100 ml. However, it must be emphasized that these are draft guidelines, not adopted standards, and are therefore both subject to change (if it is determined that the guidelines are not accurate indicators) and are not currently enforceable. In addition, these draft guidelines were established for and are only applicable to fresh water beaches. Currently, there are no numeric guidelines that have been developed for estuarine areas.

Sampling results in 2010 indicate there is a large variation in indicator bacteria levels observed through the different sections of the Estuary (Tables 4.1.2 – 4.1.6). These variations occurred under both open and closed mouth conditions and may be seasonal as well.

Sample results in 2010 did not include an absolute value for high counts of total coliforms and were reported by the lab as being greater than 1,600 MPN (>1,600). This precludes the comparison of total coliform sample results to the draft CDPH guidelines for public recreation.

In 2010, total coliform counts were generally higher during closed conditions in September and October than during open conditions earlier in the season, although there were a few counts during open conditions as high as counts observed during closed conditions. All five stations sampled in 2010 had at least one total coliform value of >1,600 MPN, with the Bridgehaven and Jenner Boat Ramp stations having five each (Tables 4.1.2 – 4.1.6). These high counts occurred during closed estuary conditions in late September and early October following increased freshwater inflows related to upstream dam removals at the end of September and during repeated barrier beach closures in early October. Total coliform values were occasionally

elevated during open conditions, with high counts of >1,600 MPN being recorded at the Bridgehaven Station on 20 July, and at the Casini Ranch Station on 14 October, two days after the mouth had been re-opened.

Fecal coliform counts were generally low during the monitoring season during open and closed estuary conditions. The Monte Rio and Casini Ranch stations had no counts above the draft CDPH guideline of 400 MPN/100 ml. The Jenner Boat Ramp and Bridgehaven stations had one high count each, of 500 MPN and 900 MPN, respectively that exceeded the draft CDPH guidelines during closed conditions on 5 October (Tables 4.1.2 and 4.1.3). The Duncans Mills station had a high count of 500 MPN that also exceeded draft CDPH guidelines during closed conditions on 30 September. These high counts occurred during closed estuary conditions in late September and early October following increased freshwater inflows related to upstream dam removals at the end of September and during repeated barrier beach closures in early October.

Enterococcus counts were higher during closed estuary conditions in September and October, and all stations exceeded draft freshwater levels during closed barrier beach conditions. The draft guidance for freshwater beach posting identifies the potential for public health concerns when *Enterococcus* levels exceed 61 MPN/100ml. The Jenner Boat Ramp Station had three counts of 1,600 MPN during closed conditions between 30 September and 7 October (Table 4.1.2). The Casini Ranch Station also had a high count of 1,600 MPN during closed conditions on 30 September and the Bridgehaven Station had a high count of >1,600 MPN during closed conditions on 5 October (Tables 4.1.5 and 4.1.3). These high counts occurred during closed estuary conditions in late September and early October following increased freshwater inflows related to upstream dam removals at the end of September and during repeated barrier beach closures in early October. Draft guideline criteria were not exceeded during open and closed conditions earlier in the season at the Jenner, Duncans Mills and Casini Ranch stations. However, draft criteria were exceeded at the Bridgehaven Station during open and closed conditions on 22 June and 6 July, respectively, and at the Monte Rio Station during the 6 July closure.

Conclusions and Recommendations

Overall, water quality conditions observed during the 2010 monitoring season were similar to conditions associated with a dynamic estuarine system observed in previous years. There were a few notable observations associated with salinity and indicator bacteria that will be discussed further below. Monitoring efforts for the 2011 season will also be discussed.

The lower and middle reaches of the Estuary up to Sheephouse Creek are predominantly saline environments with a thin freshwater layer that flows over the denser saltwater. Salinities near the mouth (1st mile of the Estuary) are mostly similar to ocean salinities. Whereas, the middle portion of the Estuary (one to five miles from the mouth) is most subject to fluctuation in salinities throughout the water column due to ocean tides and freshwater inflow rates. In the middle reach of the Estuary, salinities can range as high as 30 ppt in the saltwater layer, with brackish conditions prevailing at the upper end of the salt wedge, to less than 1 ppt in the freshwater layer on the surface. The upper reach of the Estuary transitions to a predominantly freshwater environment, which is periodically underlain by a denser, saline to brackish layer that migrates

upstream as far as the Moscow Road Bridge in Duncans Mills during summer low flow conditions. The most upstream portion of the Estuary from Duncans Mills to Austin Creek (upper one mile of the Estuary) is the only portion where a predominance of freshwater habitat is maintained throughout the summer. River flows, tides, and wind action affect the amount of mixing at various longitudinal and vertical positions within the Estuary.

When the barrier beach forms, saltwater is trapped in the lagoon and water quality conditions can undergo abrupt alteration. After closure, salinity, DO and temperature changes occur within 24 hours. After the estuary becomes stratified, the mid-depth saltwater lens traps heats (Smith, 1990; Entrix, 2004). Through natural processes, DO becomes depleted in the bottom saline layer and anoxic conditions can develop. Salinity stratification leads to reductions in DO and increases in temperature in the lower water column following closure.

During barrier beach closures, the freshwater lens deepened at the surface. Highly saline conditions were typical in the mid-depths of the lower and middle reaches of the Estuary within a few days of barrier beach closures. However, salinity levels were observed to decrease at mid-depth over time, which may be evidence that the denser saltwater was percolating out of the Estuary through the barrier beach. Conversely, brackish water extended into the lower half of the water column during barrier beach closure as far upstream as Freezeout Creek in the upper reach, providing further evidence that the salt layer was stratifying and flattening out. As the closed Estuary continued to backwater, a reduction in the hydraulic forces of freshwater inflow also appeared to contribute to the upstream migration of the salt layer. Once the barrier beach had been reopened, salinity concentrations were generally observed to increase at the surface sondes as the freshwater layer diminished and the Estuary became tidally influenced again.

Temperature stratification coincided with the presence of the halocline, as the saltwater was typically observed to be significantly colder than the freshwater during open Estuary conditions. surface sonde temperatures were observed to have the greatest degree of fluctuation due to their location at the saltwater-freshwater interface. However, temperatures were also observed to exhibit diel fluctuations based on the heating and cooling effects of night and day, as well as longer-term seasonal heating and cooling events, including barrier beach closure and reopening.

When the barrier beach closed, temperatures were observed to increase in the saline layer and often exceed temperatures in the overlying surface freshwater layer. Over time, a three-layer system would form with a cooler saline to brackish bottom layer that is below the effects of solar heating, a hot mid-depth layer of saline to brackish water subject to the effects of solar heating, and a cooler (but still relatively warm) freshwater layer on the surface.

Mean DO levels were typically higher in the freshwater layer than in the saline layer. However, DO concentrations fluctuated significantly during the monitoring season at all stations, and fluctuations were not necessarily associated with tidal cycles or a diurnal cycle. DO levels in the Estuary depend upon factors such as the extent of diffusion from surrounding air and water movement, including freshwater inflow. DO levels are also a function of nutrients, which can accumulate in standing water during an extended period of time and promote excessive plant and algal growth that utilize DO. This can reduce DO levels leading to eutrophication and

affecting overall ecological health of the Estuary. Estuaries tend to be naturally eutrophic because land-derived nutrients are concentrated where runoff enters the marine environment in a confined channel.[8] Upwelling in coastal systems, which typically occurs from March to July, also promotes increased productivity by conveying deep, nutrient-rich waters to the surface and into the estuary through tidal action, where the nutrients can be assimilated by algae.

When the barrier beach closes, salinity stratification results in pronounced DO stratification in the closed lagoon. Supersaturation, hypoxic, and anoxic events were observed, with prolonged hypoxic and/or anoxic events occurring in the deeper portions of the Estuary through the duration of barrier beach closure. DO concentrations were variable in the mid-depth saline layer of the water column during barrier beach closures with decreases and increases observed. DO levels in the freshwater at the surface of the Estuary did not appear to be negatively impacted by barrier beach closure and remained similar to open conditions (7 to 10 mg/L), or increased in some instances. Similar stratified conditions were also observed when the barrier beach was open during neap tides or low river flows, indicating that the deeper portions of the Estuary may not be subject to mixing even during open tidal conditions.

In 2010, the salt wedge migrated to the Heron Rookery and Freezeout Creek stations under higher flows than were observed in 2009 (SCWA 2011). The salt wedge migrated to the Heron Rookery and Freezeout Creek stations when flows decreased to approximately 150 cfs in 2009. Whereas, in 2010, the salt wedge migrated to the Heron Rookery station when flows were above 400 cfs, and migrated to the Freezeout Creek Station when flows were approximately 200 cfs. However, it should be noted that in 2009, the Heron Rookery Bottom Sonde was not at the absolute bottom of the pool, and the salt wedge may have been at the station, but located deeper in the water column than the sonde. For the 2011 monitoring effort, the bottom sonde at Heron Rookery will continue to be placed in the deepest portion of the pool to record the timing of the upstream migration of the salt wedge.

Indicator bacteria exhibited high variability in counts between stations and seasons. During the 2009 season, indicator bacteria were observed to have high counts that exceeded draft CDPH guidelines primarily during open estuary conditions (SCWA 2011). Whereas, in 2010, indicator bacterial counts were high and exceeded draft guidelines primarily during closed estuary conditions.

Potential causes for higher counts observed during open conditions in 2009 than in 2010 include lower flows in 2009 than in 2010. However, these differences could also be caused by other variables including higher water temperatures, more nutrient availability, more days of sun, and increased recreational usage at a given station. Higher values during closed conditions in 2010 than in 2009 may be attributable to increased freshwater inflows related to upstream dam removals at the end of September, at a time when the estuary was repeatedly closing and impounding water, and when exceedances of the draft CDPH guidelines occurred.

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[8] *National Estuarine Eutrophication Assessment* by NOAA National Centers for Coastal Ocean Science (NCCOS) and the Integration and Application Network (IAN), 1999.

Monitoring in 2011 will continue to focus on the movement of the salt wedge within the estuary and will be expanded to include a station above the Moscow Road Bridge in Duncans Mills to track potential salinity migration above Freezeout Creek, where it has been observed to occur. Monitoring will also be expanded in 2011 to include a station in the mainstem above Austin Creek, but below Monte Rio in an effort to locate potential cold water refugia in the maximum backwater area. Finally, grab sampling will continue in 2011 at the five stations sampled in 2010 and focused sampling will occur when the estuary closes and when the summer dams are removed to gain additional information on the potential for either of these two actions to increase bacterial concentrations in the estuary.

References

California Department of Public Health (CDPH), *Draft Guidance for Freshwater Beaches*. Division of Drinking Water and Environmental Management. http://www.cdph.ca.gov/healthinfo/environhealth/water/Documents/Beaches/DraftGuidanceforFreshWaterBeaches.pdf. Last update: January 2011.

Deas, M. and G. Orlob., University of California Davis, Report No. 99-04. *Klamath River Modeling Project*, Sponsored by the U.S. Fish and Wildlife Service Klamath Basin Fisheries Task Force. Project #96-HP-01, Assessment of Alternatives for Flow and Water Quality Control in the Klamath River below Iron Gate Dam, 1999.

Entrix. 2004. Russian River Biological Assessment. Prepared for: U.S. Army Corps of Engineers, San Francisco District, San Francisco, California, and Sonoma County Water Agency Santa Rosa, California. Entrix, September 29, 2004.

Horne, Alexander J. and Charles R. Goldman. 1994. Limnology. Second Edition. McGraw-Hill, Inc.

North Coast Regional Water Quality Control Board (NCRWQCB), 2011. Basin Plan Documents. Basin Plan. *Water Quality Control Plan for the North Coast Region.* http://www.waterboards.ca.gov/northcoast/water_issues/programs/basin_plan/083105-bp/basin_plan.pdf. May 2011.

Smith, J.J. 1990. The effects of the sandbar formation and inflows on aquatic habitat and fish utilization in Pescadero, San Gregorio, Wadell, and Pomponio creek estuary/lagoon systems, 1985-1989. Department of Biological Sciences, San Jose State University, San Jose, California.

Sonoma County Water Agency (SCWA), 2011. Russian River Biological Opinion Status and Data Report Year 2009 – 2010. Manning, D.J., and J. Martini-Lamb, editors. February 28, 2011.

United States Environmental Protection Agency (USEPA), *Ambient Water Quality Criteria Recommendations. Information Supporting the Development of State and Tribal Nutrient Criteria for Rivers and Streams in Nutrient Ecoregion III*. Office of Water. 4304. EPA-B-00-016. December 2000.

United States Environmental Protection Agency (USEPA), Water. Ecoregional Criteria. http://water.epa.gov/scitech/swguidance/standards/criteria/nutrients/ecoregions/index.cfm Last Updated April 27, 2011.

United States Environmental Protection Agency (USEPA), Water. Water Quality Criteria. http://water.epa.gov/scitech/swguidance/standards/criteria/index.cfm. Last Updated December 16, 2010.

4.2 Invertebrate Monitoring and Salmonid Diet Analysis

The University of Washington, School of Aquatic and Fishery Sciences' Wetland Ecosystem Team (UW-WET) is conducting studies of the ecological response of juvenile salmonids and their potential prey resources to natural and alternative management actions at the mouth of Russian River estuary. As described in the 2009-2010 Biological Opinion Annual Report (Manning and Martini-Lamb 2011), this component of the Biological Opinion study is designed to evaluate how different natural and managed ocean entrance (river mouth) conditions in the Russian River estuary affect juvenile steelhead and salmon (predominantly Chinook) foraging and their potential prey resources over different temporal and spatial scales that frame changes in estuarine conditions under different ocean entrance states (open/closed bar).

The study design addresses both: (1) systematic sampling coincident with juvenile salmon entrance to and residence in the estuary, and (2) "event" response to stochastic (and managed) changes in estuary entrance conditions. Systematic sampling is intended to capture the natural ecological responses (prey composition and consumption rate) of juvenile salmon and availability of their prey resources (insect, benthic, and epibenthic macroinvertebrates, and zooplankton) under naturally variable, seasonal water level, salinity, temperature and dissolved oxygen conditions. Event sampling is specifically intended to contrast juvenile salmonid foraging and prey availability changes over short-term estuary closure and re-opening events. Event sampling was initially designed (in 2009) around formation of the barrier beach (closed sandbar) and implementation of the lagoon outlet channel adaptive management plan. However, our sampling of closed events has been limited by the frequency and extent of estuary closures.

We are addressing four component tasks relative to estuary entrance conditions: (1) Diet Composition—documentation of diet composition of juvenile salmonids; (2) Prey Resource Task—assessment of invertebrate (insect, benthos, epibenthos) prey resource availability from representative aquatic and riparian ecosystems and segments of estuary; (3) Zooplankton Response Task—evaluation of zooplankton assemblages and dynamics; and (4) Bioenergetics Modeling and Synthesis—bioenergetic modeling of juvenile salmon performance and synthesis/interpretation. Task 1 is coordinated with the Water Agency sampling of juvenile salmonids in the estuary and our samples derive from their protocols and schedule.

Methods

Sampling Sites

Sampling for fish diet and prey availability was coincident with established Water Agency and other related sampling sites distributed in lower, middle, and upper reaches of the estuary that were established by water quality measurements (dissolved oxygen, temperature and salinity) (Figure 4.2.1; Largier and Behrens 2010). Twelve sites were sampled for juvenile salmon by the Water Agency (see *Beach Seining* Section 4.4 in this report) – (1) River Mouth; (2) Penny's Point; (3) Jenner Gulch; (4) Patty's Rock; (5) Bridgehaven; (6) Willow Creek; (7) Sheephouse Creek; (8) Heron Rookery; (9) Freezeout Bar; (10) Moscow Bridge; (11) Casini Ranch, and (12) Brown's Riffle—of which nine sites (#3-#11) provided juvenile steelhead diet samples. Invertebrate prey availability was sampled at six sites - (1) River Mouth; (2) Patty's Rock; (3) Willow Creek; (4) Sheephouse Creek; (5) Freezeout Creek; and (6) Casini Ranch (excluding insect fallout traps)—where the greatest number of steelhead were caught in each of the three reaches. Analysis is ongoing for samples collected at Patty's Rock and Sheephouse Creek. This report describes results from representative sites in the lower, middle, and upper estuary including the River Mouth, Willow Creek, and Freezeout Creek stations, respectively. In the conclusions and recommendations section of this chapter, we propose a reduction in the number of sampling sites, without loss of spatial resolution in the data, to reduce time required for sample processing and analysis.

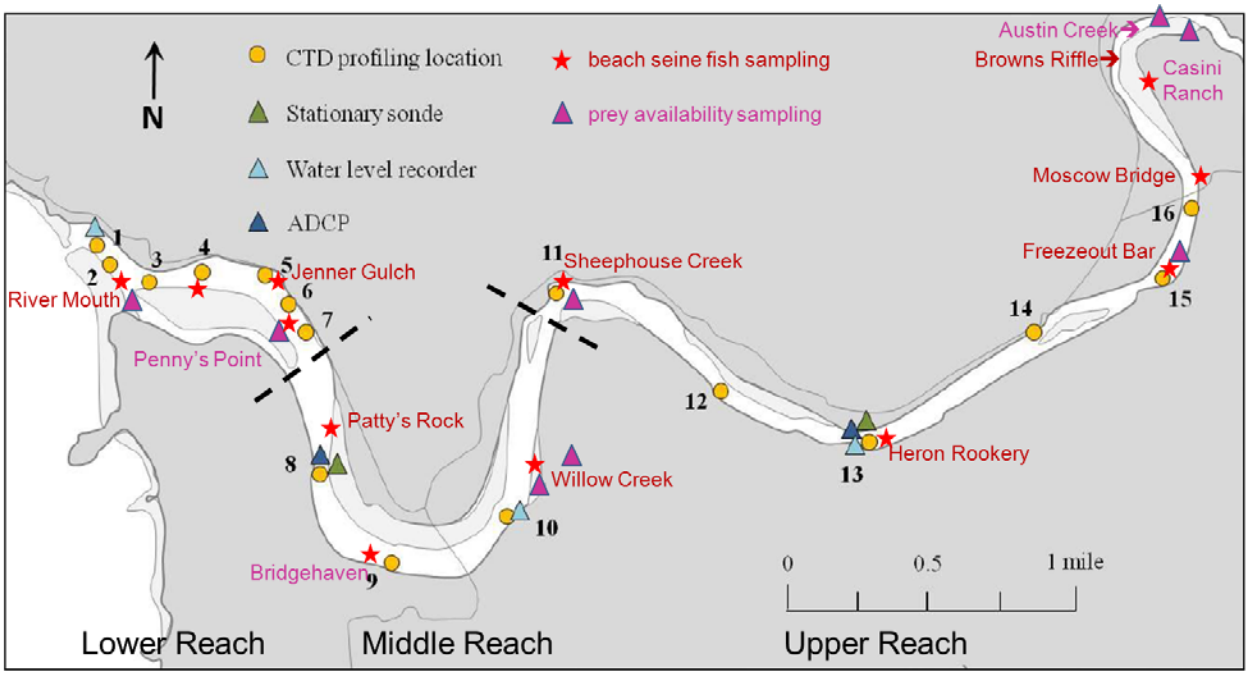


Figure 4.2.1. Locations of sampling stations for juvenile salmon diet (seining location) and prey resource availability (insect fall-out traps, benthic cores; epibenthic net and sled tows; zooplankton net hauls) in three reaches of the Russian River estuary in 2010.

Juvenile Salmon Diet Sampling

Diets of up to ten (although often even the minimum of five fish were difficult to procure) juvenile steelhead and Chinook salmon ≥55 mm fork length (FL) were obtained from the monthly to semi-monthly Water Agency beach seine samples between April 12 and October 21, 2010. The availability of samples was not uniform across the estuary sites and reaches: the largest number of juvenile steelhead between May and July were from sites in the upper reach (especially Heron Rookery and Freezeout), but were distributed more uniformly across the reaches in August and September; Chinook samples originated from predominantly the upper and middle reaches in June and at the mouth of the estuary in July and August. Samples originated predominantly from periods when the estuary was either open (June 7-15; August 12-18; September 13-20) or just opening after a closure (July 12-19), with only one collection explicitly after a closure (October 13-21, after closing October 4). Fish length and weight measurement, tag detection, and stomach lavage and preservation protocols were exactly the same as for the 2009 diet analyses (Manning and Martini-Lamb 2011).

Prey Resource Sampling

In 2010, we conducted prey resource sampling every three weeks, on each week prior to Water Agency beach seine sampling between June 3 and October 12. This corresponded to periods when the estuary was both open (July 6-7, August 9-11, and September 8) and closed (July 6-7, after closing July 4; September 27, after closing September 21; October 12, after closing October 4). In terms of the state of the estuary's tidal exchange, the open periods during sampling spanned tidally-influenced elevations of -0.01 to 0.55 m (-0.04 to 1.82 ft) NGVD (at Jenner gage) while the closed periods encompassed progressively higher water elevations from 1.38 to 2.14 m (4.54 to 7.01 ft) NGVD. The lowest water elevation during closed conditions when we sampled was 2 to 3 days after the estuary closed (July 4), while the highest elevation occurred eight days after closing (October 12).

Sampling design, techniques and protocols for epibenthic organisms (0.5m x 0.25m rectangular net; 106-µm Nitex mesh), benthic infaunal macroinvertebrates (0.0024-m^2 PVC core), emergent and drift insects (51.7 cm x 35.8 cm x 14 cm insect fall-out traps), and zooplankton (vertical water column haul, 0.33-m ring net, 73-µm Nitex mesh) were as described in the 2009-2010 Biological Opinion Annual Report (Manning and Martini-Lamb 2011). In an addition to the sampling design in 2010, we added sampling for epibenthic prey in deeper water (focusing on quantifying mysid occurrence and abundance) using a 0.125-m^2 opening, 1-m long epibenthic sled equipped with 500-µm Nitex mesh; this gear was deployed on five, 10-m transects in the center of the channel, towed parallel and against any current.

Sample Processing and Analyses

Stomach contents from juvenile salmon were processed under the same procedures and protocols as for the 2009 samples, which provided numerical, gravimetric and frequency of occurrence for prey taxa identified to the species, except for insects which were identified to family. Additional data derived from this procedure was relative consumption rate ("instantaneous" ration) for individual fish and a summary total Index of Relative Importance

(%Total IRI) that incorporates all three metrics of prey contribution to the diet. We describe the diet comprehensively as %Total IRI to indicate the relative importance of the three factors but describe differences among fish size intervals, sites and reaches over time in terms of gravimetric composition because of the importance of that variable to fish growth. See the 2009-2010 Biological Opinion Annual Report for further details (Manning and Martini-Lamb 2011).

We also utilized multivariate analyses to organize fish diet sample compositions and prey availability samples into statistically distinct categories. All statistical analyses were performed using the PRIMER v6.0 multivariate statistics analysis package (Clarke and Gorley 2006). These analytical tools, and the PRIMER package in particular, are used extensively in applied ecology and other scientific inquiries where the degree of similarity in organization of multivariate data (e.g., species, ecosystem attributes) is of interest.

Results

Juvenile Steelhead and Chinook Salmon Diet Composition

Overall diet composition of 243 steelhead, varying in length from 59 to 293 mm FL, captured in the estuary between April 12 and October 21, 2010 (Figure 4.2.2), represented a somewhat similar dominance of benthic and epibenthic amphipods (*Ameriocorophium spinicorne*, *Eogammarus confervicolus*) and isopods (*Gnorimosphaeoma insulare*) and early life stages or emerging adult insects (e.g., Ephemeroptera, Chironomidae) as found in 2009. Although they contributed lower proportional biomass and relatively equal numerical composition of the other prominent crustaceans, the >90% occurrence of *A. spinicorne* accounted for the highest %Total IRI in the diet. *G. insulare* and the early life history stages of ephemeropterans (mayflies) and chironomids (midges) were also common prey (45-60% frequency of occurrence) and typically contributed over 10% of the prey abundance and biomass. Mysids contributed just over 10% of the overall biomass of organisms consumed but occurred in only about 25% of the total sample. Unlike in 2009, corixids (water boatmen) and fish larvae contributed little to the overall diet spectrum of juvenile steelhead when we captured them in the estuary.

The diet composition of 51 co-occurring juvenile Chinook salmon 68-132 mm FL caught between June 7 and August 16 suggested more uniform feeding on relatively the same prey taxa (Figure 4.2.3). Ephemeroptera nymphs, *A. spinicorne*, chironomid pupae and mysids all occurred in 70-85% of the samples and contributed 10-25% of the prey abundance and biomass; other prey occurred in fewer fish and typically very little of the total prey biomass. The most notable contrast in diet spectrum between juvenile steelhead and Chinook salmon was the considerably lower contribution of *E. confervicolus* to the Chinook diet, which was only about 40% frequency of occurrence and <10% of the numerical or gravimetric composition.

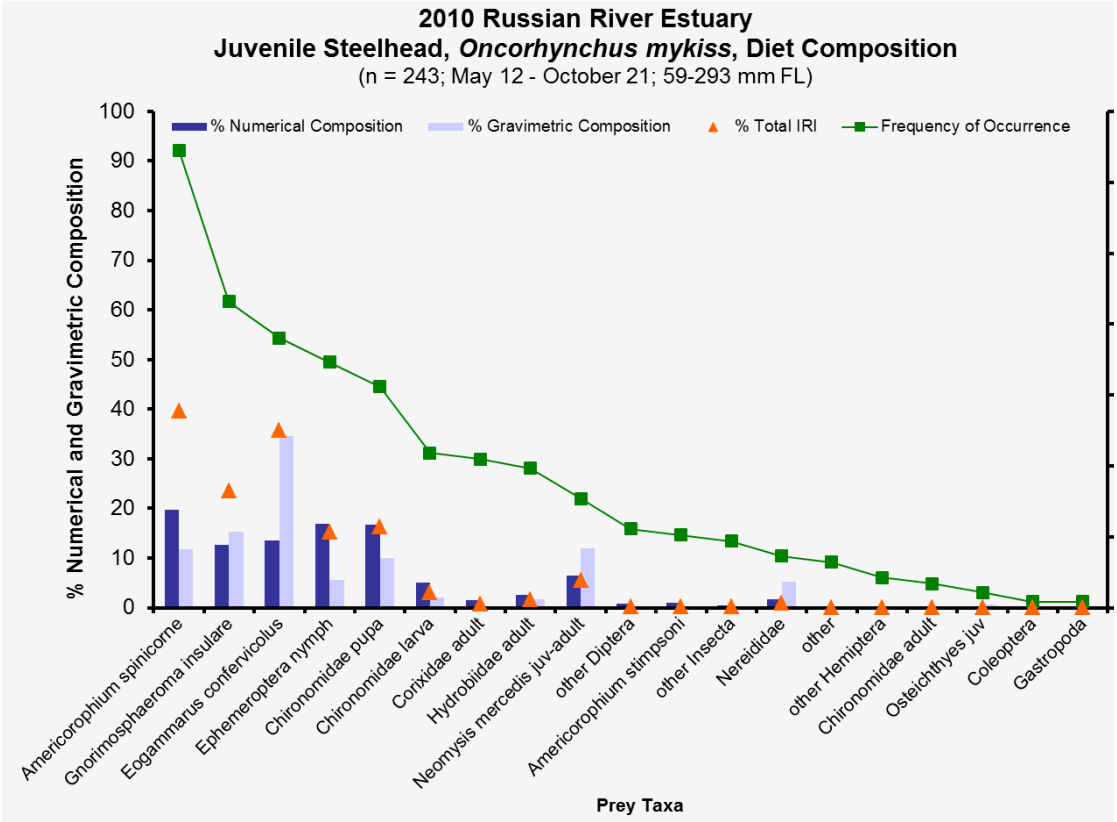


Figure 4.2.2. Index of Relative Importance (IRI) diet composition of juvenile steelhead, 56-293 mm FL, in Russian River estuary, 2010.

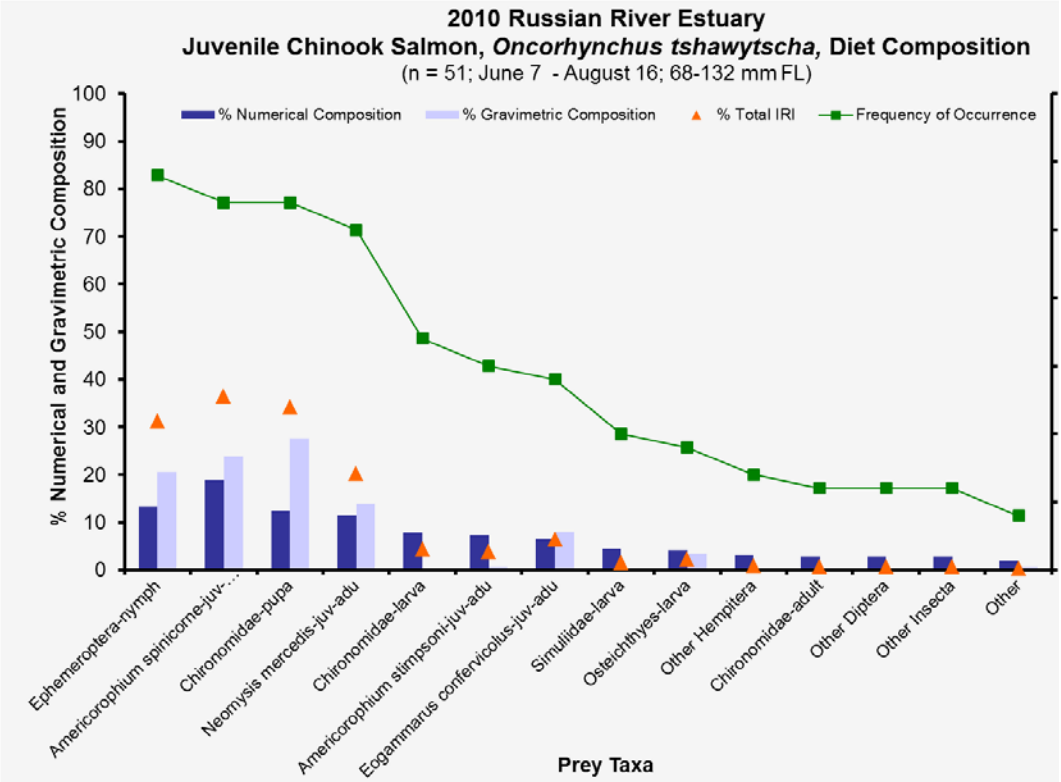


Figure 4.2.3. Index of Relative Importance (IRI) diet composition of juvenile Chinook salmon, 68-143 mm FL, in Russian River estuary, 2010.

Prey composition within each of the three size classes of juvenile steelhead was quite consistent in the lower and middle reaches of the estuary (Figure 4.2.4). Mysids were the most prominent prey of the smallest (<100 mm FL) size class in the lower and middle reaches, as well as the 100-200 mm FL fish in the lower reach. Epibenthic amphipods and isopods (*E. confervicolus, G. insulare, A. spinicorne*) were consistently represented in the diets of the larger size class fish in both the lower and middle reaches. In contrast, juvenile steelhead in the upper reach had more diverse diets comprised of predominantly ephemeropterans and chironomids (particularly within the smallest size interval) but also nereid polychaetes (worms) and other insects.

Temporal variation in the gravimetric composition of juvenile steelhead diets also demonstrates the prevalence of mysids in the lower and middle reaches of the estuary, but predominantly only in July and August, whereas *A. spinicorne*, *E. confervicolus* and *G. insulare* are represented to some degree in all reaches throughout the sampling period (Figure 4.2.5). Except for ephemeropterans, which were prevalent in the upper reach in July and August, insects (particularly chironomids) were most prevalent in the diets of steelhead in the middle and upper reaches in June. Corixids appeared only in small proportion in the middle and upper reaches in July and more prominently in the upper reach in October.

Consistent with findings in 2009, trends in the instantaneous ration (total prey biomass/fish total biomass) of juvenile steelhead among the three estuary reaches in 2010 indicates that 100-200 mm fish had relatively greater foraging success independent of reach but, contrary to the 2009 results, that the upper reach may have been the most profitable in 2010 (Figure 4.2.6). The instantaneous ration ranged from 0.1% to >0.2% prey/fish body biomass for fish <100 and >200 mm FL, but ranged from 0.4% to ~0.8% for 100-200 mm FL fish.

Multivariate (NMDS) analysis of the juvenile steelhead diet composition in the three reaches of the estuary by estuary open/closed status suggested that while there were distinct “groups” of diet compositions, they were associated more with differences among reaches than of differences among the reaches when the estuary was open as compared to when it was closed (Figure 4.2.7).

Somewhat synonymous with juvenile steelhead (Figure 4.2.5), *A. spinicorne*, *E. confervicolus* and ephemeropterans nymphs were most prominent contributors to juvenile Chinook salmon diet composition in the lower and middle estuary reaches in June and July, with a greater contribution of insects in the middle and upper reaches, and mysids appearing increasingly prominent in the diets of fish in the lower reach between June and August (Figure 4.2.8). Larval and juvenile fish (Osteichthys) contributed more to Chinook diets than steelhead, particularly in the lower reach later in the summer.

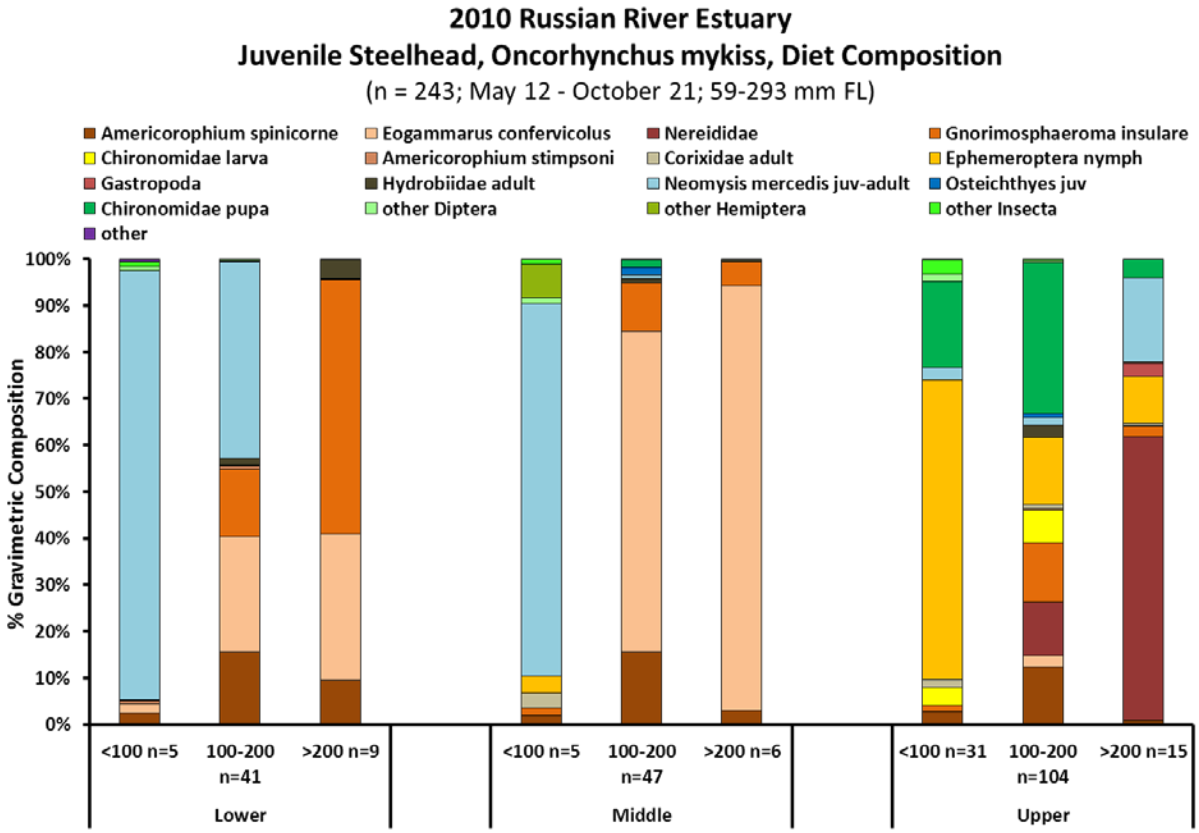


Figure 4.2.4. Gravimetric diet composition (% total prey biomass) of three size classes of juvenile steelhead in the lower, middle and upper reaches of Russian River estuary, 2010.

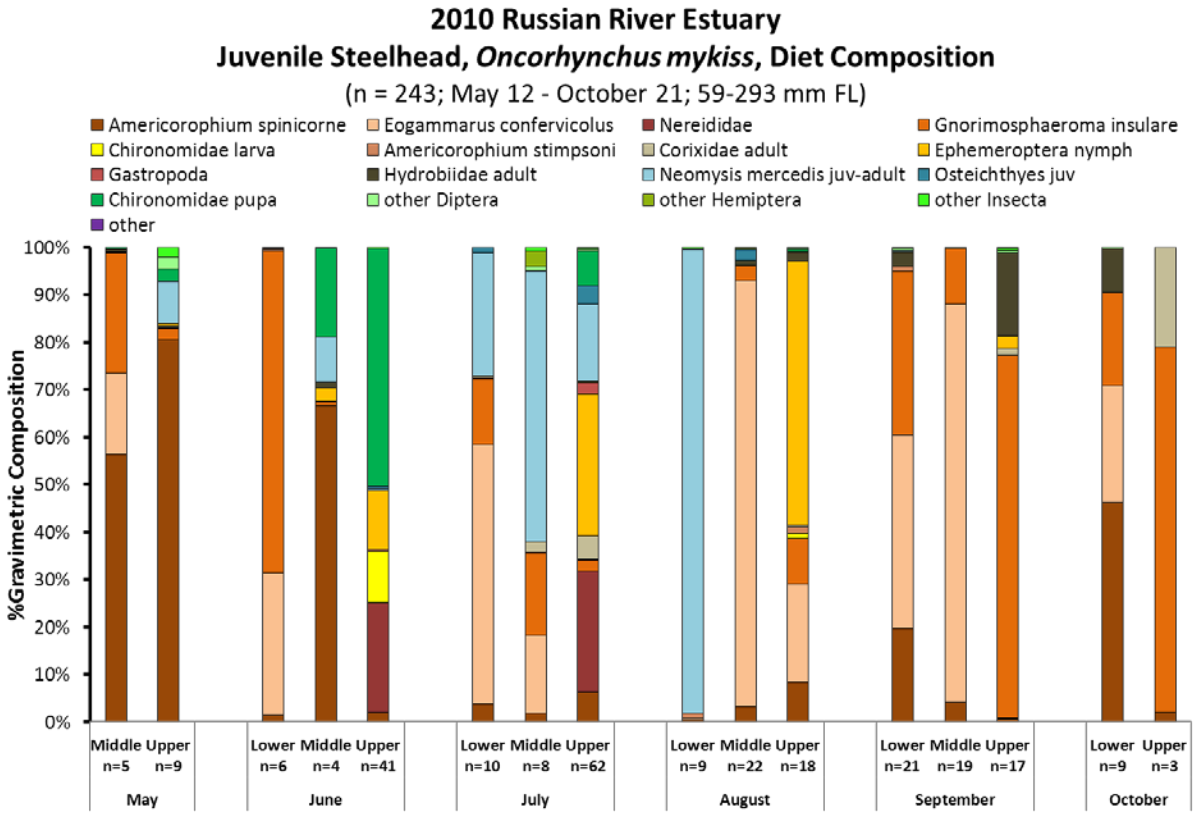


Figure 4.2.5. Gravimetric diet composition (% total prey biomass) of juvenile steelhead by reach over time in Russian River estuary, 2010.

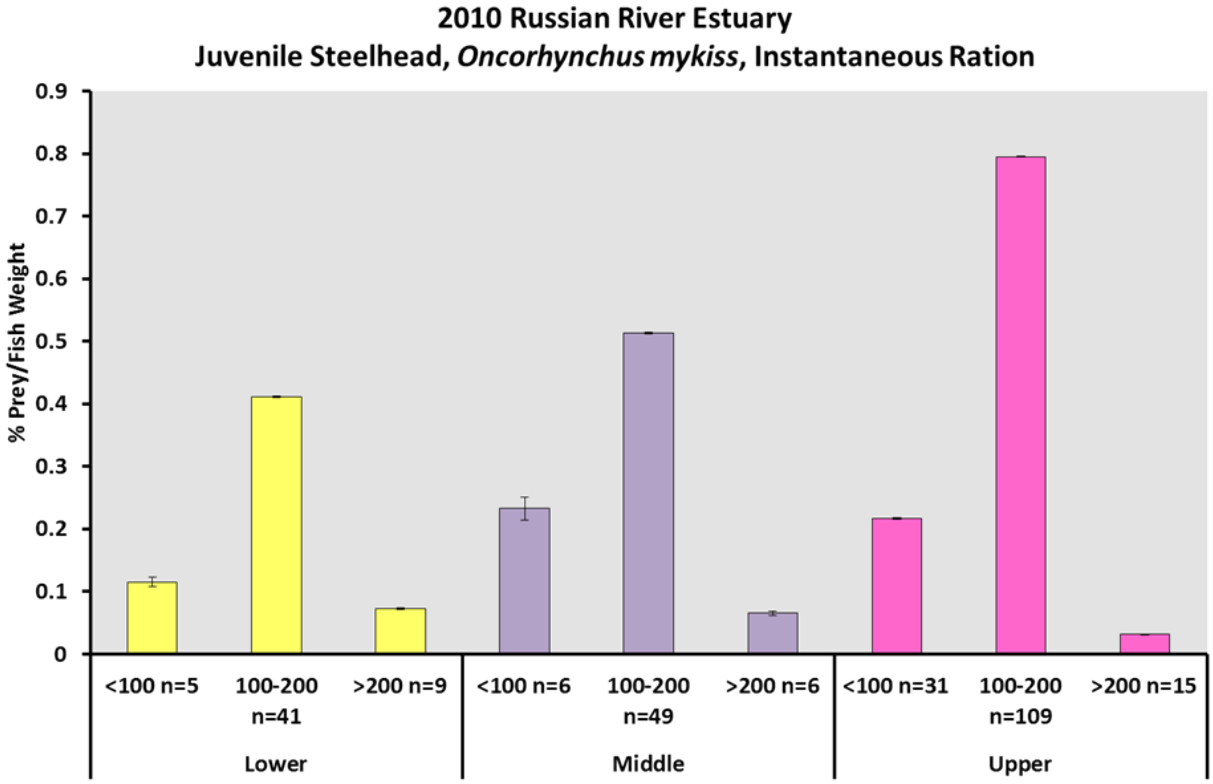


Figure 4.2.6. Instantaneous ration (total prey wt/fish wt) of three size intervals of juvenile steelhead in three reaches of Russian River estuary, 2010.

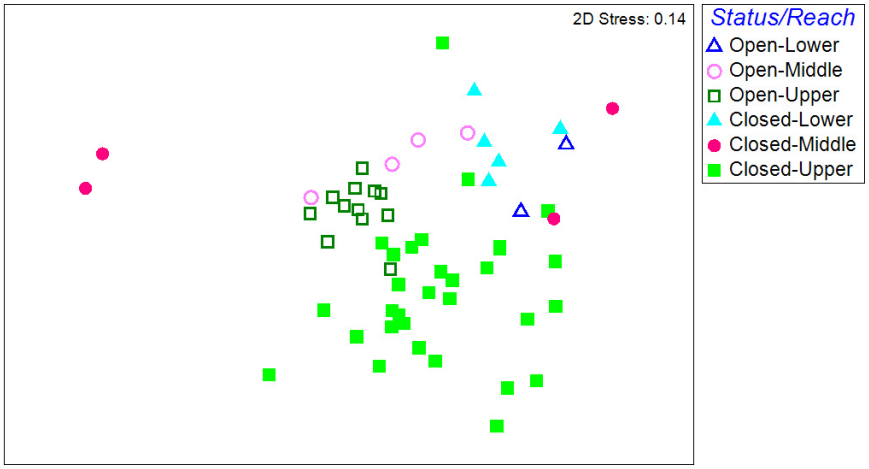


Figure 4.2.7. Primer Non-Metric Multi-Dimensional Scaling (NMDS) plot of diet composition of 100-200 mm FL juvenile steelhead by estuary reach and status (open/closed) in June-July 2010; data points represent individual fish. There is not statistical difference between open/closed (R = 0.30; p = 2%) but a significant difference among reaches (R = 0.52, p = 1%).

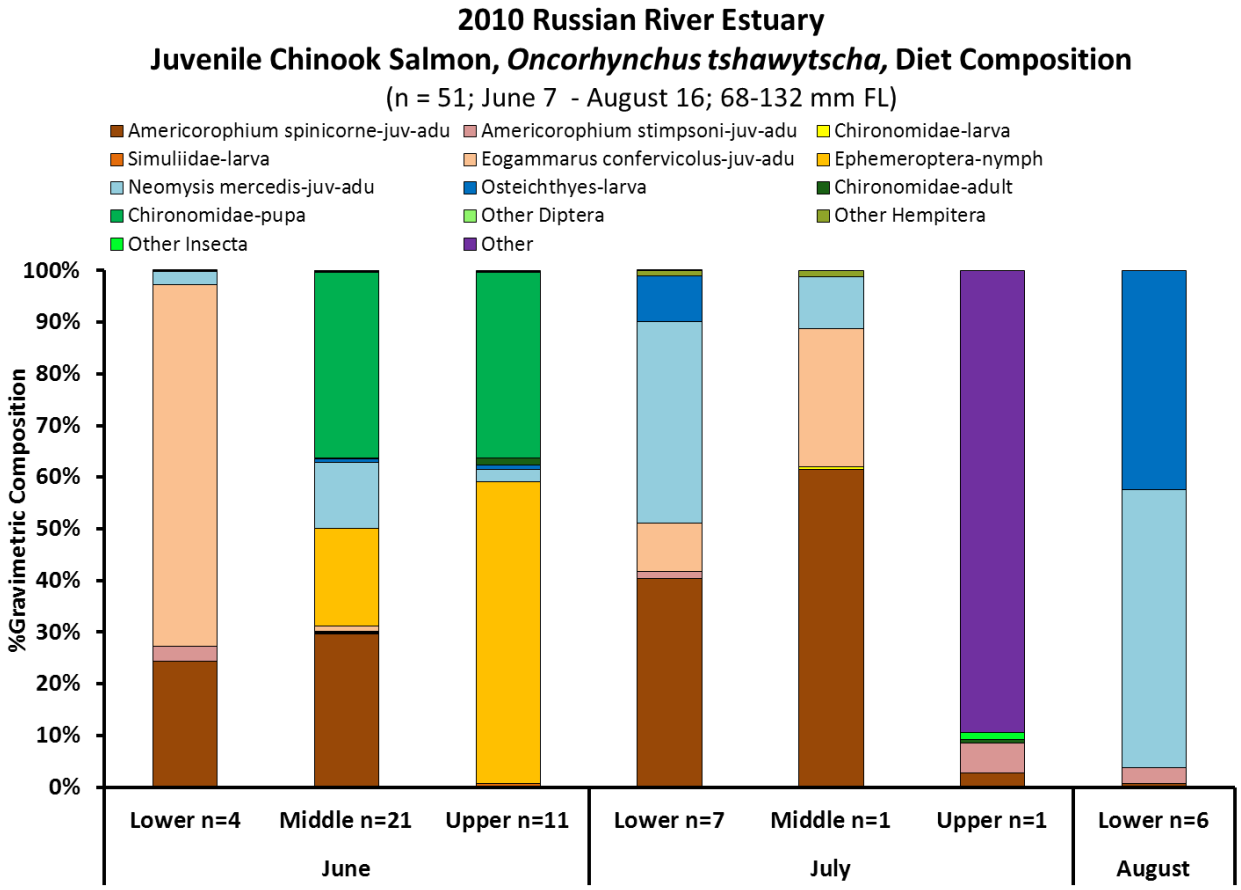


Figure 4.2.8. Gravimetric diet composition (% total prey biomass) of juvenile Chinook salmon in the lower, middle and upper reaches of Russian River estuary in June-August, 2010.

Instantaneous ration estimates for juvenile Chinook salmon among the three reaches over the three months sampling (Figure 4.2.9) suggest, that except for the middle reach in June when 21 fish had consumed approximately 0.4% of their body weight, foraging success was less than that observed for juvenile steelhead. However, the smaller sample sizes for Chinook do not allow for more direct comparison among size intervals, which may clarify the validity of that observation.

Prey Resource Availability

Macroinvertebrates potentially available as prey for juvenile steelhead and Chinook salmon are presented for June through October 2010. In a few cases, not all replicates are represented in these results but the final database will include all available samples as they are completed (by July 2011).

Epibenthos—Epibenthos sampled from the 10-m transects perpendicular to shore indicated distinct assemblages in each of the reaches (Figure 4.2.10), generally reflecting those documented in 2009 and reflecting some of the variation in prey consumed by juvenile

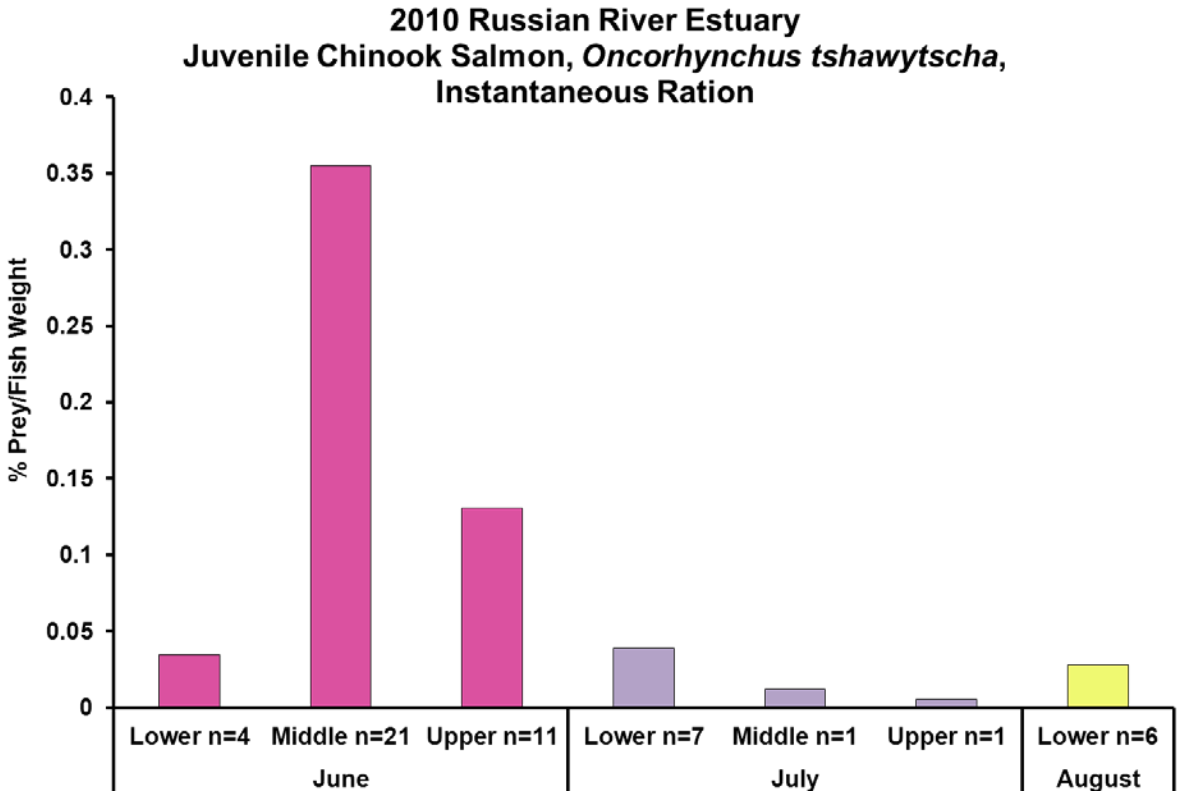


Figure 4.2.9. Instantaneous ration (total prey wt/fish wt) of juvenile Chinook salmon in three reaches of Russian River estuary, June-July, 2010.

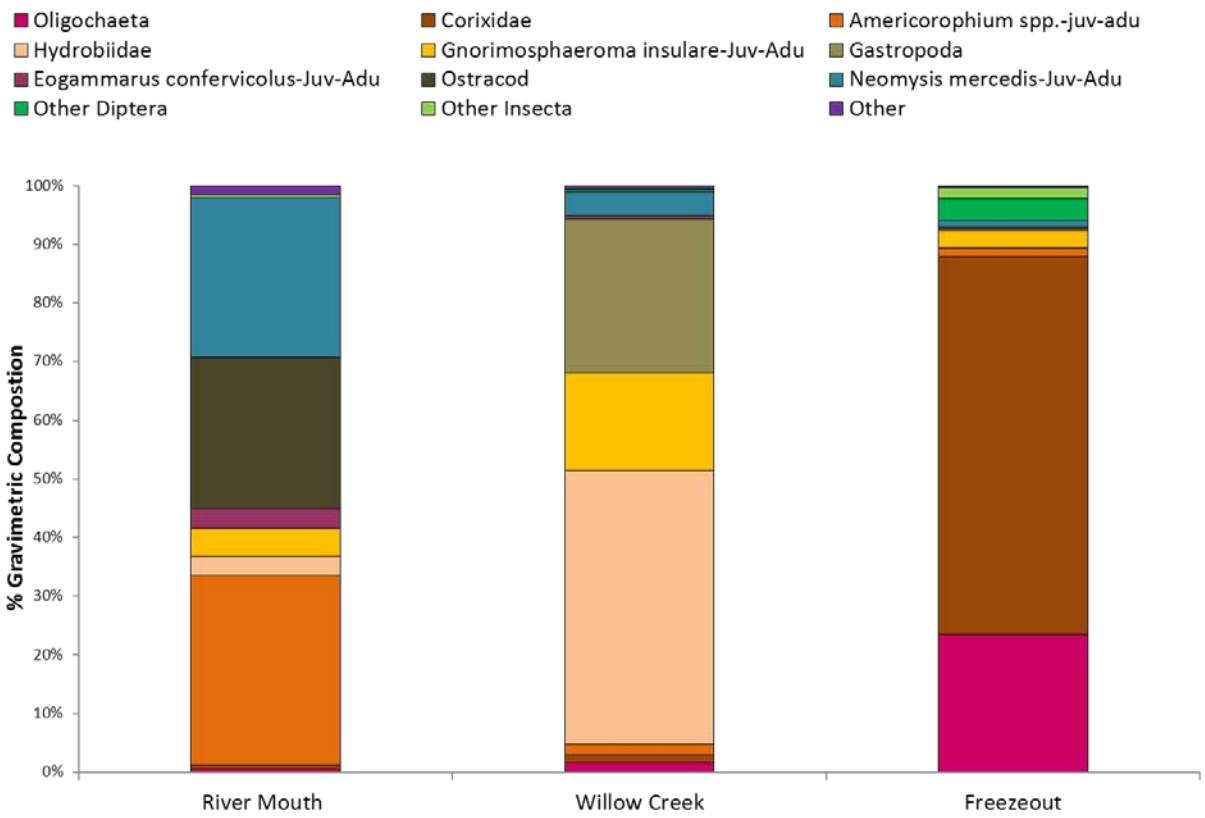


Figure 4.2.10. Numerical composition of epibenthos at three sites representative of lower to upper reaches (left to right), Russian River estuary, 2010.

steelhead and Chinook salmon along the estuarine gradient. *Americorophium* amphipods and mysids combined to contribute over 60% of the organism abundance in the lower reach (River Mouth), while *G. insulare* isopods constituted over half of the organism abundance in the middle reach (Willow Creek). Corixids (water boatman) and oligochaetes dominated the upper reach epibenthos at Freezeout. These upper reach epibenthic organisms, as well as the other dominant organisms in the lower (ostracods) and middle (gastropods) reaches, were not found prominently in the diets of steelhead or Chinook salmon in 2010.

Among the prominent epibenthic prey of juvenile steelhead and Chinook salmon sampled with this technique, *Americorophium* spp. were most dense (>500m^{-2}) in June in the lower reach while *G. insulare* occurred most consistently at high densities (approx. >300m^{-2}) June-September in the middle reach (Figure 4.2.11). *Americorophium* spp. and *G. insulare* were abundant only in August in the upper reach. Mysids occurred in abundance (approx. 150m^{-2}) sporadically throughout all three reaches during all months. There was no obvious pattern in potential prey abundance between open and closed estuary conditions. These distinct assemblage compositions among the three reaches are also substantiated by the NMDS analysis (Figure 4.2.12), which shows stronger association (grouping) of sampling dates within reach than between estuary condition.

Benthic Infauna—As found in 2009 (2009-2010 Biological Opinion Annual Report), the composition of benthic infauna assemblages in 2010 was relatively consistent across the three estuary reaches (Figure 4.2.13). *Americorophium* spp., *G. insulare* and oligochaetes contribute significant proportions of the assemblage biomass across the three reaches, with oligochaetes, *G. insulare* and nematodes decreasing and Hydroibiidae (mud snails) increasing, from the lower to upper reaches.

Given this relatively consistent composition of the benthic infauna across reaches, we pooled samples from across the estuary to explore patterns over time and by estuary open-closed status (Figure 4.2.14). While some of the prominent benthic taxa, such as oligochaetes and *Americorophium* spp., show no consistent temporal or estuary open/closed status trends, there is suggestion that taxa such as *G. insulare* and mud snails are more prominent under open estuary conditions and nematodes and other insects become more prominent under closed conditions.

Mid-channel Epibenthos—The epibenthic sled sampling was primarily designed to evaluate whether mysids and other large epibenthic organisms that are potential prey of juvenile steelhead and Chinook salmon occupied the deeper, higher current environments of the three reaches. These samples revealed that *Americorophium* spp., *G. insulare* and mysids were well represented in the mid-channel (Figure 4.2.15). As found in the other epibenthic sampling in shallow waters, mysids and *E. confervicolus* occurred primarily in the lower and middle reaches and *G. insulare* and *E. confervicolus* in the middle and upper reaches, while *Americorophium* spp. was uniformly distributed across all three reaches.

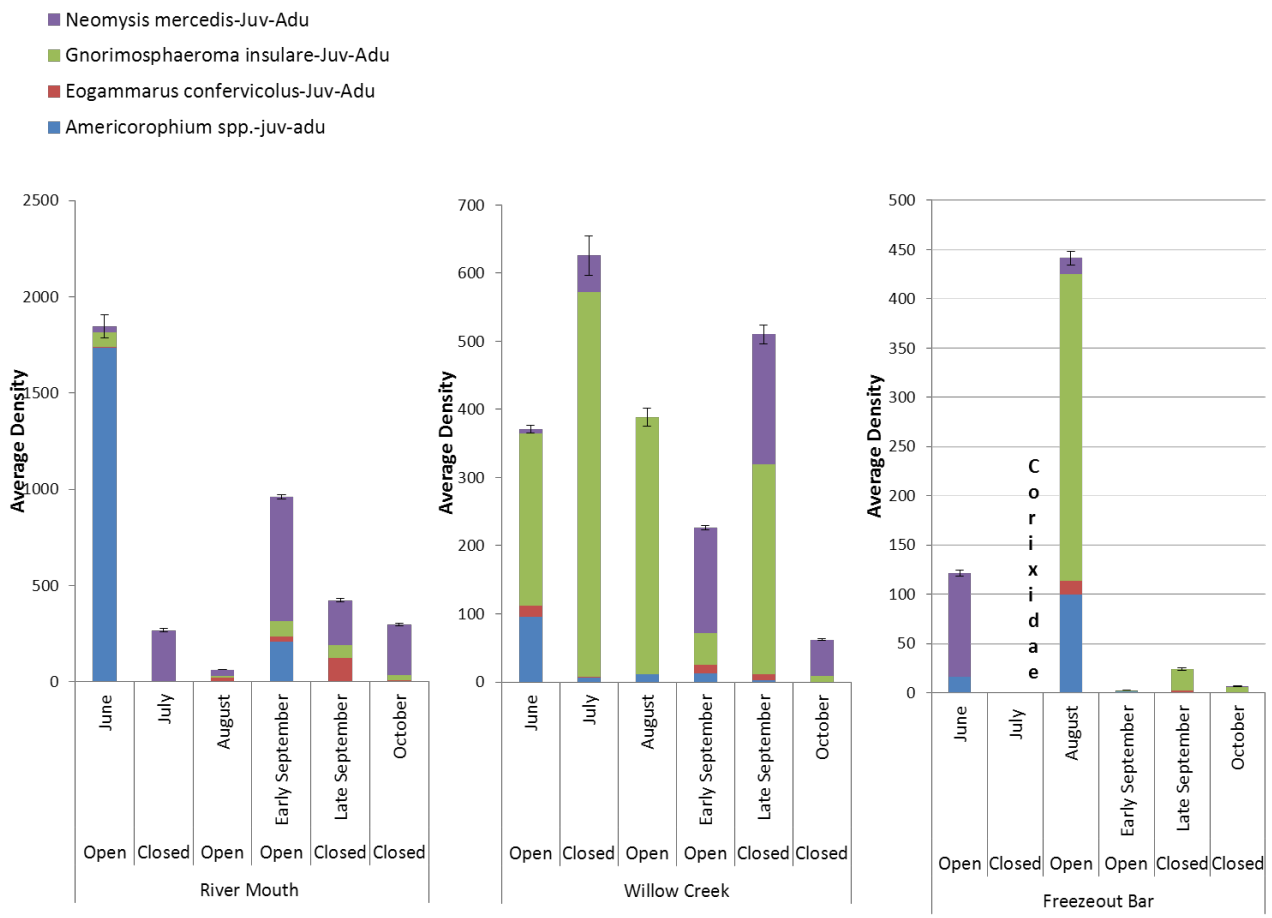


Figure 4.2.11. Density of epibenthic prey taxa at three sites representative of lower to upper reaches (left to right) between June and October, during open and closed mouth conditions, Russian River estuary, 2010.

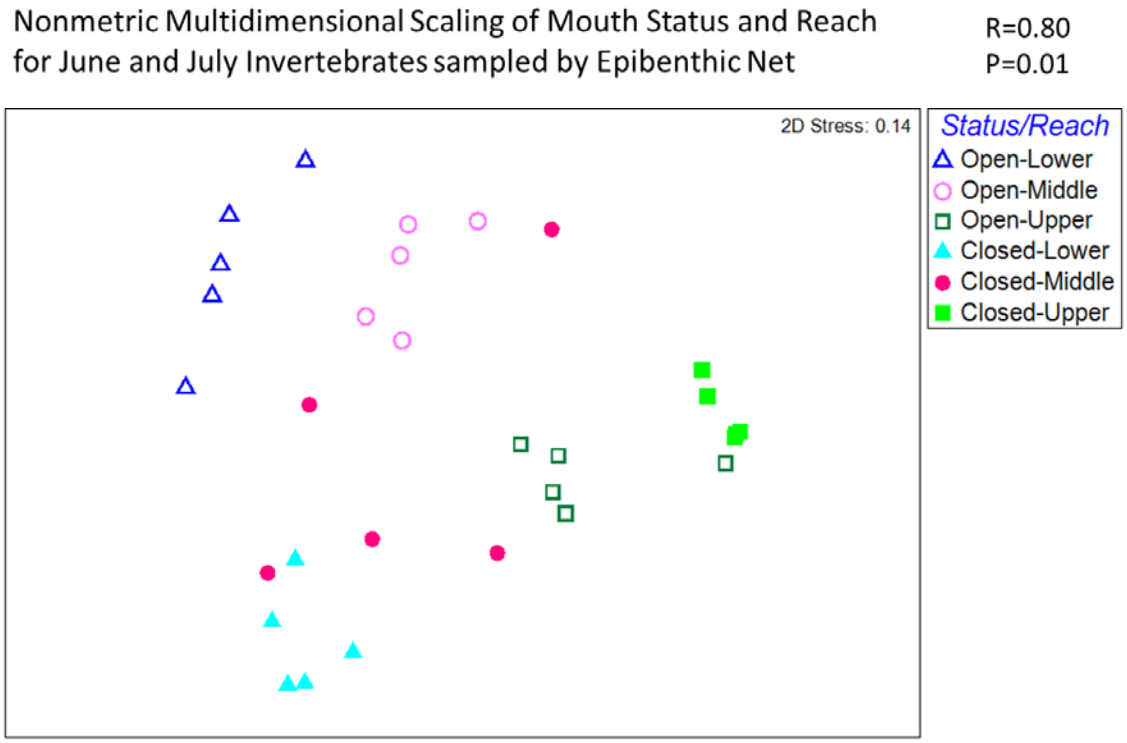


Figure 4.2.12. Primer Non-Metric Multi-Dimensional Scaling (NMDS) plot of epibenthos composition by estuary reach and status (open/closed) in June-July 2010; data points represent means for months. There is a statistical difference among groups (R = 0.80; p = 2%), but not between open and closed estuary conditions.

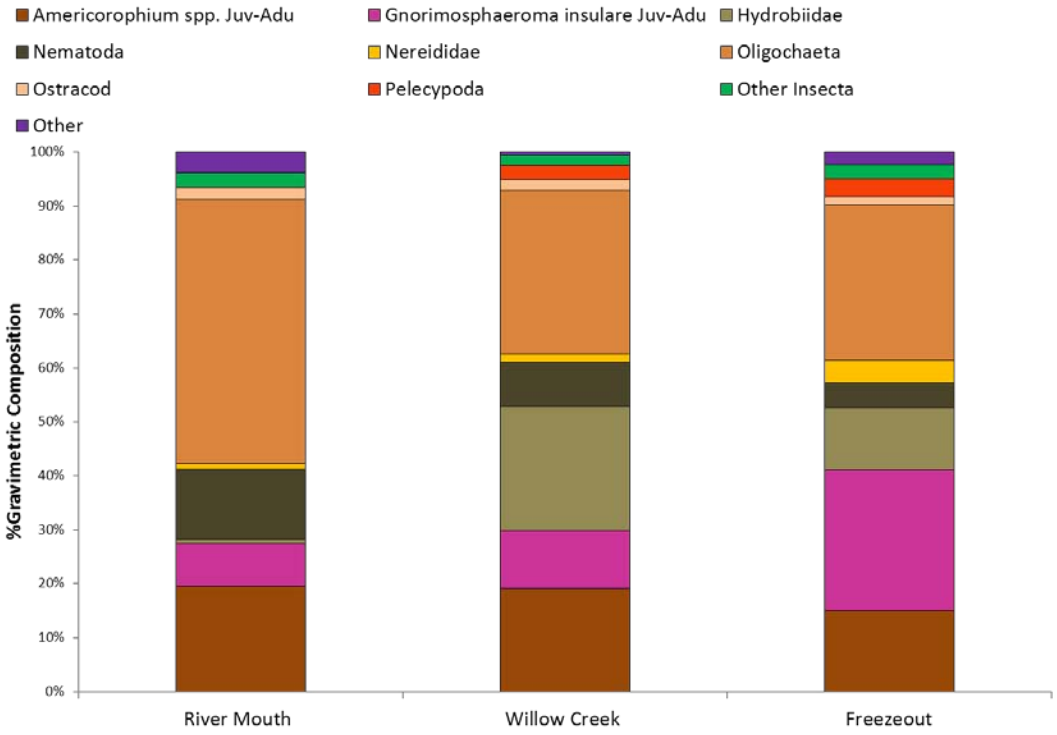


Figure 4.2.13. Gravimetric composition of benthic infauna macroinvertebrates at three sites representative of lower to upper reaches (left to right), Russian River estuary, 2010.

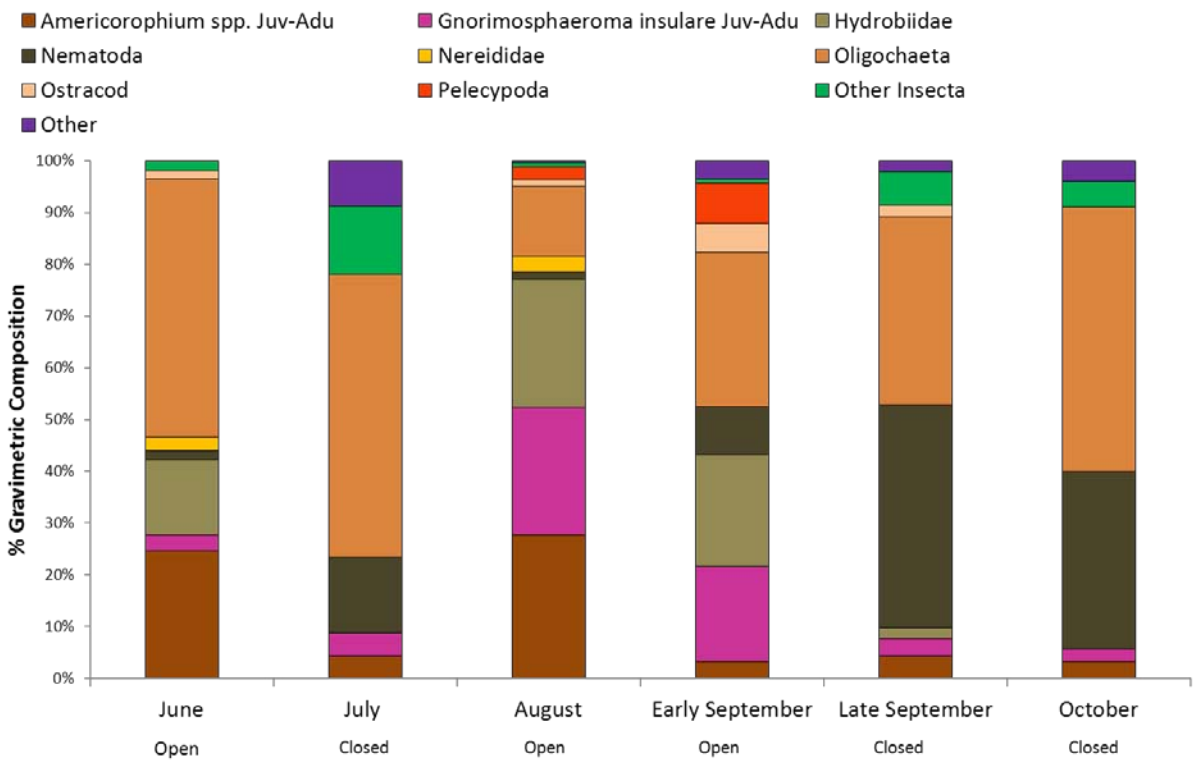


Figure 4.2.14. Gravimetric composition of benthic macroinvertebrates between June and October, during open and closed mouth conditions, Russian River estuary, 2010.

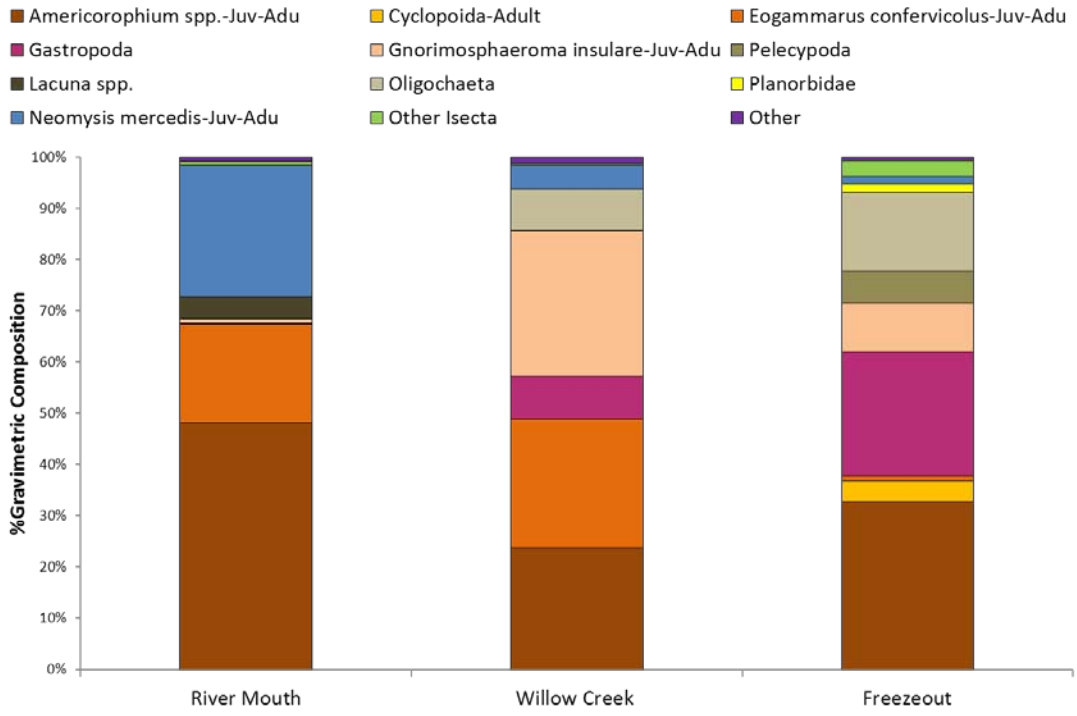


Figure 4.2.15. Gravimetric composition of mid-channel epibenthic macroinvertebrates at three sites representative of lower to upper reaches (left to right), Russian River estuary, 2010.

Densities of prominent prey in the mid-channel habitat were lower and less consistent than in the shallow epibenthos (Figure 4.2.11) and suggested no obvious correspondence to the open/closed condition of the estuary (Figure 4.2.16).

Emergent and Drift Insects—Fallout traps deployed between June and August 2010 indicated extremely consistent composition of the taxa of insects that would be deposited on shallow waters along the estuary (Figure 4.2.17). There was some decrease in the proportional representation by dipterans from approximately 50% of the total numerical composition in the lower reach to <20% in the upper reach, offset by increases in coleopterans (beetles) and hemipterans (true bugs). While the composition of these assemblages was comparable across reaches, the relative densities were higher in the middle reach compared to either the lower or upper reaches (Figure 4.2.18).

Zooplankton—Composition of zooplankton across the three estuary reaches reflects estuarine mixing across that gradient (Figure 4.2.19), from freshwater taxa (represented in green in Figure 4.2.19) in the upper reach to marine-oriented taxa (represented in blue) in the lower reach, and taxa reflecting intermediate salinity (e.g., *Eurytemora affinis*; represented in red) and those tolerant of multiple salinity conditions (represented in black and white) in the middle reach. The prominent estuarine copepod, *E. affinis*, constituted a significant proportion of the zooplankton at Freezeout Creek in early fall. It may be worth noting that on the June 3 and September 8 sampling dates, when the estuary was open, there were higher percentages of more marine plankton than on the other dates at River Mouth.

Comparison of the mean densities of taxa, excluding rotifers and copepod nauplii (not likely to be prey of juvenile salmon) demonstrates that zooplankton populations were lowest in the tidal freshwater reach (Casini Ranch) and the highest consistent densities occurred in the middle reach during closed conditions, when *Eurytemora* dominated (Figure 4.2.20). The highest densities documented, >20,000 m-3, occurred when there were high densities of *Acartia* spp., a coastal marine taxa, on August 9, when the estuary was open.

Conclusions and Recommendations

Juvenile Steelhead and Chinook Salmon Diet Composition

As documented for 2009, epibenthic crustaceans (*Ameriocorophium* spp., *Eogammarus confervicolus*, *Gnorimospheroma* i*nsulare*, *Neomysis mercedis*) and benthic invertebrates (Ephemeroptera nymph), or both (nereid polychaetes; male *Americorophium* spp.) were also the prominent prey of juvenile steelhead in 2010; only corixids (water boatmen) did not appear prominent in their diets in 2010. Juvenile Chinook salmon examined from the same sampling routine in 2010 illustrated the same diet composition; if anything, juvenile Chinook were more specific and consistent in their foraging. Zooplankton did not contribute directly to the diets of either juvenile steelhead or Chinook salmon, but might contribute indirectly as prey of small planktivorous fishes that larger salmonids might feed on (e.g., *Eurytemora*).

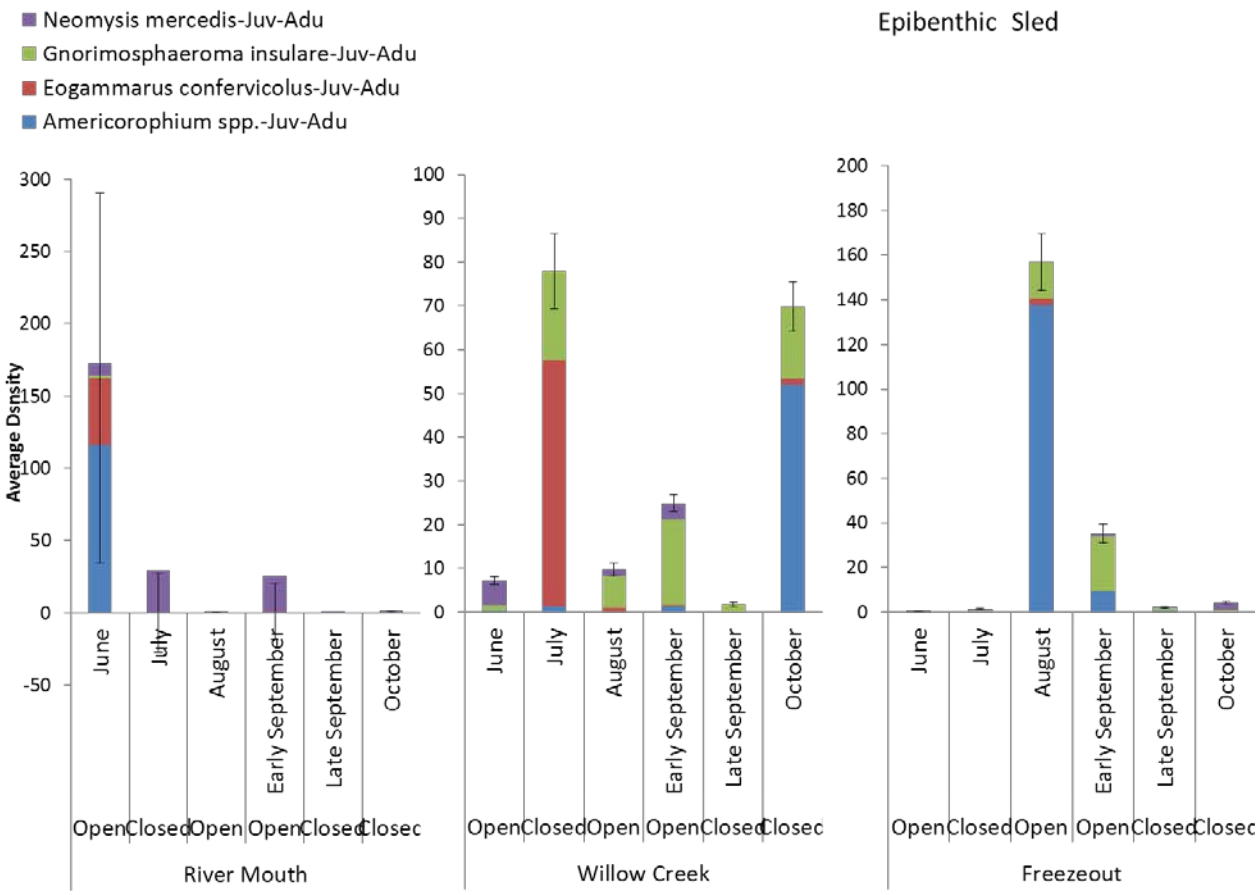


Figure 4.2.16. Density of mid-channel epibenthic prey taxa at three sites representative of lower to upper reaches (left to right) between June and October, during open and closed mouth conditions, Russian River estuary, 2010.

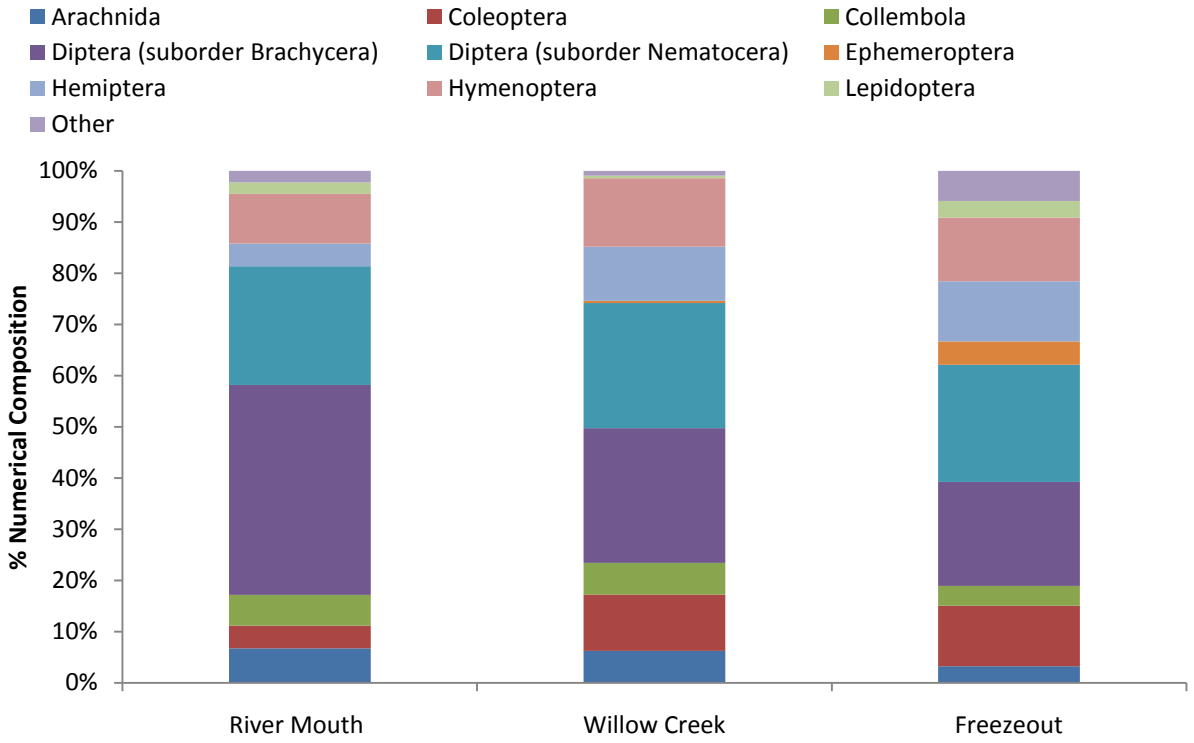


Figure 4.2.17. Numerical composition of invertebrates in insect fallout samples at a three sites representative of lower to upper reaches (left to right), Russian River estuary, 2010.

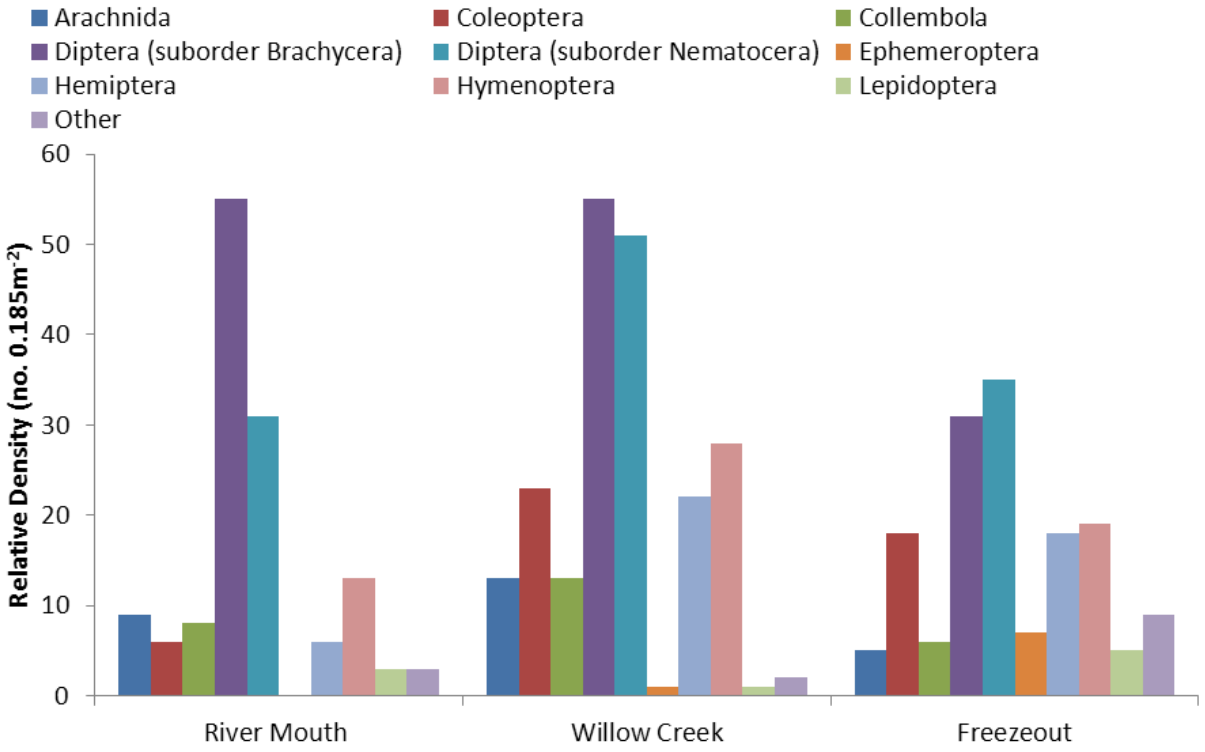


Figure 4.2.18. Relative density of invertebrates in fallout traps at three sites representative of lower to upper reaches (left to right), Russian River estuary, 2010.

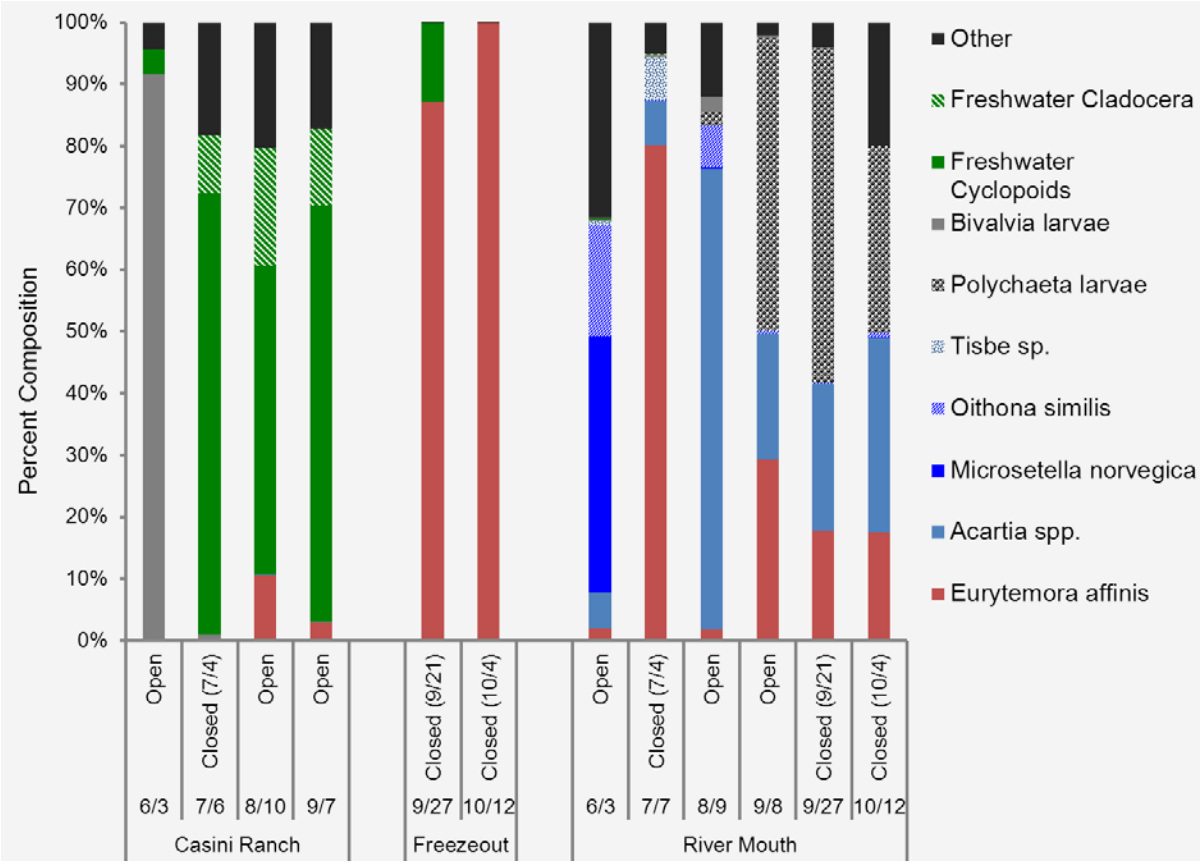


Figure 4.2.19. Percent composition of major zooplankton taxa at three sites representative of upper to lower reaches (left to right), Russian River estuary, June-October 2010.

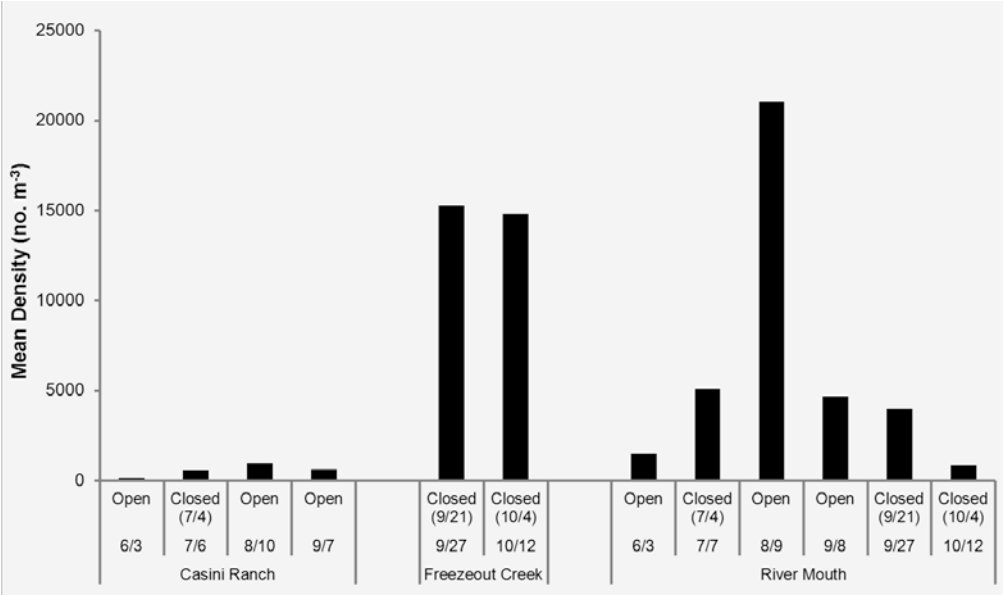


Figure 4.2.20.Cumulative mean densities of major zooplankton taxa, excluding rotifers or copepod nauplii, at three sites representative of upper to lower reaches (left to right), Russian River estuary, June-October 2010.

Prey Availability in Response to Estuary Open/Closed Condition

Many of the prey we documented are motile[9], estuarine tolerant and multivoltine[10]. That is, they maintain populations that can passively or perhaps even actively (by active movement) shift and recolonize with diffusion/advection of waters under open and closed estuary conditions. Mysid distributions appeared to shift into the upper reach when the estuary opened, and concentrate in the lower reach when closed. *E. confervicolus* and *G. insulare* were pervasive in all reaches when closed, perhaps shifting by diffusion.

Although we do not yet have a sampling design that can verify this, many of the epibenthic taxa (e.g., *E. confervicolus*, *G. insulare*, mysids; perhaps even *Americorophium* spp,) may also be able to shift their distributions laterally into the shallows under the increasing water volume and inundation of higher elevations as the estuary fills. Only ephemeropteran nymphs are fixed, freshwater tidal organisms that would be more directly influenced by changing local salinity, temperature and dissolved oxygen regimes.

Considerations and Recommendations for 2011 Sampling

Two modifications are recommended to better determine the effect of estuary opening and closing on predator-prey relationships involving juvenile steelhead and Chinook salmon in the Russian River estuary:

1. Be more reactive to opening/closing events in order to more completely capture any incremental response and change in juvenile steelhead and Chinook salmon diet. Perhaps this can be achieved with more control, especially timing, of the breach?
2. Add integrated sampling across (perpendicular to) the channel to determine uniformity of prey distribution in depth/habitat zones ("hypsometric habitat" sampling) under different water level (estuary open/closed) conditions.

While the first recommendation is contingent on the ability of the field operations to adapt to estuary opening/closing events, based on the results of 2009-2010 prey availability studies, we have adopted a revised sampling design that is intended to detect shifts in prey distribution and numerical response (e.g., population expansions) at three representative positions in the estuary (Figure 4.2.21). The sampling points would be fixed in all cases but would be added at higher intertidal elevations as water rises under continued closed estuary conditions. By this modification, we are redistributing the sampling points spatially but expanding the number of samples within a representative reach site. We have also shifted the zooplankton sampling to correspond to the epibenthos, benthos and insect fallout traps.

[9] Capable of moving spontaneously.
[10] Produce several broods in a year.

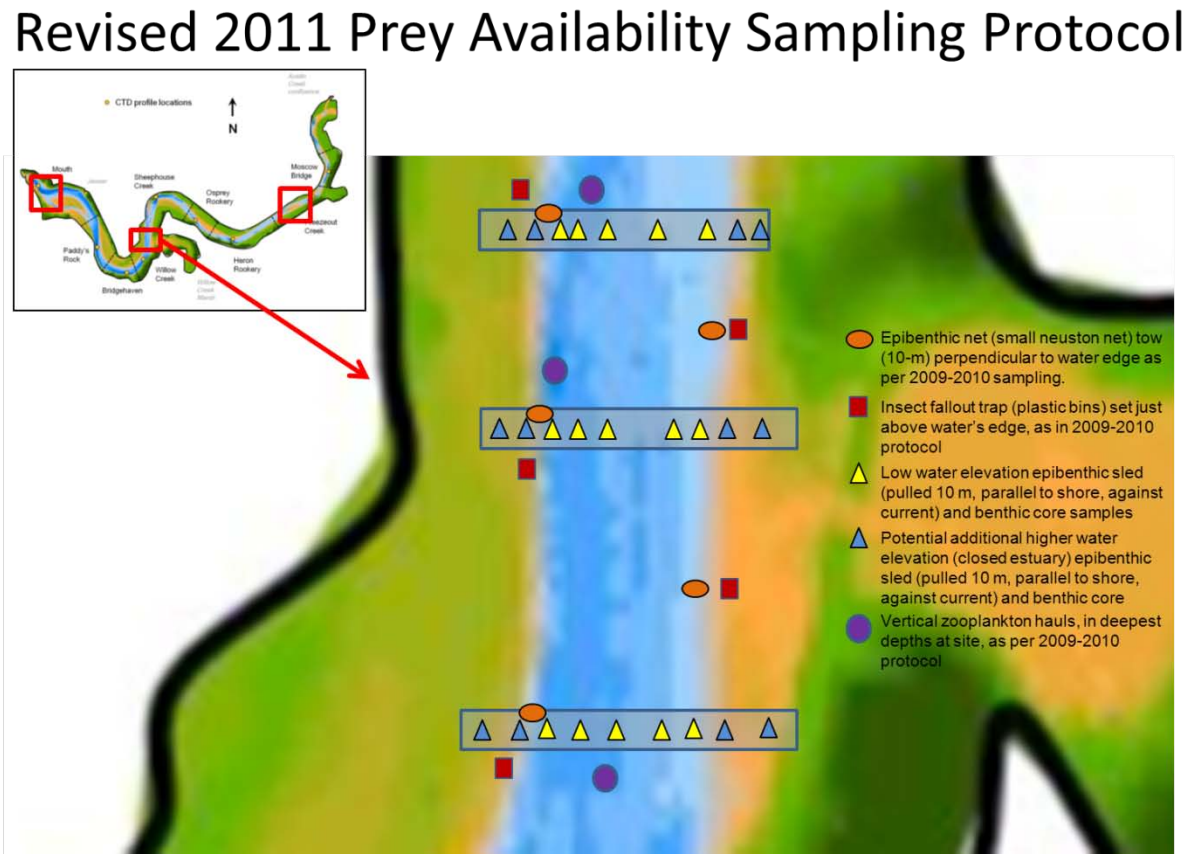


Figure 4.2.20. Proposed alteration of sampling design for juvenile steelhead and Chinook salmon prey availability in the Russian River estuary, June-October 2011.

In additions, our ability to establish the locations (reach, depth) and environmental conditions under which juvenile steelhead and Chinook salmon forage in the estuary is severely constrained by our lack of knowledge of their estuary gradient and depth distributions and movements. The project should continue to pursue the feasibility of using temperature/depth logging acoustic tags on subyearling steelhead as a means to document real-time spatial and water depth/temperature distribution of fish coincident with water quality structure. In combination with linking fish depth/position with an estuarine circulation model for along-gradient advection-diffusion, we could advance considerably our understanding of how prey resource shifts in composition and abundance are exploited by juvenile salmonids under different estuary open/closed conditions.

MS Thesis Research

Erin Seghesio, MS student at the University of Washington, School of Aquatic and Fishery Sciences, has been the lead field and laboratory scientist conducting and overseeing the

research described above. For her MS research thesis, Erin will be adapting the Wisconsin bioenergetics model to develop an energy balance equation. The equation estimates and compares growth given the consumption rate and value of prey over a specific time interval and also accounts for waste losses and metabolic demands that are affected by temperature. This analysis will draw on the 2009 and 2010 fish diet composition and prey availability data to evaluate the hypotheses that:

> H_1: Steelhead will experience increased growth rates with an ephemeral lagoon because of increased foraging space.
>
> HY: Invertebrates would take advantage of newly flooded vegetation and calmer water, and forage on invertebrate prey that move into or are produced in these areas.

References

Clarke, K.R., and R.N. Gorley. 2006. PRIMER v6: User Manual/Tutorial. PRIMER-E, Plymouth, United Kingdom.

Largier, J., and D. Behrens. 2010. Hydrography of the Russian River estuary Summer-Fall 2009, with special attention on a five-week closure event. Unpubl. Rep. to Sonoma County Wat. Agency, Bodega Mar. Lab., Univ. Calif. Davis. 72 pp.

Manning, D. J., and J. Martini-Lamb, editors. 2011. Russian River Biological Opinion status and data report year 2009-10. Sonoma County Water Agency, Santa Rosa, CA. 200 p.

4.3 Downstream Migrant Trapping

An objective of the Biological Opinion is to provide information about the timing of downstream movements of juvenile salmonids, relative abundance, and the size/age structure of the population. The sampling design implemented by the Water Agency and described in this section specifically targets the detection and capture of anadromous salmonid YOY (age-0) parr (≥age-1) (collectively referred to as juveniles) as well as smolts. In order to help accomplish the objectives listed above, the Water Agency undertook a variety of fish detection activities in the estuary at Duncans Mills and at selected sites upstream of the estuary (Austin, Dutch Bill, Green Valley Creeks and the mainstem at Wohler-Mirabel, Figure 4.3.1). Implementation of the monitoring activities described here represent a slight departure from the original RPA in the Russian River Biological Opinion; however, after consultation with NMFS and CDFG all parties agreed to evaluate the approach presented here in 2010. Descriptions and data from other monitoring activities conducted in the estuary (e.g., water quality monitoring, beach seining) as well as fish trapping operations in Dry Creek are presented elsewhere in this report.

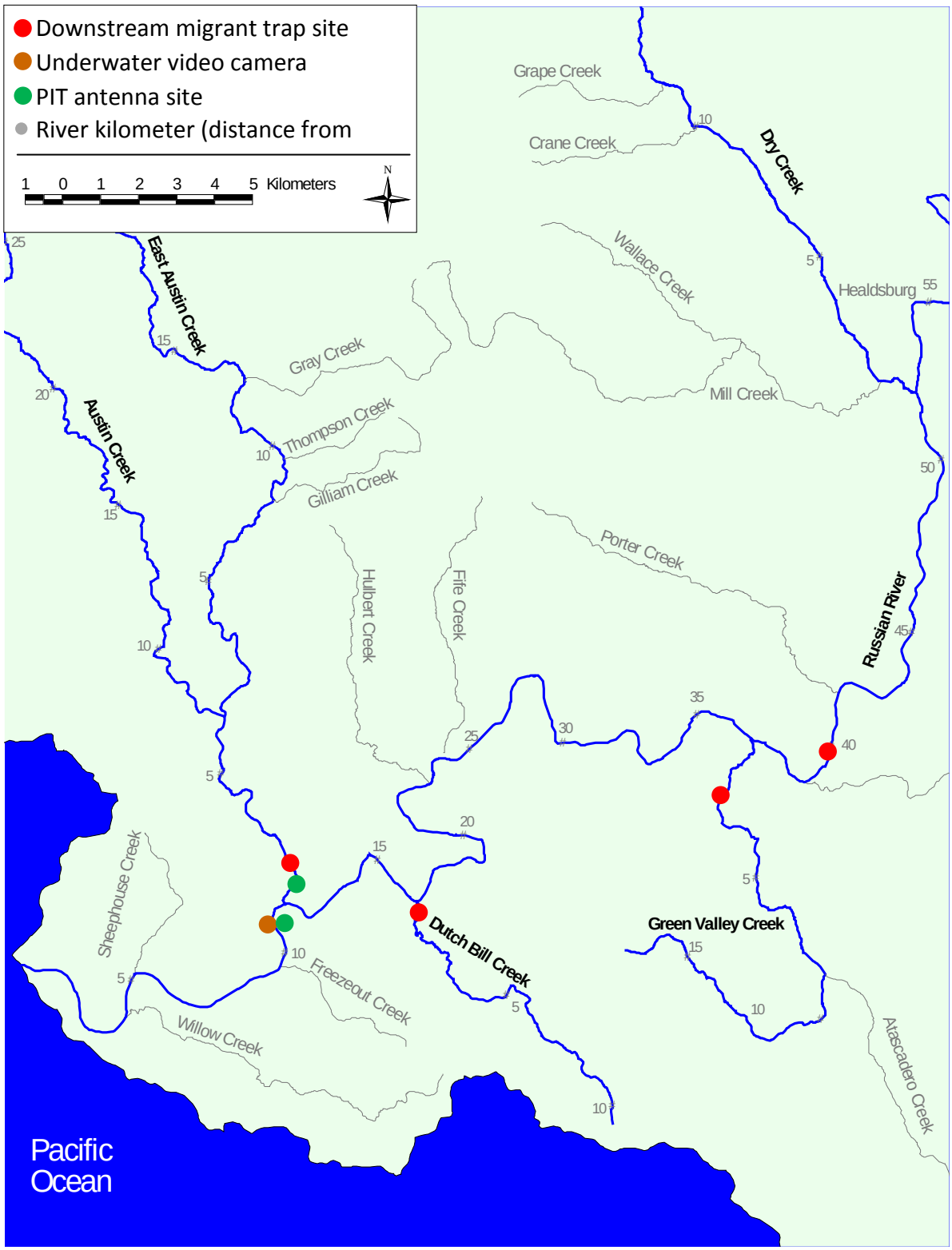


Figure 4.3.1. Location of fyke net video camera system, PIT antennas and lower river fish traps operated to address estuary objectives relevant to NMFS's Russian River Biological Opinion, 2010.

Methods

In 2010, we employed remote monitoring methods at a site where fish were not physically captured (underwater video and PIT antennas were used instead) as well as fish traps at sites where fish were physically captured (rotary screw trap, funnel trap, pipe trap), sampled for biological data and released. In the following sections, we describe the sampling methods and analyses conducted for data collected at each site.

Estuary video camera and PIT tag antenna systems

On May 27, we constructed a fyke net at the same location as the 2009 fyke net on a low gradient riffle between the Cassini Ranch campground and the Moscow Road Bridge at river km 10.5 (Figure 1; see Manning and Martini-Lamb 2011 for details of gear and installation). In 2009, our method of species identification and enumeration relied on physically capturing fish and, when water temperatures allowed ($\leq$21°C), fork length and weight measurements for all salmonids as well as surgical implantation of passive integrated transponder (PIT) tags in steelhead $\geq$75 mm FL. In 2009, we found that relatively warm spring water temperatures, high spring discharge and variable water depths and flow direction associated with tidal movements precluded effective trap operation during much of the 2009 trapping season. Furthermore, there was evidence that a significant level of escape from the trap back upstream through the entrance by salmonids and within-trap predation on salmonids occurred in 2009 (Manning and Martini-Lamb 2011). For these reasons, in 2010 the Water Agency abandoned the sampling plan of trapping and handling fish at the fyke net location and instead turned to evaluating the effectiveness of monitoring methods that obviated the need to trap and handle fish.

The remote monitoring systems we installed were an underwater video system and PIT antenna on the cod end of the fyke net. This allowed fish to freely move through a viewing chamber which allowed us to identify fish to species and life stage on video footage as well as detect PIT-tagged fish from upstream locations as they moved downstream through the PIT antenna (Figure 4.3.2). Date, time and direction of movement (upstream or downstream) was noted for each fish observed passing through the viewing chamber. Because we relied on the video footage for species identification and because the video images were of variable quality, we adopted a system of rating the certainty of species identification for each individual. The rating was dichotomous indicating a high or low level of confidence. In order to estimate fish lengths from the video footage, vertical lines spaced 10 mm and 50 mm apart were drawn on the viewing chamber so that lengths could be estimated from the line spacing (Figure 4.3.2). The video camera and PIT antenna were operated 24 hours a day during the trapping season except for brief periods when the camera was inoperable. In all other ways, the construction of the fyke net was very similar to 2009 (see Manning and Martini-Lamb 2011 for details).

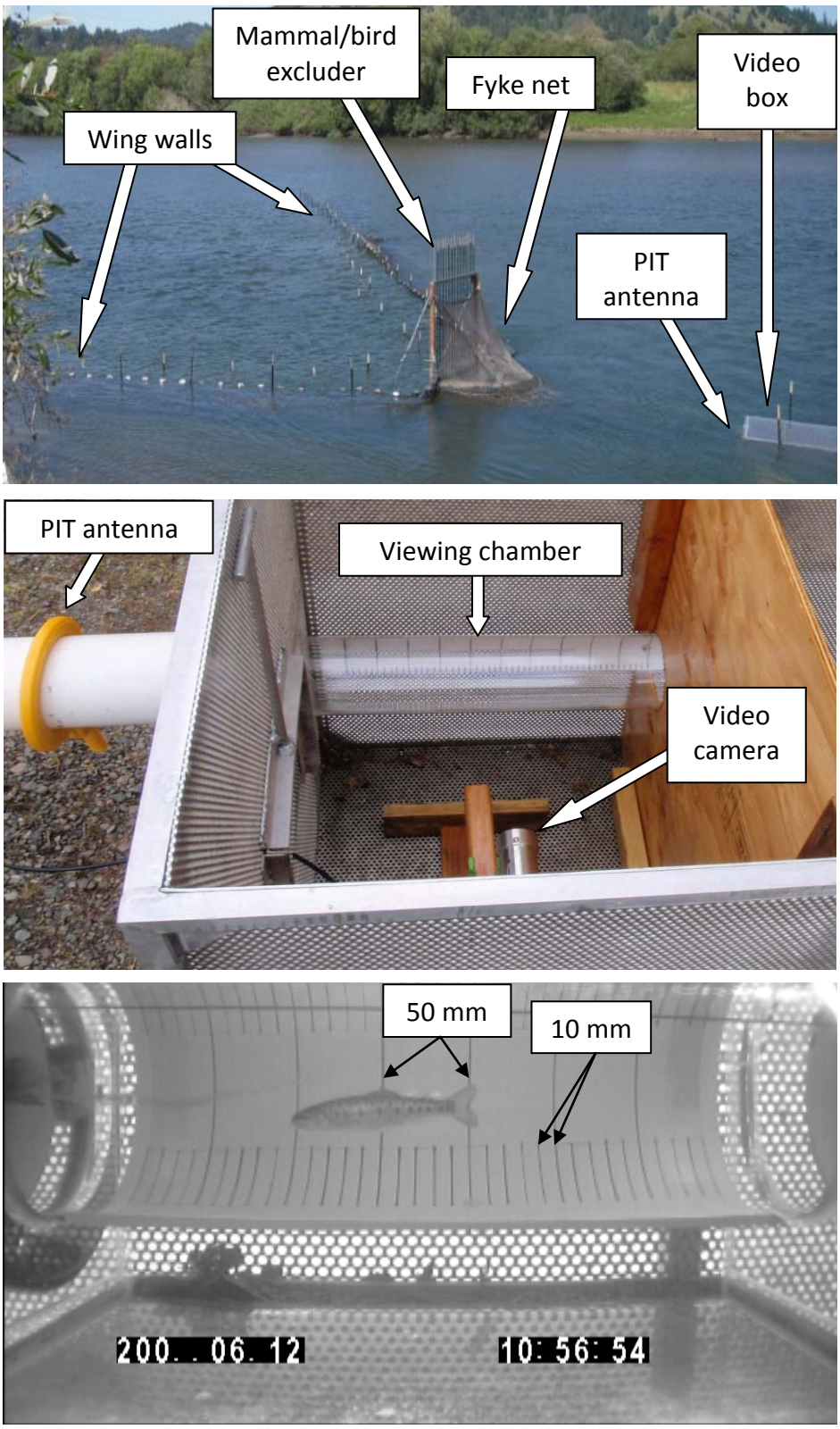


Figure 4.3.2. Video box, PIT antenna and example image from continuous underwater video footage at Duncans Mills fyke net location (RiverKm=10.5), 2010.

Lower River fish trapping and PIT tagging

As a result of consultation with NMFS and DFG, the Water Agency identified 3 lower River tributaries (Austin Creek, Dutch Bill Creek, Green Valley Creek) in which to operate fish traps as a way to supplement data collected from the PIT antenna and video monitoring system at the estuary fyke net. In 2010 the Water Agency operated three types of downstream migrant traps in these tributaries; a rotary screw trap, funnel traps and pipe traps (Figure 4.3.3). In addition, juvenile steelhead were captured and PIT-tagged at the Water Agency's downstream migrant trapping site at Wohler-Mirabel; this resulted in a total of four possible sources of PIT-tagged fish that we could monitor as they entered and resided in the estuary. Water Agency rotary screw trap methods are detailed in Chase (2005) and Manning and Martini-Lamb (2011). For detailed methods on pipe and funnel net trapping in Russian River tributaries see Obedzinski *et al.* (2006, 2007, 2008).

Fish traps located near the mouth of Austin and Dutch Bill Creeks were operated and checked daily by Water Agency staff during the trapping season (April through July). Data from a trap operated on Green Valley Creek were collected by the University of California Cooperative Extension (UCCE). Captured fish were enumerated and identified to species and life stage at all traps. Fork length ($\pm$1 mm) and weight ($\pm$0.1 g) were measured on a subset of individuals each day. PIT tags were implanted in a portion of steelhead non-smolts $\geq$60 mm in fork length.

Rotary screw trap on Austin Creek (operated by the Water Agency)

Pipe trap on Dutch Bill Creek (operated by the Water Agency)

Funnel net on Green Valley Creek (operated by UCCE)

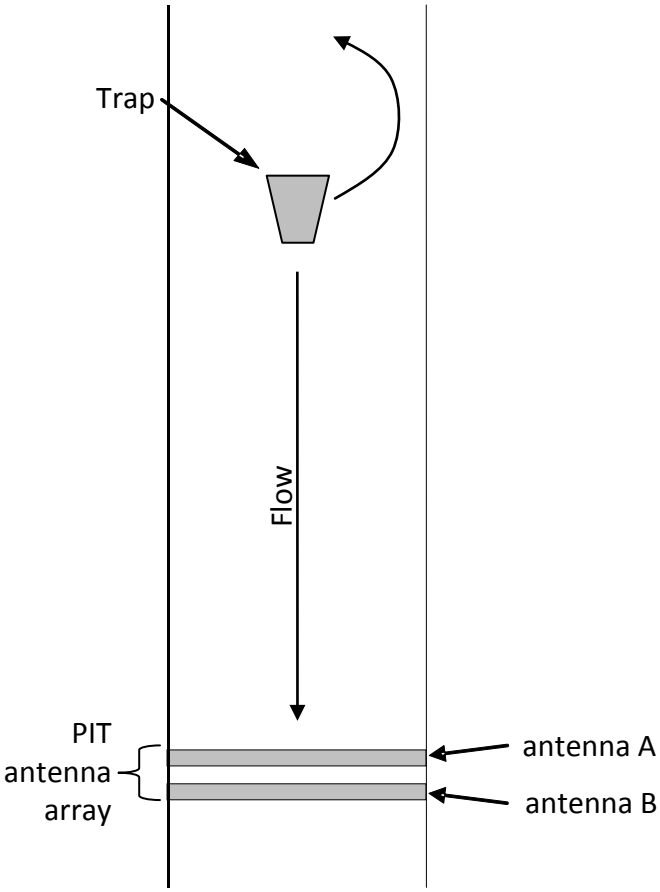
Figure 4.3.3. Photographs of downstream migrant traps operated by the Water Agency (Austin Creek and Dutch Bill Creek) and the University of California Cooperative Extension (Green Valley Creek). The Green Valley Creek photograph is courtesy of UCCE.

Austin Creek- A rotary screw trap was installed on Austin Creek on April 15. On May 3, wood-frame/plastic-mesh weir panels and a metal-mesh ramp were installed to direct fish into the screw trap. By late June, the rotary screw trap was not fishing effectively due to low stream velocities; therefore, on June 23 we replaced the screw trap with a funnel trap that was fished until the completion of trapping operations on July 19. The funnel trap consisted of wood-frame/plastic-mesh weir panels, a funnel net and a wooden live box; it was located on a riffle approximately 200 m downstream of the rotary screw trap. Trapping continued until surface flow in Austin Creek was no longer contiguous and daily catches of steelhead dropped rapidly.

A portion of the steelhead PIT-tagged at the Austin Creek fish trap were released upstream of the trap in order to estimate trap efficiency. Trap efficiencies are commonly calculated by releasing fish that are highly motivated to move downstream (e.g., smolts) upstream of a fish trap (Bjorkstedt 2000). Because not all juvenile steelhead are necessarily motivated to move downstream, this is not necessarily a suitable life stage to use for estimating trap efficiency. Therefore, although failure to recapture a juvenile steelhead released upstream of the trap may be due to trap inefficiency (e.g., fish passage but failure to capture), it may also be due to some fish remaining upstream of the trap where it may take up residence or die.

To help distinguish between failure to capture due to trap inefficiency vs. failure to re-emigrate, a dual antenna PIT antenna array was installed on May 18 approximately 0.6 km downstream of the rotary screw trap in order to detect PIT-tagged steelhead. The PIT tag antenna array was located approximately 0.5 km from the mouth of Austin Creek just upstream of the area that can be inundated by the Russian River during closure of the barrier beach; therefore, we assumed that once fish passed the antenna array they had effectively entered the estuary/lagoon.

To gain estimates of the number of fish emigrating from Austin Creek, weekly trap efficiencies were calculated by using the total number of PIT tagged steelhead that were released upstream of the trap, recaptured in the trap and detected on the downstream antennas. Because the antenna array consisted of two antennas, we could estimate antenna efficiency using a similar approach (Figure 4.3.4; Zydlewski et al. 2006).



1. Methods:
Capture and PIT-tag juvenile steelhead, then release newly tagged fish upstream while releasing previously-tagged fish (recaptures) downstream.

2. Estimating trap efficiency:
Of the PIT-tagged fish released upstream of the trap, how many were recaptured in the trap before being detected on the downstream antenna array?

3. Estimating antenna efficiency:
Of the fish PIT-tagged fish detected on the downstream antenna in the array (antenna B), how many were also detected on the upstream antenna (antenna A).

Figure 4.3.4. Diagram illustrating the relative location of the downstream migrant trap and PIT antenna array operated on Austin Creek in 2010 and outline of how trap and antenna efficiencies were estimated.

Dutch Bill Creek- A funnel trap was installed on Dutch Bill Creek adjacent to the park in downtown Monte Rio (approximately 0.3 km upstream of the creek mouth) on April 20. By mid-may, stream velocity and depth resulted in decreased effectiveness of the funnel trap; therefore, on May 11 we replaced the funnel trap with a pipe trap that was fished until the completion of trapping operations on July 13 when stream flow in lower Dutch Bill Creek became disconnected.

Green Valley Creek- A funnel trap was installed on Green Valley Creek approximately 2.1 km upstream of the mouth on March 18. The data were provided by UCCE who installed and operated this trap as well as a second trap located 9.3 km upstream of the mouth (the data from the upper trap are not reported here). Details of trapping operations will be reported by UCCE.

Mainstem Russian River at Wohler- A rotary screw trap was operated on the mainstem Russian River immediately downstream of the Water Agency's inflatable dam site at Wohler-Mirabel (approximately 39.7 km upstream of the river mouth) from May 3 to July 16. The purpose of this trap was to fulfill a broader set of objectives in the Biological Opinion than what

is described in the current section of this report. However, one of the objectives was to provide a source of PIT-tagged steelhead juveniles that may enter the estuary and be detected during downstream monitoring efforts. Therefore, in this chapter we report the number of steelhead that we applied PIT tags to at the Wohler-Mirabel downstream migrant trapping site. Other details on the methods and results of the Wohler-Mirabel fish trapping effort in 2010 are detailed in the Mirabel downstream monitoring section of this report (Chapter8.3).

Results

In 2010, we learned that the fyke net and video monitoring equipment could be safely installed and operated when flows at Hacienda Bridge (USGS gauge 11467000) dropped below 1000 cfs (Figure 4.3.5). The video camera recorded footage 24-hours per day through July 31, with the following exceptions; from May 29, 2010 through May 30, 2010 when turbidity was too high to detect fish and from June 2, 2010 through June 5, 2010 when the camera was damaged and out for repair (Figure 4.3.5). Compared to 2009, the fyke net video camera system was installed later in 2010 due to high stream flows, but operated 21 days longer because operation of the remote monitoring systems was not hindered by elevated water temperatures. We were also able to operate both remote monitoring systems during closure periods (Figure 4.3.5) unlike 2009 when water depth during closure approached 3 meters and was much too deep to effectively trap.

Because of high flow conditions in 2010, downstream migrant traps in lower river tributaries could not be installed until mid-April to early-May with the exception of Green Valley Creek (Table 4.3.1). Therefore only a portion of the downstream migrant season for salmonid smolts was sampled. However, traps at all sites were operated for a high proportion of the juvenile steelhead movement period (Figure 4.3.6). Water temperatures in the tributaries were low enough to safely handle and PIT tag fish throughout the 2010 trapping season (Figure 4.3.6).

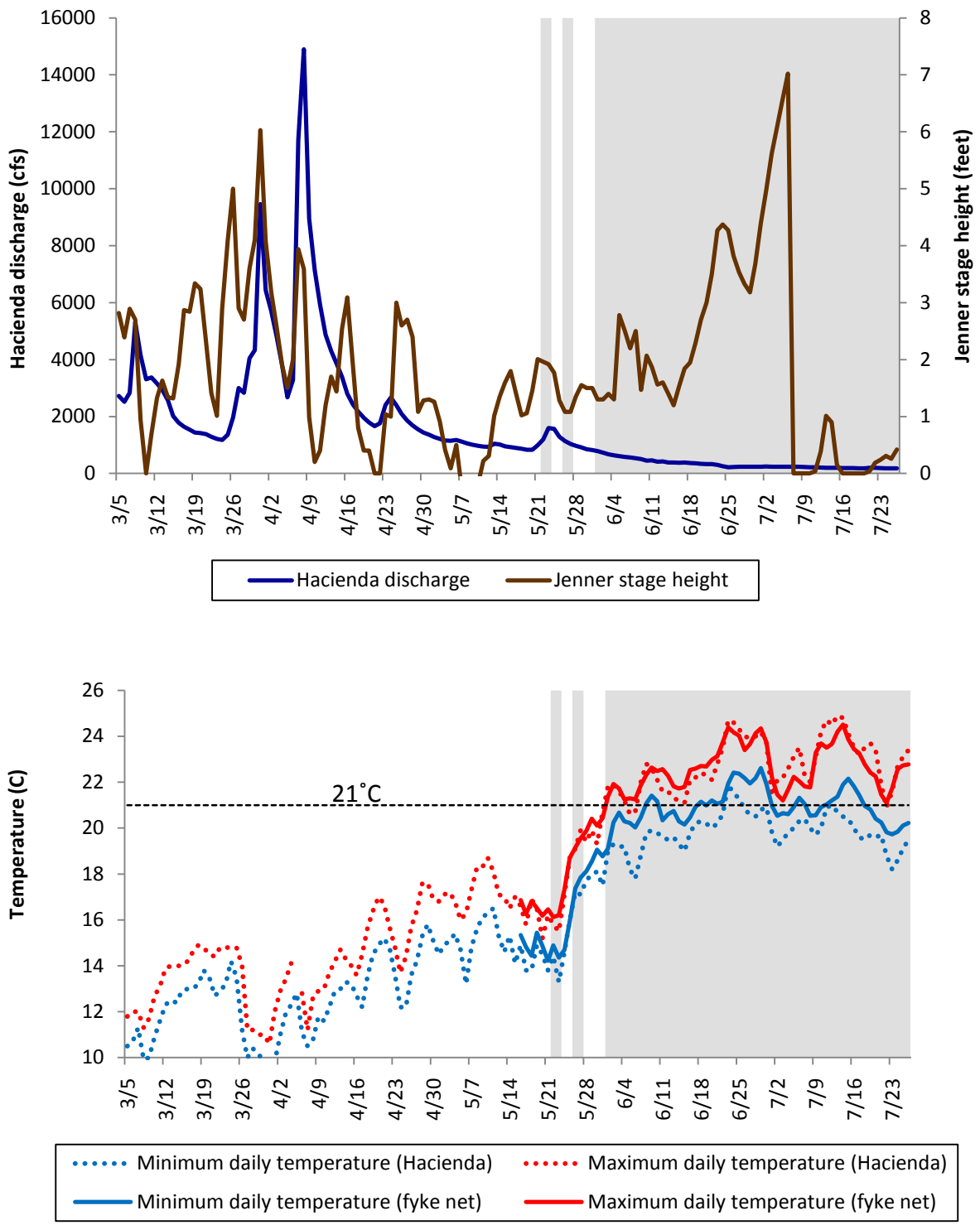


Figure 4.3.5. Environmental conditions in the lower river and estuary during March-July, 2010. Gray shading indicates the days the underwater video camera was operating. Black horizontal line indicates 21˚C temperature handling threshold.

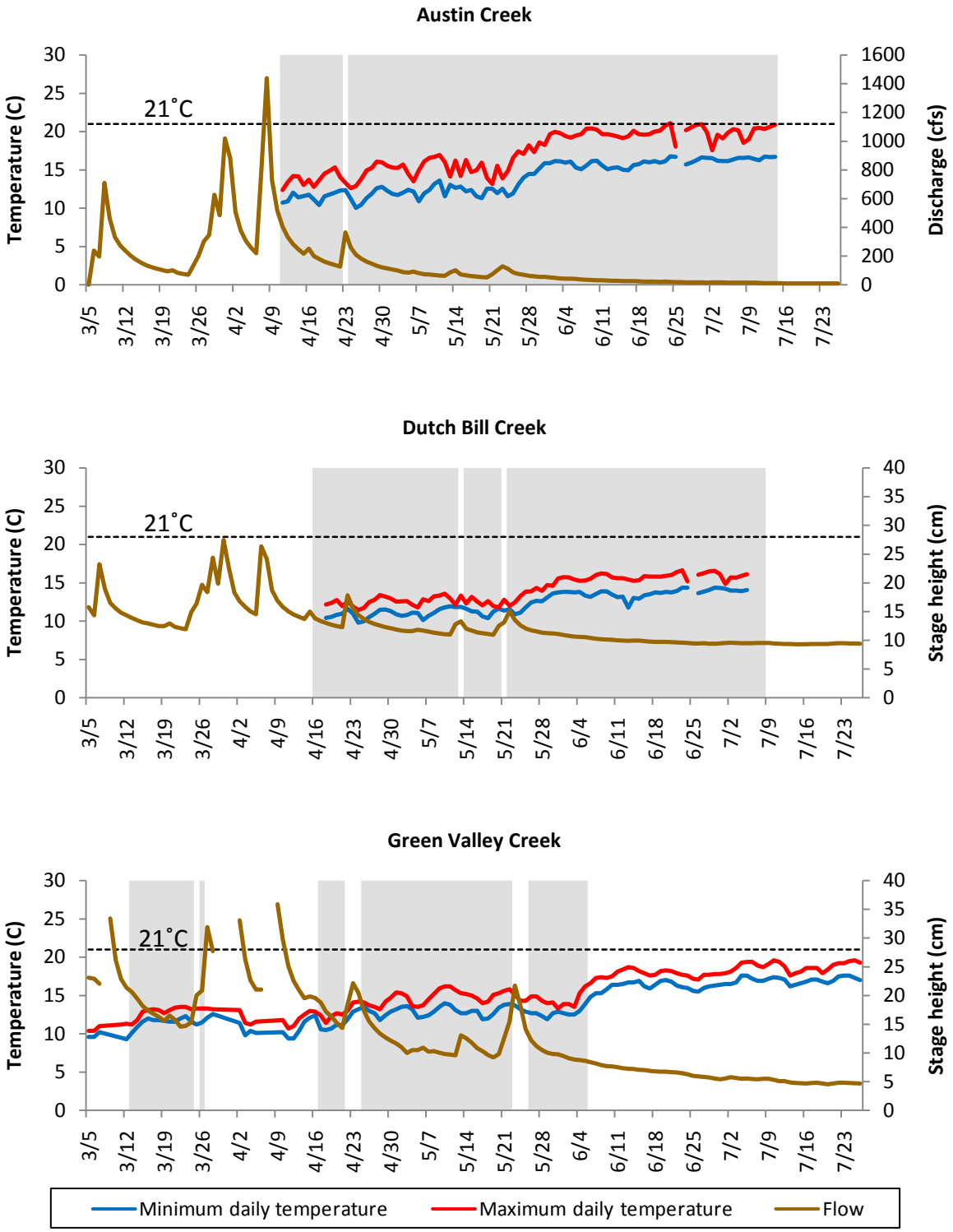


Figure 4.3.6. Environmental conditions at tributary trapping sites March-July, 2010. Gray shading indicates the days each trap was operated and discharge data are from USGS gauge 11467200 (Austin Creek) or stage height from data loggers operated at nearby sites (**http://www.azonde.com/azondeView/map.htm**). Temperature data are from data loggers at the same site (Green Valley) or SCWA data loggers located at the trap site (Austin, Dutch Bill).

Table 4.3.1. Installation and removal dates and total number of days fished for the downstream migrant traps operated by the Water Agency and UCCE.

Trap	Installed	Removed	Total days sampled
Estuary – Duncans Mills	5/27	7/31	60
Austin – Gravel mine	4/15	7/19	95
Dutch Bill – Monte Rio Park	4/20	7/13	82
Green Valley – Martinelli property	3/17	6/10	57
Mainstem - Wohler-Mirabel	5/3	7/16	74

Steelhead

The number of juvenile steelhead detected at the fyke net in 2010, when the underwater video system was the means of detection, was markedly higher than in 2009 when the fyke net was operated as a trap. In 2010, 956 steelhead (juvenile and smolt combined) were observed (Figure 4.3.7), while in 2009, when the fyke net was operated as a trap, only 64 juvenile steelhead were captured. In 2010, we have a high degree of certainty in the correct species identification for 754 (78.9%) of the steelhead detected on the fyke net video. Fork lengths could be estimated from the video for 926 steelhead (Figure 4.3.8).

By expanding our trapping operations into Austin, Dutch Bill and Green Valley Creeks, we were also able to PIT tag more steelhead in 2010 (total=1135, Table 2) as compared to 2009 (total=9). Of the sites monitored in 2010, steelhead were most frequently encountered in Austin Creek; over the course of the season, 4,682 steelhead juveniles were captured (Figure 4.3.7). The Water Agency applied 993 PIT tags to these fish of which 963 were estimated to be YOY based on their size. In total, 795 PIT-tagged steelhead were released upstream of the trap (Table 4.3.3). Of those 795, we have high certainty that at least 405 moved downstream because they were detected on the downstream PIT antenna array. Of the individuals detected on the downstream PIT antenna array, 52 were first recaptured in the trap resulting in an estimated trap efficiency of 12.8% (52/405). Based on this trap efficiency, we estimate that the population size of YOY steelhead moving past (or in the vicinity of) the trap was approximately 23,300. Of the 288 individuals detected on the downstream antenna in the array, 241 were also detected on the upstream antenna in the array resulting in an estimated upper antenna efficiency of 83.6% (241/288). This results in an estimate of 68% (654/963) of the PIT-tagged population that moved downstream. By inference, we assume that a similar proportion of the entire YOY steelhead population estimated at the trap site also moved downstream. Therefore, we estimate that approximately 15,800 steelhead YOY emigrated into the estuary/lagoon from Austin Creek in 2010.

In 2010, relatively few steelhead were caught at Dutch Bill and Green Valley Creek fish traps as compared to Austin Creek. In total, 58 and 5 steelhead juveniles were caught at Dutch Bill and Green Valley Creek, respectively (Figure 4.3.7). PIT tags were applied to 46, 0, and 96 juvenile steelhead in Dutch Bill Creek, Green Valley Creek and at Wohler-Mirabel, respectively. Sizes of fish over the course of the trapping season generally increased (Figure 4.3.8). We assume that the few steelhead smolts captured at any of the trap sites in 2010 is likely due to a large portion

of the smolt outmigration occurring before trap installation and generally low trap efficiencies for steelhead smolts that is well-documented in the Russian River and elsewhere.

Table 4.3.2. The number of PIT tagged steelhead juveniles tagged at downstream migrant monitoring locations in the lower river in 2009 and 2010.

Site	2009	2010
Estuary fyke net	4	no trapping
Austin Creek	not fished	993
Dutch Bill Creek	not fished	46
Green Valley Creek	no PIT tagging	0
Wohler-Mirabel	5	96

Table 3. PIT tag and trap capture metrics and values for YOY steelhead in Austin Creek.

Metric	Formula	Value
Number released upstream of trap		795
Number released downstream of trap		110
Number detected on antenna array that were tagged in Austin Creek		547
Number released upstream & detected on antenna array		405
Number released upstream & recaptured in trap & detected on antenna		52
ESTIMATED TRAP EFFICIENCY	**52/405**	**12.8%**
Number detected on both antennas in array		241
Number detected on downstream antenna only		288
ESTIMATED ANTENNA EFFICIENCY	**241/288**	**83.6%**
Number captured and PIT-tagged		963
Total number captured (≥60 mm only)		2986
ESTIMATED NUMBER OF PIT-TAGGED EMIGRANTS (≥60 mm only)	**547/0.836**	**654**
ESTIMATED PROPORTION OF PIT-TAGGED FISH THAT EMIGRATED (≥60 mm only)	**654/963**	**67.9%**
ESTIMATED POPULATION SIZE AT TRAP	**2986/0.128**	**23328**
ESTIMATED NUMBER IN POPULATION THAT EMIGRATED	**23327*0.659**	**15840**

Chinook

A total of 404 Chinook smolts were observed on the estuary fyke video (Figure 4.3.9). We had a high degree of certainty in correct species identification for 232 (57.4%) of the individuals observed. The video footage could be used to estimate fork lengths for 392 Chinook (Figure 4.3.10).

In 2010 relatively few Chinook smolts were captured in Austin Creek, Dutch Bill Creek, and Green Valley Creek (24, 4 and 14 respectively) (Figure 4.3.9).

Coho

In 2010, 212 coho (YOY and smolt combined) were observed on the fyke net video (Figure 4.3.11) of which we were highly confident in the identification of 138 (65.1%) of the individuals observed on the video. Fork lengths could be estimated from the video footage for 184 coho (Figure 4.3.12).

The Green Valley Creek trap operated by the UCCE detected the most coho salmon smolts of the traps operated. A total 245 hatchery coho smolts and no wild coho salmon smolts (coho with adipose fins were presumed to be wild) were captured at the lower trap site on Green Valley Creek. At Dutch Bill Creek 221 hatchery coho smolts and 1 wild coho smolt were detected at the trap and on Austin Creek 109 hatchery coho smolts were detected at the fish trap (Figure 4.3.11). An additional 2,419 hatchery coho parr were captured between June 25, 2010 and July 16, 2010 at the Austin Creek fish trap. Most of these fish were captured within a few days following the release of hatchery coho in tributaries to East Austin Creek. For detailed analysis of downstream migrant trapping catches of coho in the Russian River see UCCE Coho Salmon Monitoring Program results for 2010.

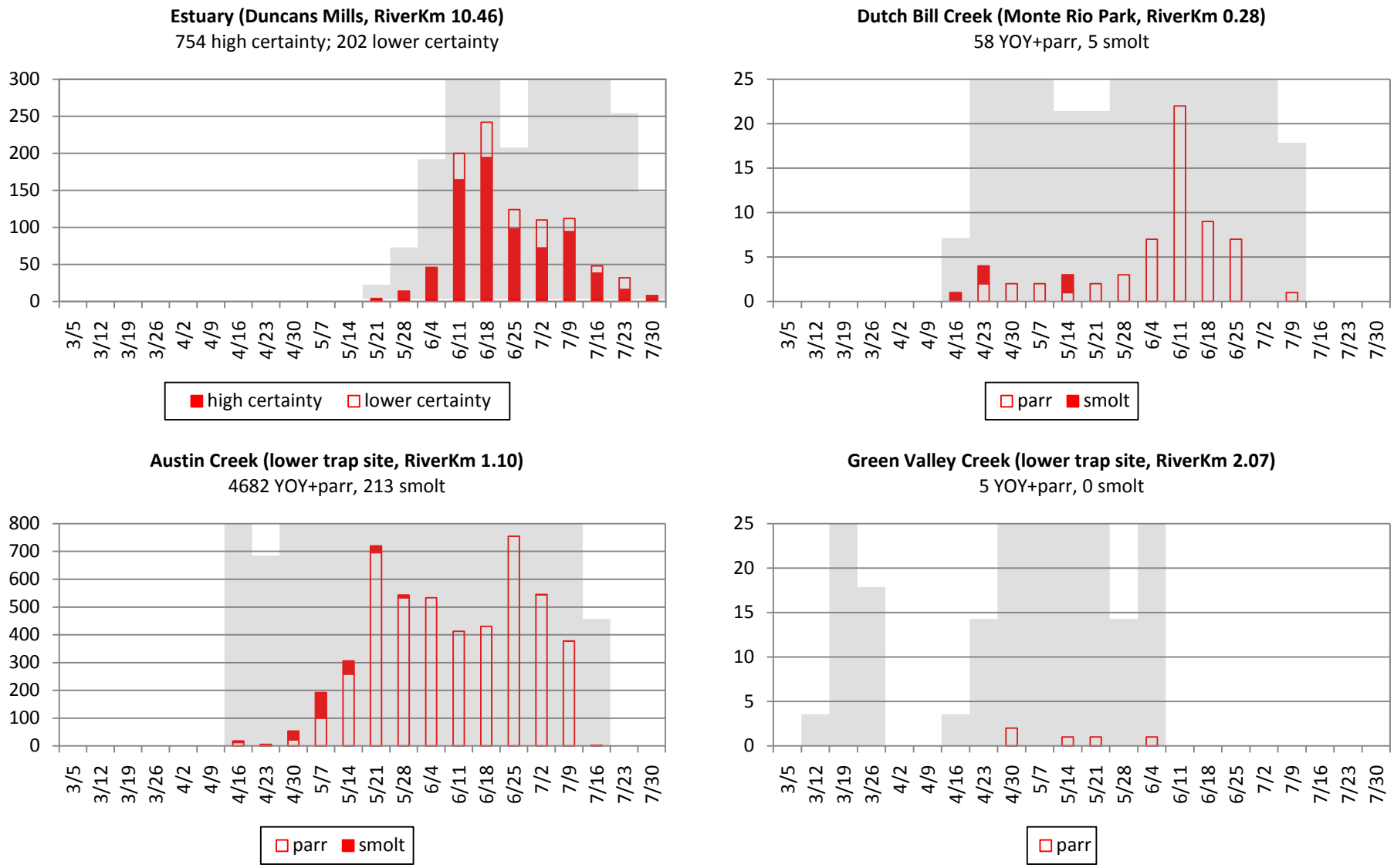


Figure 4.3.7. Weekly detection/catch of steelhead by life stage captured at lower river detection sites operated by SCWA and UCCE, 2011. Gray shading indicates portion of each week trap was fishing. See text for description of "certainty" classification for estuary video. Note the different vertical scale for the estuary and Austin Creek.

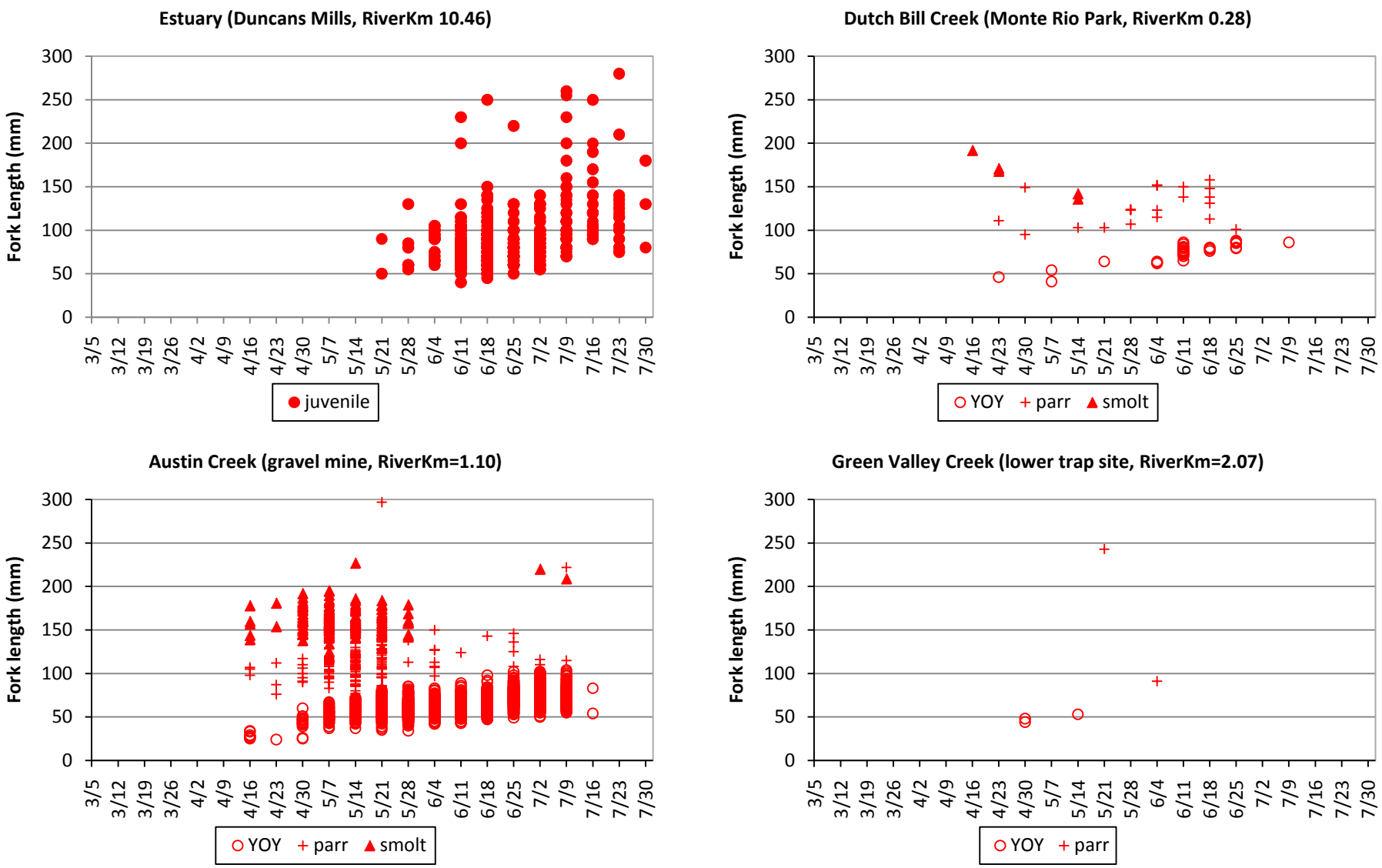


Figure 4.3.8. Weekly steelhead fork lengths at lower river detection sites operated by SCWA and UCCE, 2011.

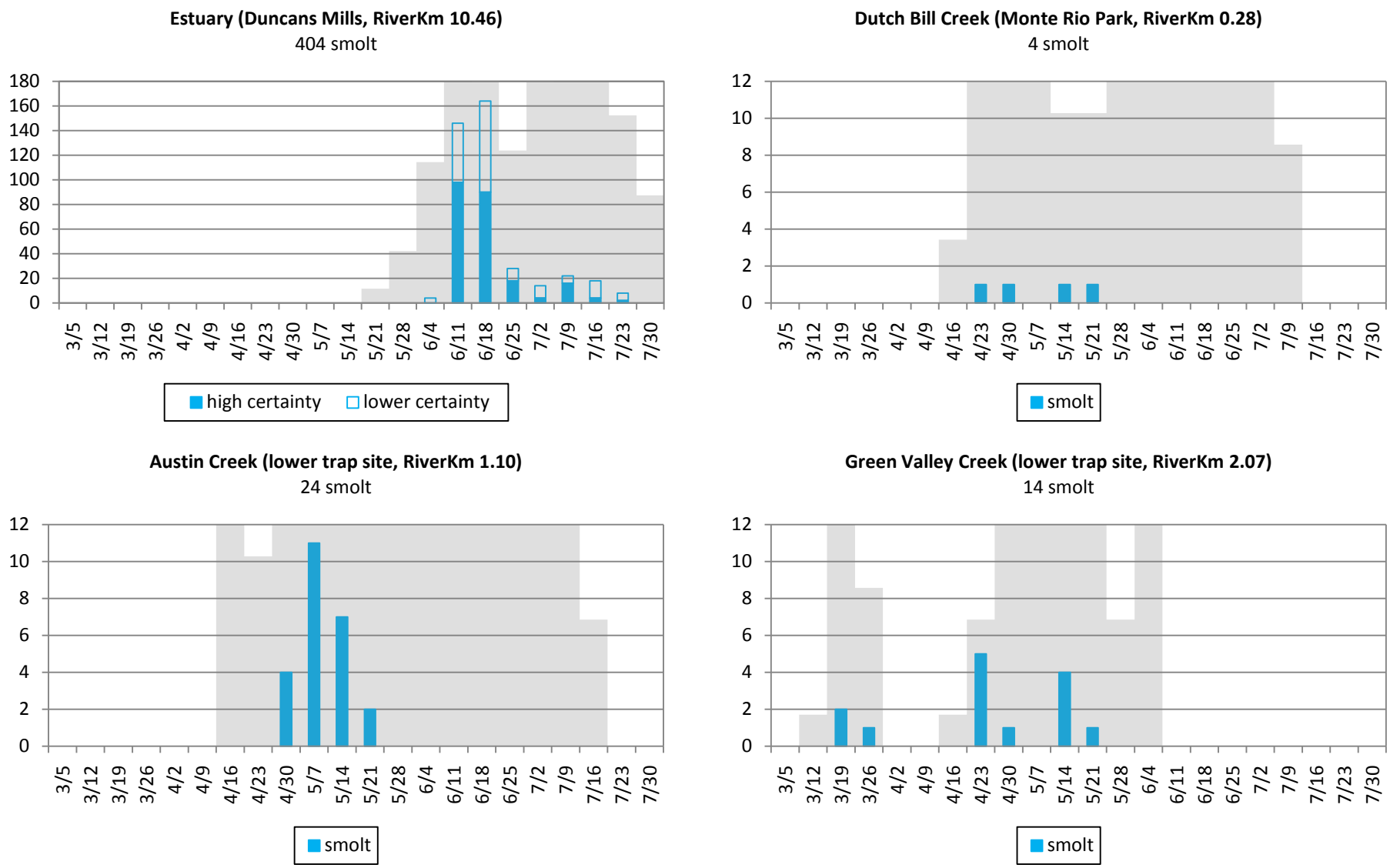


Figure 4.3.9. Weekly detection/catch of Chinook salmon smolts captured at lower river detection sites operated by SCWA and UCCE, 2011. Gray shading indicates portion of each week trap was fishing. See text for description of "certainty" classification for estuary video. Note the different vertical scale for the estuary.

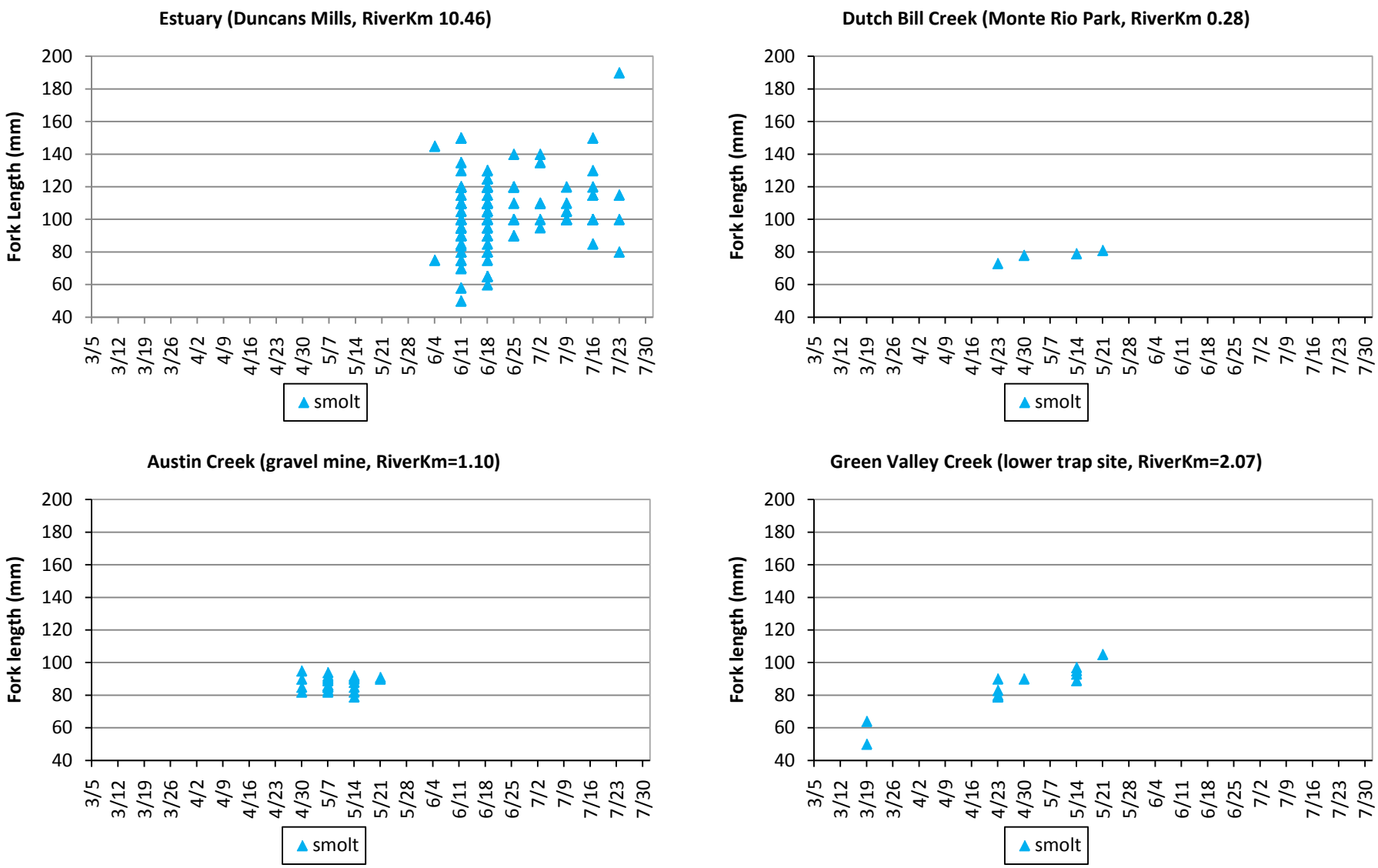


Figure 4.3.10. Weekly Chinook salmon fork lengths at lower river detection sites operated by SCWA and UCCE, 2011.

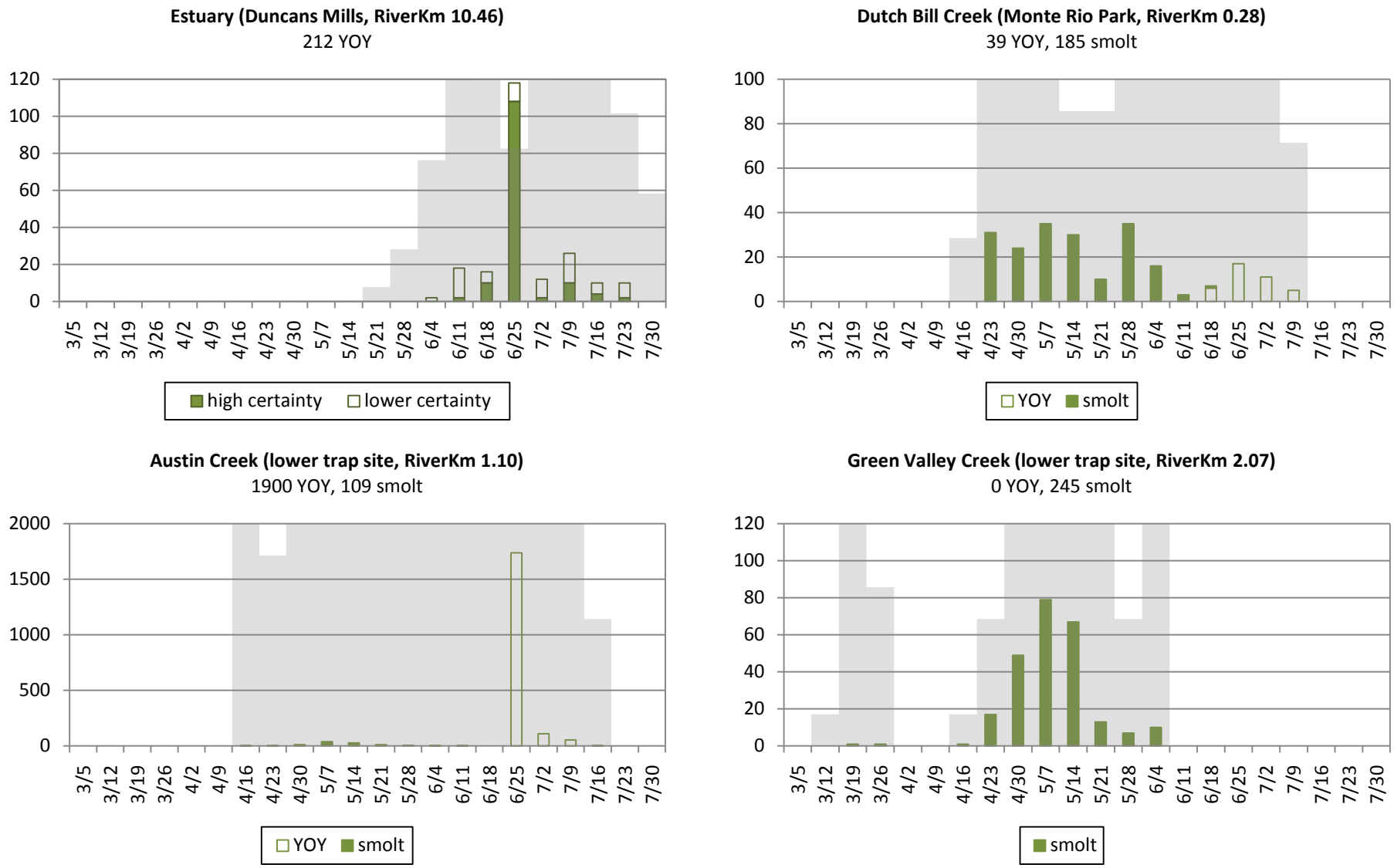


Figure 4.3.11. Weekly detection/catch of coho salmon by life stage captured at lower river detection sites operated by SCWA and UCCE, 2011. Gray shading indicates portion of each week trap was fishing. See text for description of "certainty" classification for estuary video. Note the different vertical scale for Austin Creek.

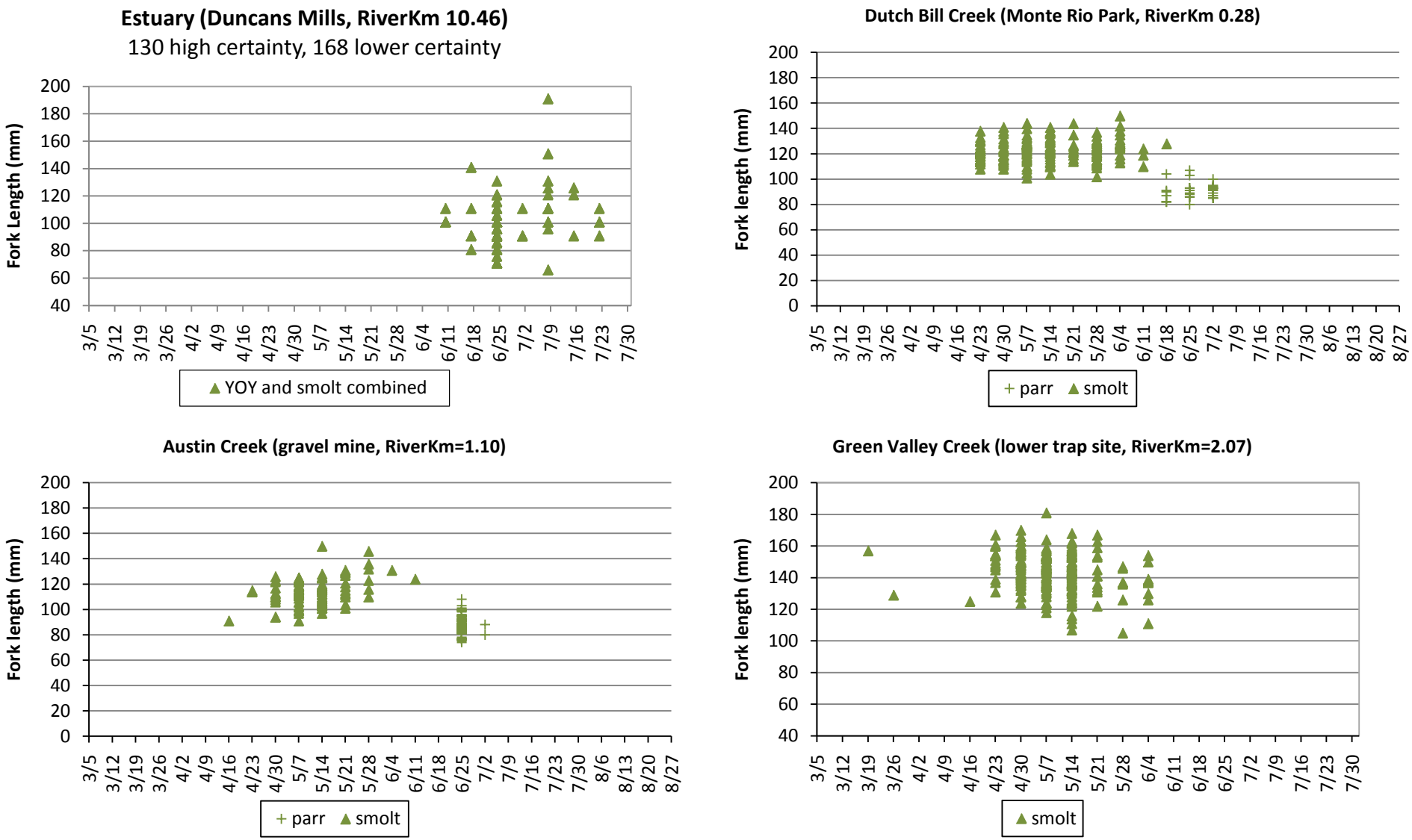


Figure 4.3.12. Weekly coho salmon fork lengths at lower river detection sites operated by SCWA and UCCE, 2011. Because of uncertainty in classification of life stage on the fyke net video, we combined YOY and smolts into a single category.

Conclusions and Recommendations

Estuary video camera and PIT tag antenna systems

When compared to the 2009 estuary fyke net trapping operations, the 2010 estuary fyke net video monitoring system and PIT antenna improved our ability to detect juvenile steelhead movement into the estuary/lagoon. Inclusion of the remote monitoring system also increased the length of time we could monitor (Figure 4.3.13). Approximately 20 times more juvenile steelhead were detected in the 2010 sampling season as compared to the 2009 sampling season. However, because no fish were physically captured, not all individuals could be confidently identified to species. The increase in the number of steelhead detected at the estuary fyke net is likely due to the increase in the length of the 2010 trapping season (21 more days in 2010 than in 2009) and an increase in the effectiveness of the newly-implemented remote monitoring systems. However, without the ability to measure trap efficiency it is not possible to determine if the difference between the number of steelhead detected during the 2009 and 2010 monitoring seasons is related to the increased sampling season, a change in the number of steelhead entering the estuary, or to an increased detection rate.

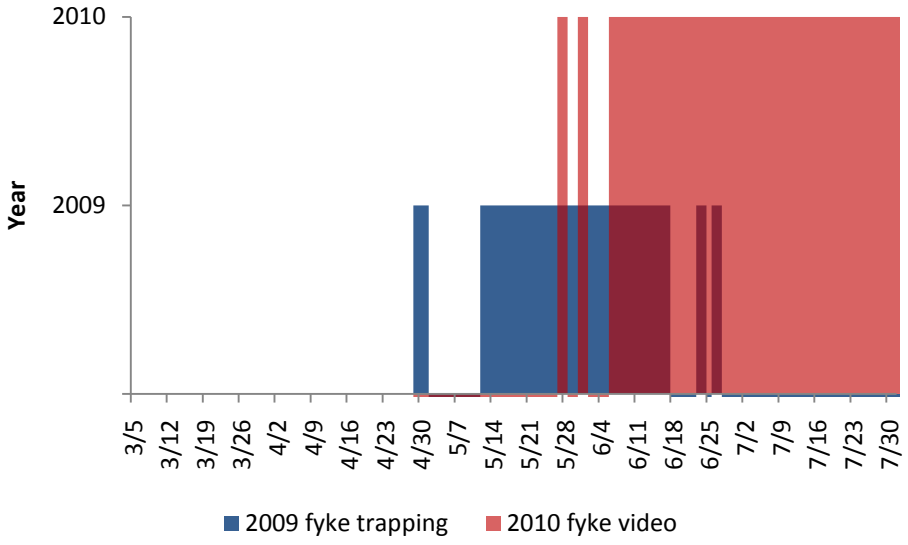


Figure 4.3.13. The dates that the estuary fyke net was operated as a trap in 2009 and as a remote monitoring system in 2010.

Image quality and residence time of individuals in the viewing chamber also affected our ability to accurately identify life stage and accurately measure fish size. As was the case with species identification, our confidence varied with image quality and the length of time individuals were present in the viewing chamber which ranged from approximately 1 second to several minutes. Furthermore the artificial lighting used to illuminate the viewing chamber degraded image quality to the point that parr marks became difficult to see. Based on detections of PIT-tagged fish that were tagged in Austin Creek and observed a short time later on the fyke net video, there was some error in fork length obtained from the fyke video. This is most likely associated with the distance of the fish from the camera lens which could vary by as much as 15 cm.

Another issue which affected the accuracy of length estimation was the orientation of the fish to the camera lens. Because parr marks were often difficult to see and the accuracy of fork length measurements was low when compared to trapping and handling fish, we ultimately abandoned our attempts to identify the life stage of salmonids observed on the camera. in future years we will explore alternative lighting and measurement methods. Despite these issues and as long as the uncertainties outlined above are acknowledged, we are sure that the system of detecting fish movements into the estuary in 2010 is superior to physically capturing and handling fish.

Lower River fish trapping and PIT tagging

Much of the 2010 steelhead smolt migration likely took place before the fish traps were installed. However, because low streamflow in these tributaries in the late summer and spring often disconnects these tributaries from the mainstem it is likely that most of the juvenile movement out of Austin, Dutch Bill, and Green Valley creeks was detected. Eleven years of downstream migrant trapping at Wohler-Mirabel shows wide variability in the number of fish captured (see Mirabel Downstream Migrant Trapping Section 8.3 in this report). Some of this could be due to naturally variability, but some may be due to trap efficiency which we are unable to measure for this life stage without additional monitoring tools (e.g., PIT antenna; Table 4.3.3). The Synthesis section of this report (Chapter 10) relates detections of downstream migrants in the lower river tributaries that were monitored in 2010 to the objectives in the Russian River Biological Opinion.

References

Bjorkstedt, E.P., 2000. DARR (Darroch analysis with rank reduction): a method for analysis of mark-recapture data from small populations, with application to estimate abundance of smolts from outmigrant trap data. National Marine Fisheries Service, Southwest Fisheries Science Center, Santa Cruse/Tiburon. Administrative repot SC-00-02

Chase, S. D., Benkert R., Manning D., White S., 2005. Sonoma County Water Agency's Mirabel rubber dam/Wohler pool fish sampling program: year 5 results, Santa Rosa, CA.

Chase, S. D., Manning, D., Cook, D., White S., 2007. Historical accounts, recent abundance, and current distribution of threatened Chinook salmon in the Russian River, California. California Fish and Game 93(3): 130-148.

Manning, D.J., and J. Martini-Lamb, editors. 2011. Russian River Biological Opinion status and data report year 2009-10. Sonoma County Water Agency, Santa Rosa, CA. 200 P.

NMFS. 2008. Biological Opinion for Water Supply, Flood Control, and Channel Maintenance to the U.S. Army Corps of Engineers, the Sonoma County Water Agency and the Mendocino County Russian River Flood Control and Water Conservation Improvement District in the Russian River watershed. National Marine Fisheries Service, South West branch. 2008.

Obedzinski, M., J. Pecharich, G. Vogeazopoulos, D. Lewis, and P. Olin. 2006. Monitoring the Russian River Coho Salmon Captive Broodstock Program:Annual Report July 2005 to June 2006. University of California Cooperative Extension and Sea Grant Program. Santa Rosa, California.

Obedzinski, M., J. Pecharich, J. Davis, D. Lewis, P. Olin. 2007. Russian River Coho Salmon Captive Broodstock Program Monitoring Activities Annual Report; July 2006 to June 2007. University of California Cooperative Extension and Sea Grant Program. Santa Rosa, California.

Obedzinski, M., J. Pecharich, J. Davis, S. Nossaman, P. Olin, and D. Lewis. 2008. Russian River Coho Salmon Captive Broodstock Program Monitoring Activities Annual Report: July 2007 to June 2008. University of California Cooperative Extension and Sea Grant Program. Santa Rosa, California.

Zydlewski, G., G. E. Horton, T. L. Dubreuil, B. H. Letcher, S. Casey, and J. Zydlewski. 2006. Remote monitoring of fish in small streams: A unified approach using PIT tags. Fisheries 31(10): 492-502.

4.4 Fish Sampling – Beach Seining

The Water Agency has been sampling the Russian River Estuary since 2004 - prior to receipt of the Biological Opinion. An Estuary fish survey methods study was completed in 2003 (Cook 2004). To provide context to data collected in 2010, we present and discuss previous years of data in this report. Although survey techniques have been similar since 2004, some survey locations and the sampling extensity changed in 2010 as required in the Biological Opinion. The distribution and abundance of fish in the Estuary are summarized below. In addition to steelhead, coho salmon, and Chinook salmon, we describe the catch of several common species to help characterize conditions in the Estuary.

Methods

Study Area

The Estuary fisheries monitoring area included the tidally influenced section of the Russian River and extended from the sandbar at the Pacific Ocean to Duncans Mills, located 9.8 km (6.1 mi) upstream from the coast (Figure 4.4.1).

Fish Sampling

A beach-deployed seine was used to sample fish species, including salmonids, and determine their relative abundances and distributions within the Estuary. The rectangular seine consisted of approximately 5 mm (¼ inch) mesh netting with pull ropes attached to the four corners. Floats on the top and weights on the bottom positioned the net vertically in the water. During

INSERT 4.4.1 – VICINITY MAP

2004-2006 a 30 m long (100 feet) by 3 m deep (10 feet) purse seine was used. This seine was replaced in 2007 with a conventional seine (dimensions 46 m (150 ft) long by 4 m (14 ft) deep). The seine was deployed with a boat to pull an end offshore and then around in a half-circle while the other end was held onshore. The net was then hauled onshore by hand. Fish were placed in aerated buckets for sorting, identification, and counting prior to release. A few non-salmonid voucher specimens were preserved in ethanol to verify identification.

Salmonids were anesthetized with Alka-seltzer tablets or MS-222 anesthetic and then measured, weighed, and examined for general condition, including life stage (i.e., parr, smolt). Salmonids were identified as wild or hatchery stock (indicated by a clipped adipose fin). Tissue and scale samples were collected from some steelhead. Fish were allowed to recover in aerated buckets prior to release. Also, juvenile steelhead great than 60 mm fork length were marked by surgically implanting a passive integrated transponder (PIT) tag. PIT tags provide a unique identification to each fish. All captured steelhead were scanned with a PIT tag receiver to detect recaptured fish. This data was used to better understand the movement patterns and growth rates of steelhead in the Estuary.

From 2004 to 2009 eight seining stations were located throughout the Estuary in a variety of habitats based on substrate type (i.e., mud, sand, and gravel), depth, tidal, and creek tributary influences. Three seine sets adjacent to each other were deployed at each station totaling 24 seine sets per sampling event. Stations were surveyed approximately every 3 weeks from late May through September or October. Total annual seine pulls ranged from 96 to 168 sets.

During 2010 fish seining sampling was doubled in effort with 300 sets completed for the season. Surveys were conducted monthly from May to October. Between 3 and 7 seine sets where deployed at 10 stations for a total of 50 sets for each sampling event. Twenty-five sets were in the lower and middle Estuary and 25 in the upper Estuary. Aerial photographs showing the locations of seining stations and each seine site are in Appendix B-4.

For data analysis the Estuary study area was divided into three reaches, including Lower, Middle, and Upper, which is consistent with study areas for water quality and invertebrate studies (Figure 4.4.1). For the fish seining study, the Upper Reach of the Estuary was divided into Upper1 and Upper2 sub-reaches to improve clarity on fish patterns. Fish seining stations in 2010 were located at previous stations or placed in areas that could be sampled during open and closed river mouth conditions. Suitable seining sites are limited during closed mouth conditions due to flooded shorelines. Capture per unit effect (CPUE), defined as the number of fish captured per seine set (fish/set), was used to compare the relative abundance of fish among Estuary reaches and study years.

The habitat characteristics and locations of 2010 study reaches, fish seining stations, and number of monthly seining sets are below.

Lower Estuary

- River Mouth (7 seine sets): sandbar separating the Russian River from the Pacific Ocean, sandy substrate with a low to steep slope, high tidal influence.
- Penny Point (3 seine sets): shallow water with a mud and gravel substrate, high tidal influence.

Middle Estuary

- Patty's Bar (3 seine sets): large gravel and sand bar with moderate slope, moderate tidal influence.
- Bridgehaven (7 seine sets): large gravel and sand bar with moderate to steep slope, moderate tidal influence.
- Willow Creek (5 seine sets): shallow waters near the confluence with Willow Creek, gravel and mud substrate, aquatic vegetation common, moderate tidal influence.

Upper Estuary

Upper1 Sub-Reach

- Sheephouse Bar (5 seine sets): opposite shore from Sheephouse Creek, large bar with gravel substrate and moderate to steep slope, low to moderate tidal influence
- Heron Rookery Bar (5 seine sets): gravel bank adjacent to deep water, low to moderate tidal influence.
- Freezeout Bar (5 seine sets): opposite shore from Freezeout Creek, gravel substrate with a moderate slope, low tidal influence.

Upper2 Sub-Reach

- Moscow Bridge (5 seine sets): steep to moderate gravel/sand bank adjacent to shallow to deep water, aquatic vegetation common, low tidal influence.
- Casini Ranch (5 seine sets): moderate slope gravel/sand bank adjacent to shallow to deep water, upper end of Estuary at riffle, very low tidal influence.

Results

Fish Distribution and Abundance

Fish captures from seine surveys in the Russian River Estuary from 2004 to 2010 are summarized in Table 4.4.1. During the 7 years of study, over 120,000 fish comprised of 50 species were caught in the Estuary. In 2010, 46,051 fish comprised of 37 species were recorded. In comparison, during 2009 there were 27,119 fish caught comprised of 32 species; however, the seining effort in 2009 was about half that during 2010. Fish studies in the 1990s detected 18 to 28 species/year for a total of 49 species (Sonoma County Water Agency and Merritt Smith Consulting 2001). Four new fish species were detected in the Estuary in 2010, including fathead (*Pimephales promelas*), hardhead (*Mylopharodon conocephalus*), white catfish (*Icalurus catus*), and poacher. The poacher could not be identified to species, but was possibly a sturgeon poacher (*Agonus acipenserinus*). All of these fish, except for the marine poacher, are freshwater species.

Table 4.4.1: Total fish captured by beach seine in the Russian River Estuary from May to October 2010. Each station was sampled monthly from May to October.

		Seine Station										
Life History	**Species**	**River Mouth**	**Penny Point**	**Patty's Bar**	**Bridge-haven**	**Willow Creek**	**Sheep-house Bar**	**Heron Rookery Bar**	**Freeze-out Bar**	**Moscow Bridge**	**Casini Ranch**	**Total**
Total Sets per Station		42	18	18	42	30	30	30	30	30	30	300
Anadromous	American shad	2			60		68	7	44	451	243	875
	Chinook salmon	34	15		68	25	38	30	13	7	29	259
	coho salmon	15	8	4	7	1	5	7	10	1	1	59
	steelhead	1		1	13	9	11	48	11	110	53	257
Estuarine	bay pipefish	16	17	11	16	4	2					66
	shiner surfperch	13	17	89	394	259		21				793
	staghorn sculpin	49	134	45	54	113	13	4	1		1	414
	starry flounder	22	86	5	65	6	6	20	53	11	50	324
	topsmelt	68		285	87							440
Freshwater	black crappie									1		1
	bluegill			1		1					4	6
	California roach					1		7	36	23	8	75
	common carp				1	1		4	42	38	8	94
	cyprinid sp.				2			4		3		9
	fathead minnow						1					1
	hardhead								1	1		2
	hitch					1		2		41	30	74
	largemouth bass									4	2	6
	Russian River tule perch		1	1	1	10		8	30	621	6	678
	Sacramento blackfish									1		1
	Sacramento pikeminnow				3	15	9	285	32	337	45	726
	Sacramento sucker	2	1	2	20	266	105	1933	1909	1072	1367	6677
	white catfish								1			1

		Seine Station										
Life History	**Species**	**River Mouth**	**Penny Point**	**Patty's Bar**	**Bridge-haven**	**Willow Creek**	**Sheep-house Bar**	**Heron Rookery Bar**	**Freeze-out Bar**	**Moscow Bridge**	**Casini Ranch**	**Total**
Marine	buffalo sculpin	2										2
	cabezon	7	1									8
	English sole	37										37
	northern anchovy				7							7
	Pacific herring				9							9
	Pacific sanddab	1										1
	poacher sp.	1										1
	saddleback gunnel	3	6									9
	Sebastes sp.	366	1									367
	sharpnose sculpin	3	7									10
	silver spotted sculpin	1										1
	surf smelt	387	50	20	63	16						536
Generalist	prickly sculpin*	472	545	575	1112	902	130	148	535	51	96	4566
	sculpin sp. (prickly)*	7	51			4	1	1	8	9	3	84
	threespine stickleback	60	1067	2299	3807	4963	1709	3023	6510	2791	2346	28575
Total	**37**	**1569**	**2007**	**3338**	**5789**	**6597**	**2098**	**5552**	**9236**	**5573**	**4292**	**46051**

*Prickly Sculpin counts may include small numbers of the freshwater-resident Coast Range sculpin (*Cottus aleuticus*) and riffle sculpin (*Cottus gulosus*), although neither of these species has been reported from the Estuary.

The distribution of fish in the Estuary is, in part, based on a species preference for or tolerance to salinity (Figure 4.4.2). In general, the influence of cold seawater from the ocean results in high salinity levels and cool temperatures in the Lower Reach transitioning to warmer freshwater in the Upper Reach from river inflows (Figure 4.4.3). For more detail please refer to water quality in Chapter 4.1. Fish commonly found in the Lower Reach were marine and estuarine species including topsmelt (*Atherinops affinis*), surf smelt (*Hypomesus pretiosus*), staghorn sculpin (*Leptocottus armatus*), and starry flounder (*Platichthys stellatus*). The Middle Reach had a broad range of salinities and a diversity of fish tolerant of these conditions. Common fish in the Middle Reach included those found in the Lower Reach and shiner surfperch (*Cymatogaster aggregata*). Freshwater dependent species, such as the Sacramento sucker (*Catostomus occidentalis*) and California roach (*Hesperoleucus symmetricus*), were predominantly distributed in the Upper Reach. Anadromous fish, such as steelhead (*Oncorhynchus mykiss*) and American shad (*Alosa* sapidissima), which can tolerate a broad range of salinities, occurred throughout the Estuary. Habitat generalists, such as threespine stickleback (Gasterosteus aculeatus) and prickly sculpin (Cottus asper), occurred in abundance in the Estuary, except within full strength seawater in the Lower Reach.

Steelhead

During 2010, a total of 257 steelhead were captured (Table 4.4.1) in 300 seine sets. The resulting Catch per Unit Effort (CPUE) was 0.86 fish/set (Figure 4.4.4). In comparison, 91 steelhead were caught in 2009 for a CPUE of 0.54 fish/set. The highest CPUE for all study years was 1.7 fish/set in 2008, which is over double the captures in 2010. All steelhead captured in 2010 were wild, except one hatchery steelhead caught in the Middle Reach on July 17, 2010. Most captured juvenile steelhead were age 0+ parr or age 1+ smolts and ranged in size from 38 mm to 350 mm fork length. The average sizes of steelhead are shown in Table 4.4.2.

The seasonal abundance of steelhead captured varied annually in the Estuary (Figure 4.4.5). Although the highest steelhead abundance was typically in May/June, juveniles were captured consistently through September/October. During 2010, steelhead captures were highest during June at 1.8 fish/set and lowest in May at 0.3 fish/set. The highest capture abundance among all study years was in August 2008 at 4.3 fish/set.

Over the past 7 years of sampling, steelhead appeared to be patchily distributed and variably abundant in the Estuary (Figure 4.4.6). In 2004 and 2006, relatively low numbers of steelhead were captured and only in the Middle and Upper1 Reaches (Upper2 Sub-Reach sampling began in 2010). While in 2005, juvenile steelhead were caught throughout most of the Estuary. Over all years surveyed, captures were typically highest in the Upper Reach with a high of 6.9 fish/set in the Upper1 Sub-Reach in 2008. In 2010, captures were highest in the Upper2 Sub-Reach at 3.3 fish/set followed by Upper1 Sub-Reach at 1.4 fish/set.

The temporal distribution of juvenile steelhead in the Estuary in 2010 was strongly influenced by large captures in the Upper Reach (Figure 4.4.7). Very few steelhead were captured in the Lower and Middle Reaches. Based on fish size most of the steelhead in the Estuary are age 0+

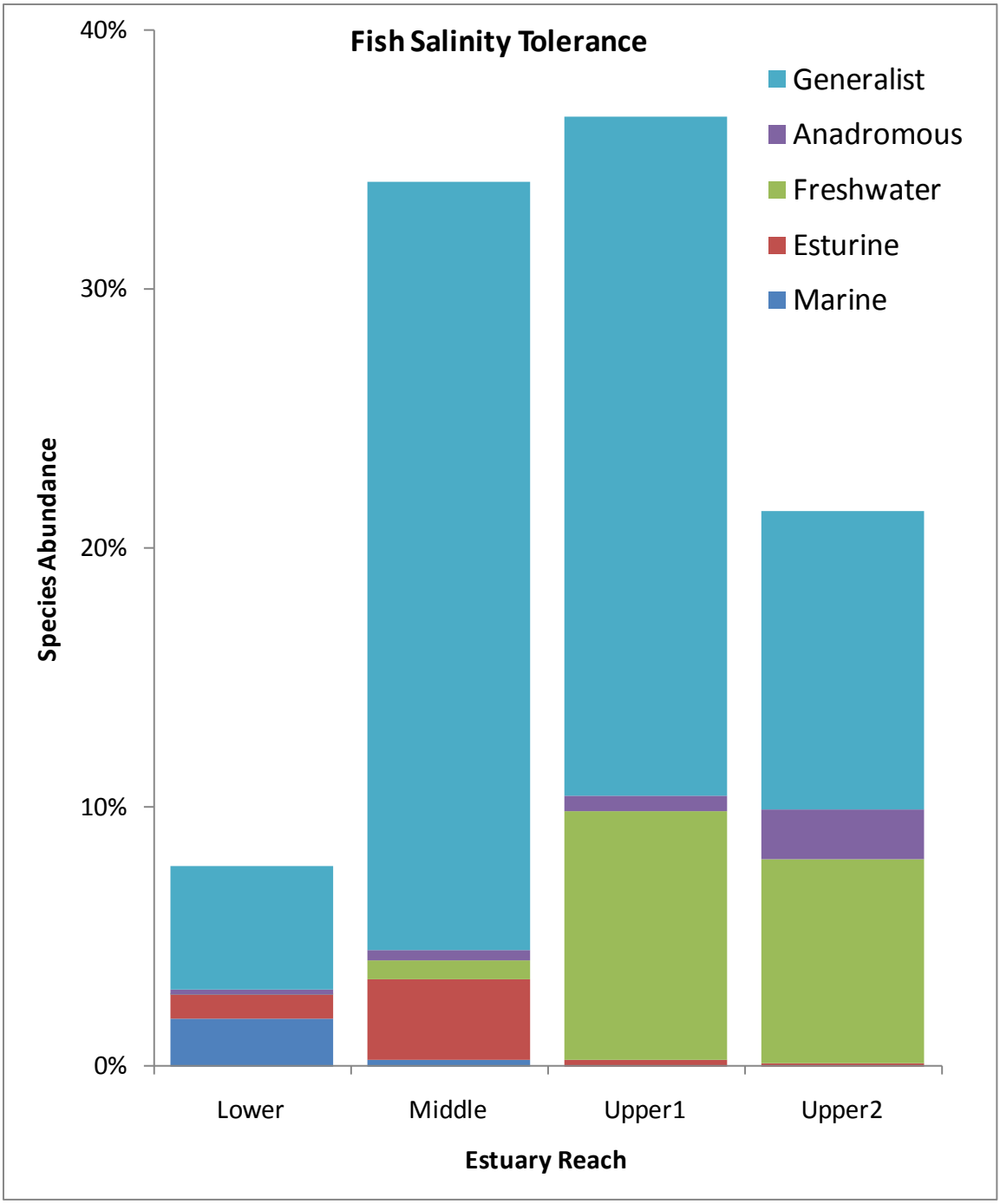


Figure 4.4.2. Distribution of fish captured by beach seine in the Russian River Estuary based on salinity tolerance and life history, 2010. Groups include: generalist species that occur in a broad range of habitats (threespine stickleback and prickly sculpin); species that are primarily anadromous; freshwater resident species; brackish-tolerant species that complete their lifecycle in estuaries; and species that are predominantly marine residents. See Table 4.4.1 for a list of species in each group.

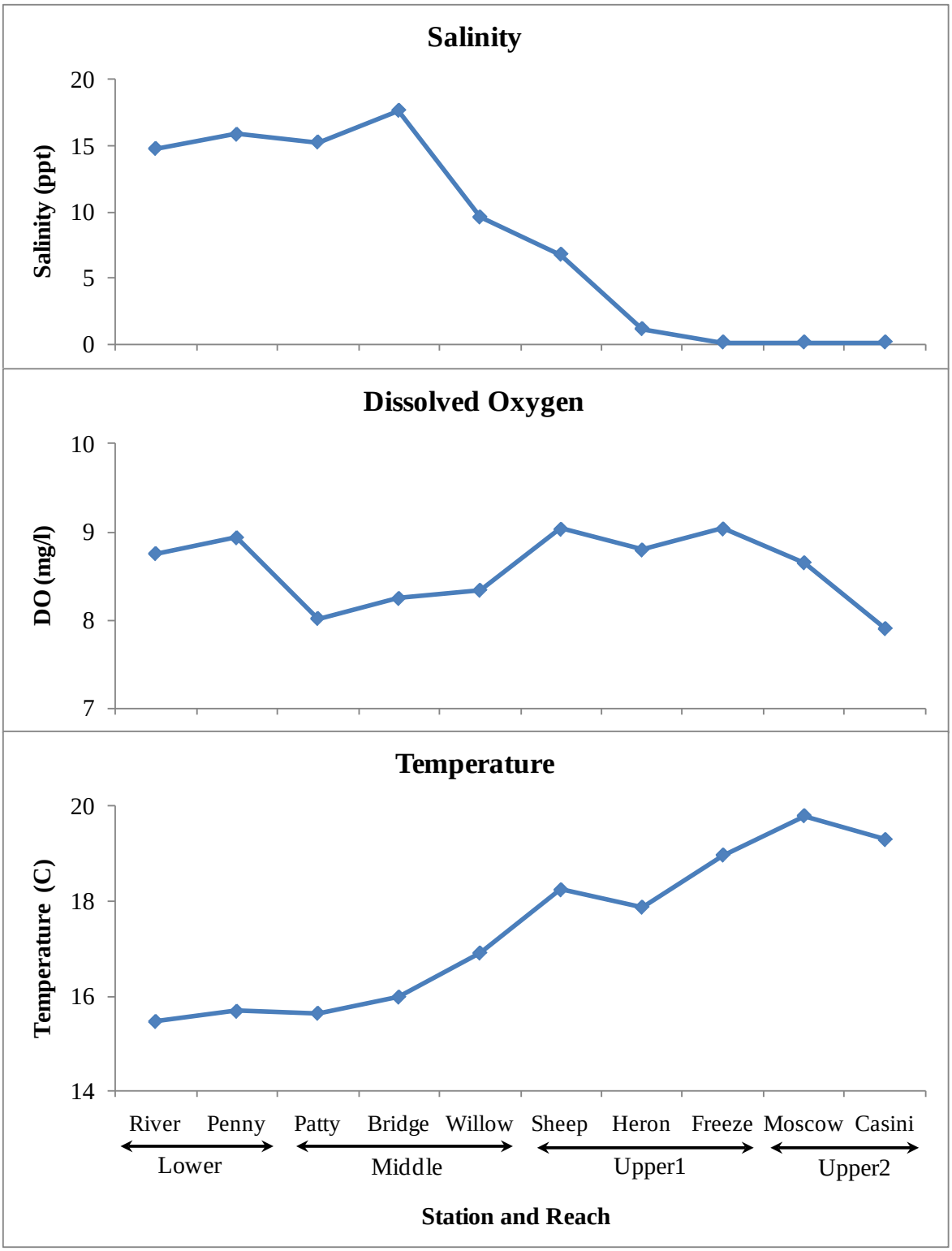


Figure 4.4.3. Water quality conditions at fish seining stations in the Russian River Estuary, 2010. Values are averages collected at 0.5 m intervals in the water column during beach seining events from May to October. Salinity values are in parts per thousand (ppt), dissolved oxygen (DO) are in milligrams per liter, and water temperature is in degrees Celsius (C).

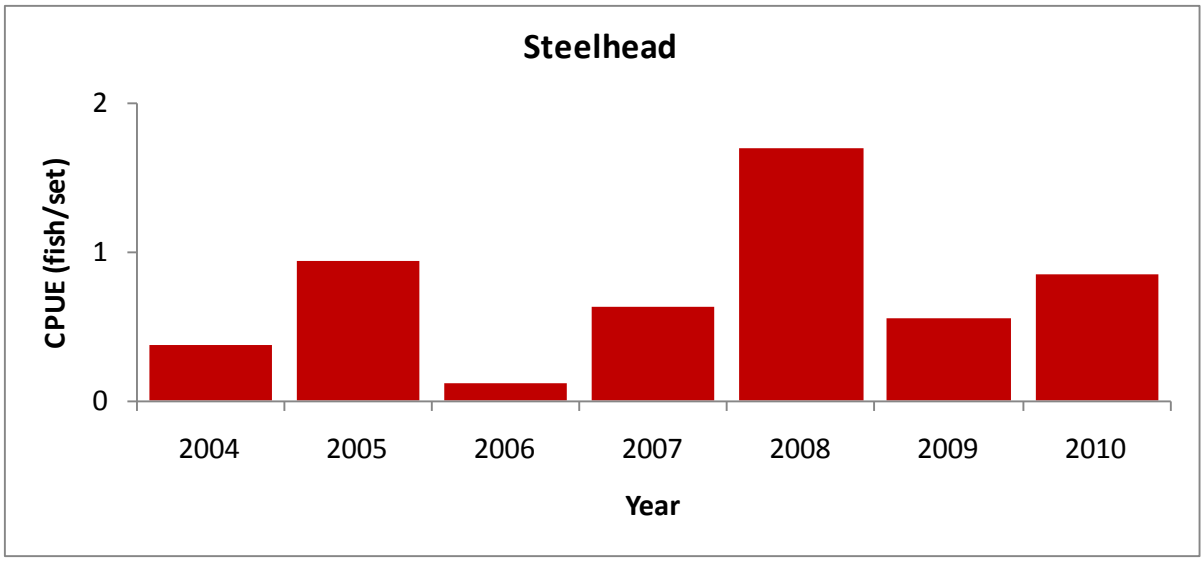


Figure 4.4.4: Relative abundance of juvenile steelhead captured by beach seine in the Russian River Estuary. Samples are capture per unit effort (CPUE) from 96 to 300 seine sets conducted yearly between May and October.

Table 4.4.2. Sizes of juvenile steelhead captured by beach seine in the Russian River Estuary, 2004-2010. N values reflect numbers of measured fish and not necessarily total captures.

		Steelhead Fork Length (mm)			
Year	N	Mean	Standard Deviation	Minimum	Maximum
2004	55	113.4	55.3	55	320
2005	138	111.6	48.4	43	275
2006	12	90.6	43.5	50	198
2007	106	133.4	49.5	45	255
2008	286	121.4	49.5	46	276
2009	91	121.0	55.5	48	296
2010	236	127.6	46.0	38	350

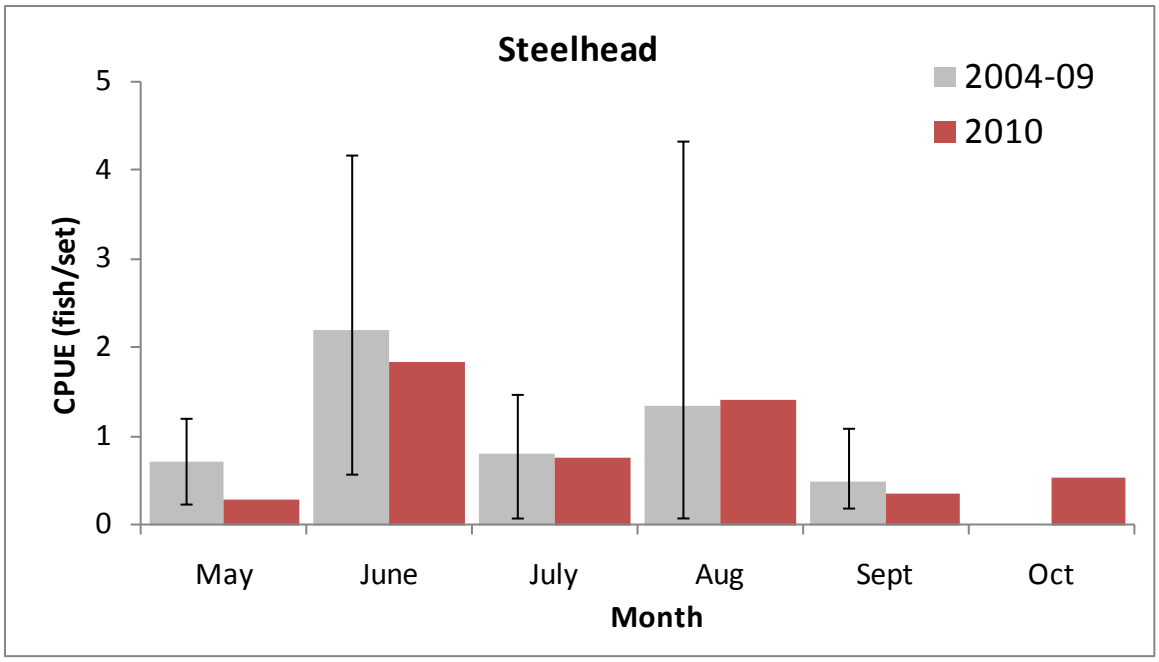


Figure 4.4.5. Seasonal abundance (CPUE) of juvenile steelhead captured by beach seine in the Russian River Estuary, 2004-2010. Seining events consisted of 21 to 50 seine sets approximately monthly. October surveys began in 2010. Data from 2004 to 2009 was averaged and whiskers indicate minimum and maximum values.

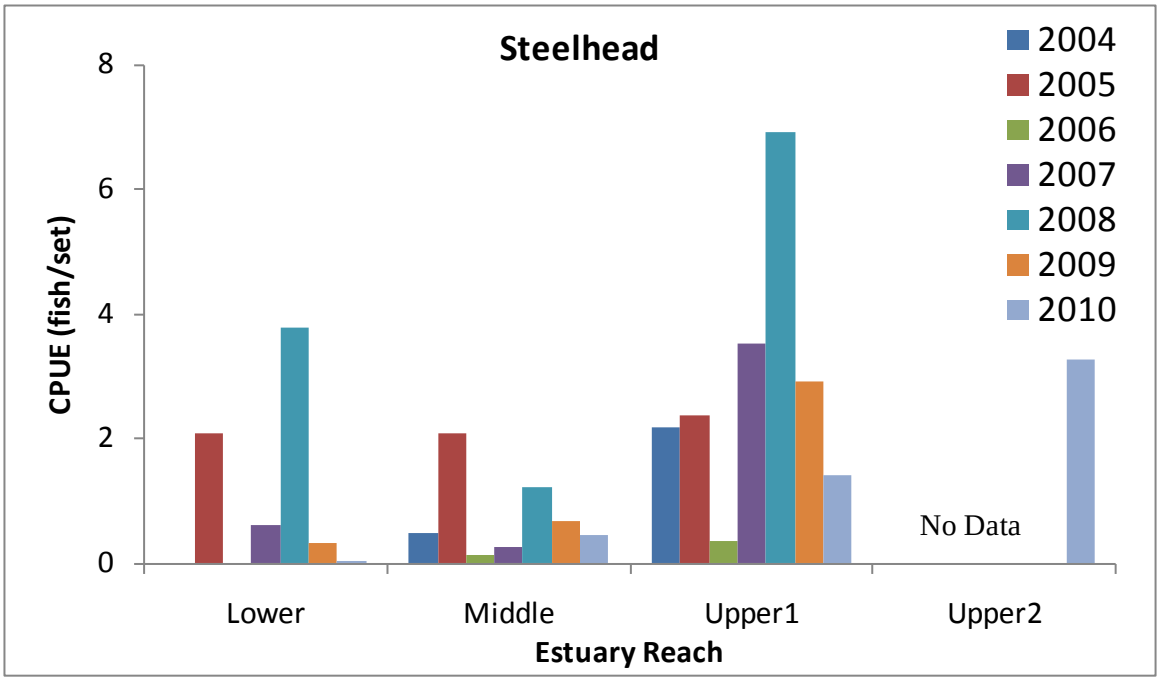


Figure 4.4.6. CPUE of juvenile steelhead captured by beach seine in the Russian River Estuary, 2004-2010. Fish were sampled by beach seine consisting of 96 to 300 sets annually. No surveys were conducted in the Upper2 Sub-Reach (Casini Ranch and Moscow Bridge stations) from 2004 to 2009.

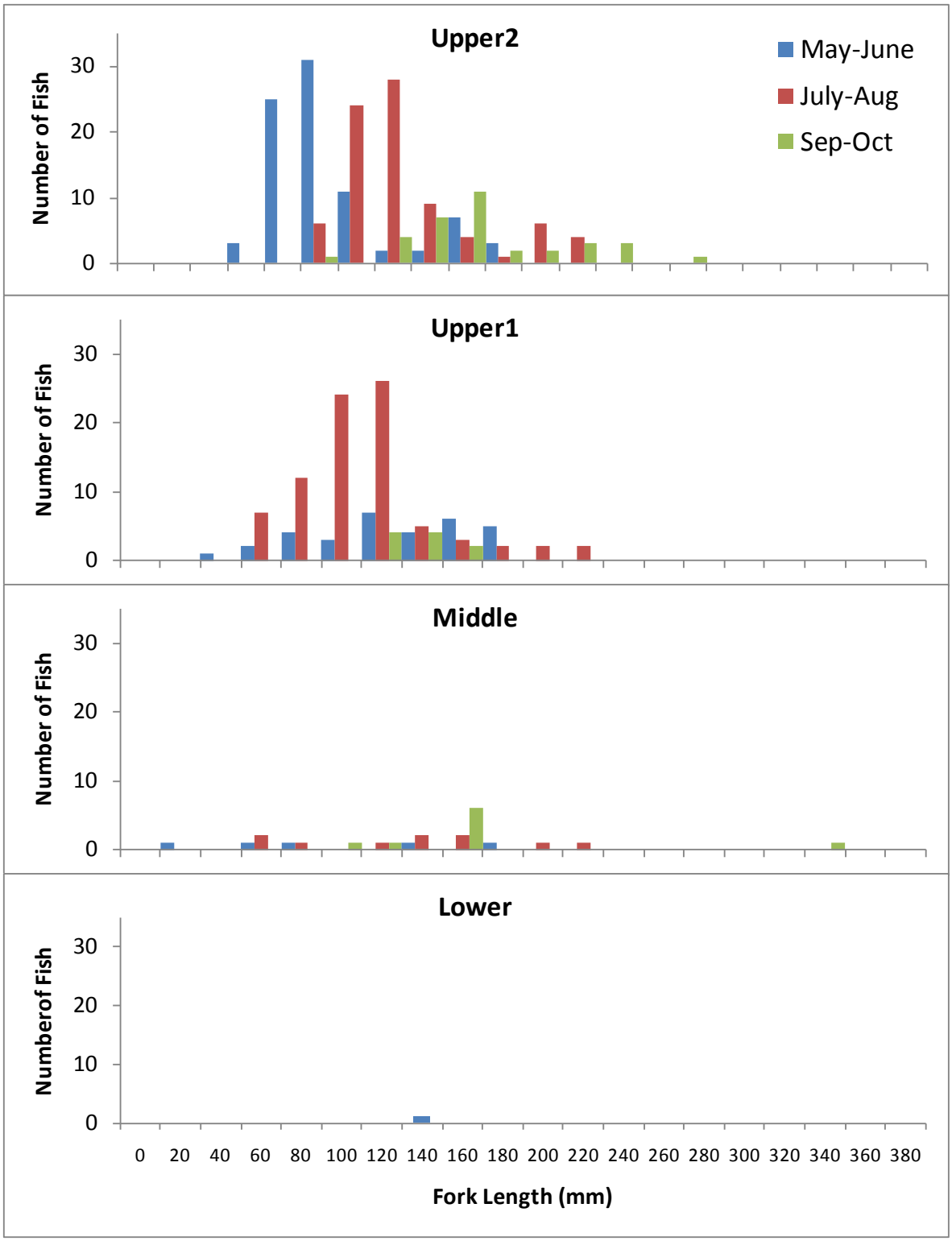


Figure 4.4.7: Length frequency of juvenile steelhead captured by beach seine in the Russian River Estuary, 2010. Fish captures were grouped by Estuary reach and month.

(young-of-the-year) followed by age 1+ fish. Average fork length of Estuary steelhead in May-June was 107.7 mm, 128.6 mm in July-August, and then 174.8 mm in September-October.

In 2010, 88 juvenile steelhead captured during Estuary seining surveys were implanted with a PIT tag. An additional 154 steelhead were tagged during fish diet studies conducted in collaboration with the University of Washington prey availability study (see Chapter 4.2). Of the total 242 tagged fish, 18 were later recaptured in the Estuary. Of these recaptured steelhead only 2 fish were originally tagged during seining surveys. The other 16 fish were tagged during fish diet/prey availability studies. In addition, there were 12 steelhead captured during seining surveys that were PIT tagged upstream of the Estuary during downstream migrant trapping studies (see Chapter 10 – Synthesis).

Of the 18 PIT-tagged juvenile steelhead recaptured in the Estuary in 2010, 12 were from the Lower Reach and 6 from the Upper Reach. All recaptured Estuary-tagged steelhead were found at the same site where they were initially tagged. The only exception was a steelhead tagged at the Heron Rookery Bar station and then recaptured at the adjacent Sheephouse Bar station (Appendix B-4), which are both located in the Upper1 Sub-Reach. This suggests strong site fidelity for steelhead that rear in the Estuary.

The growth rates of PIT-tagged steelhead are shown in Figure 4.4.8. The longest time between captures was 99 days. The average growth rate of steelhead throughout the Estuary was 0.79 mm/day. All of the Lower Reach recaptures occurred during fish diet/prey availability studies located at the mouth of Jenner Gulch. These juvenile steelhead had slightly higher mean growth rates of 0.82 mm/day compared to Upper1 Sub-Reach mean growth rates of 0.67 mm/day.

Chinook Salmon

A total of 259 Chinook salmon smolts were captured by beach seine in the Estuary during 2010 (Table 4.4.1). The relative abundance of smolts has decreased since a peak in 2008 and has decreased by about half each year since (Figure 4.4.9). Chinook salmon abundance was lowest in 2005 at 0.7 fish/set and highest in 2008 at 4.6 fish/set. Smolt captures in 2010 were 0.9 fish/set. Chinook salmon smolts were usually most abundant during May or June (Figure 4.4.10) and rarely encountered after July. Monthly smolt captures in 2010 were highest during May (3.6 fish/set). Very few smolts were captured late in the survey season in September and October. Chinook salmon smolts were distributed throughout the Estuary with captures at most sample stations and all reaches annually (Figure 4.4.11).

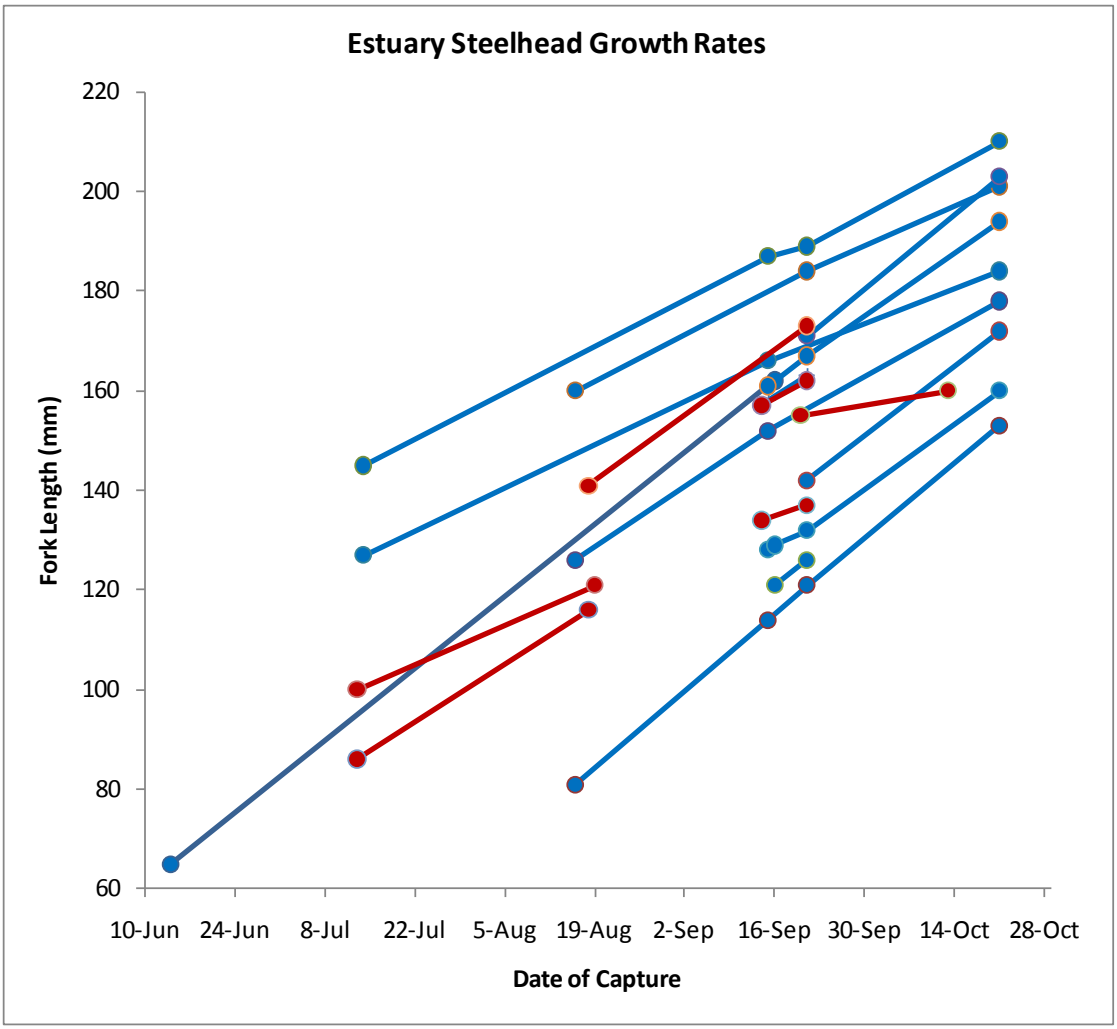


Figure 4.4.8. Growth rates of juvenile steelhead marked and recaptured in Russian River Estuary, 2010. Fish (n = 18) were marked with PIT tags, released, and later recaptured. Blue lines represent fish captured in the Lower Reach (Jenner Gulch) and red lines are fish from the Upper1 Sub-Reach.

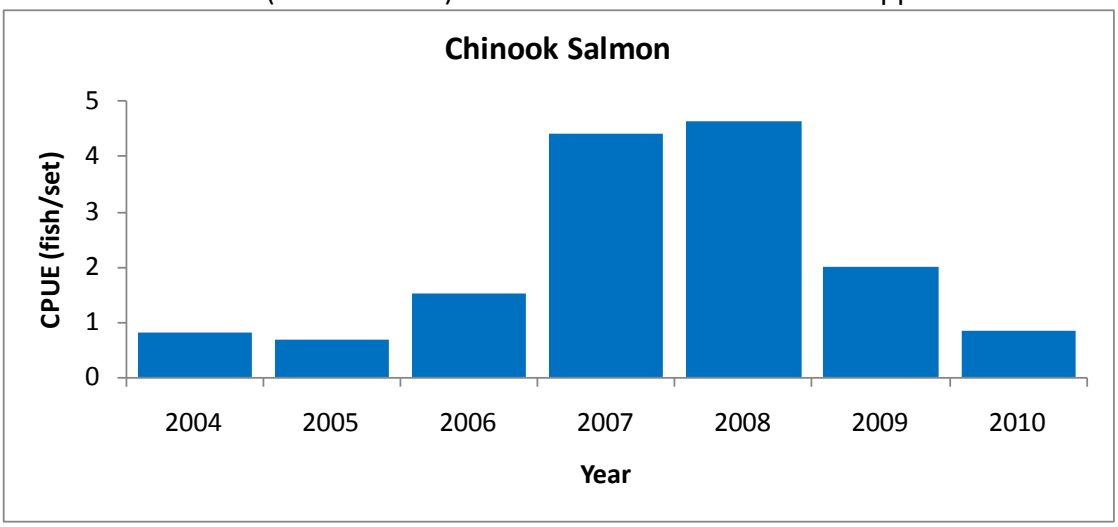


Figure 4.4.9. Relative abundance of Chinook salmon smolts captured by beach seine in the Russian River Estuary. Samples are capture per unit effort (CPUE) from 96 to 300 seine sets yearly between May and October.

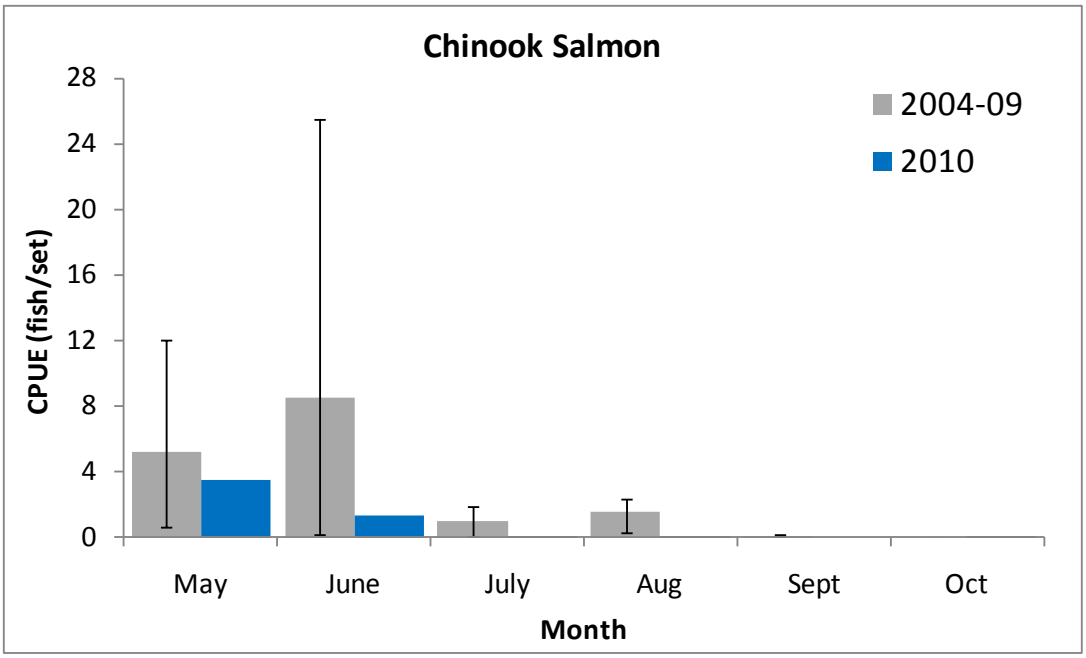


Figure 4.4.10. Seasonal abundance (CPUE) of Chinook salmon smolts captured by beach seine in the Russian River Estuary, 2004-2010. Seining events consisted of 21 to 50 seine sets approximately monthly. October surveys began in 2010. Data from 2004 to 2009 was averaged and whiskers indicate minimum and maximum values.

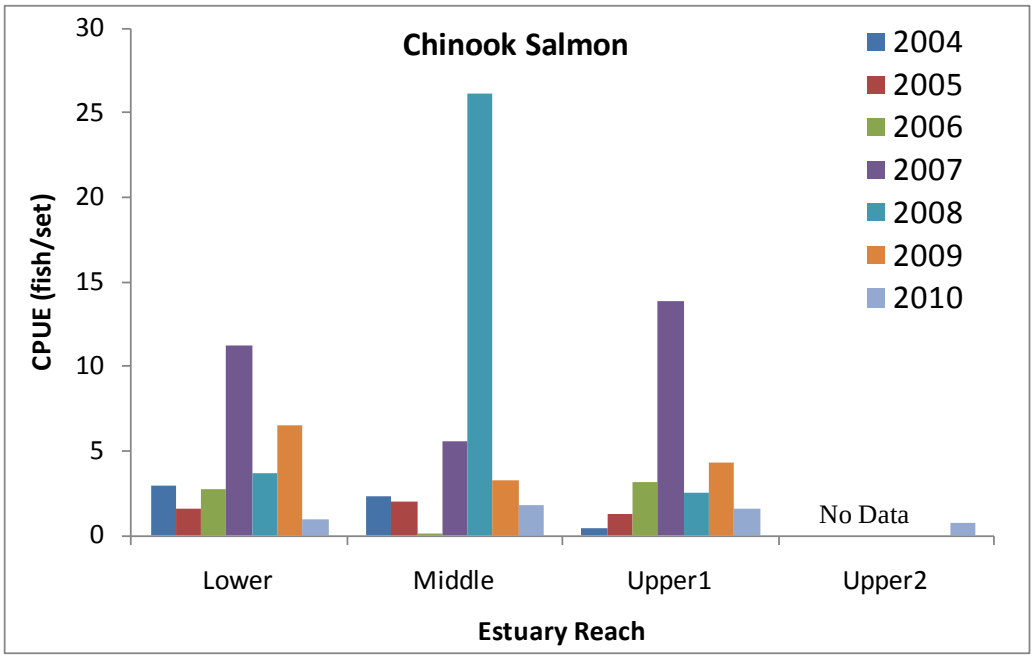


Figure 4.4.11. CPUE of Chinook salmon smolts in the Russian River Estuary, 2004-2010. Fish were sampled by beach seine consisting of 96 to 300 sets annually. No surveys were conducted in the Upper2 Sub-Reach (Casini Ranch and Moscow Bridge stations) from 2004 to 2009.

Coho Salmon

Very few coho salmon smolts have been captured in the Estuary during our beach seining surveys (Table 4.4.1; Figure 4.4.12). The first coho smolt captured in the Estuary was a single fish in 2006. Since then a total of 159 smolts have been captured. There were 59 smolt captures in 2010. Coho abundance was highest in 2007, 2009, and 2010 (0.2 fish/set). The low coho captures in the Estuary are related to their low numbers in the Russian River watershed, but also the timing of our seining surveys that begin in late-May or June when most smolts have already migrated to the ocean. Nearly all smolts were captured during May or early June (Figure 4.4.13). The spatial distribution of coho smolts has varied annually (Figure 4.4.14). During 2007 most coho were captured in the Upper1 Sub-Reach, while in 2009 and 2010 smolts appeared to occur throughout the Estuary. Most captured smolts had a clipped adipose fin indicating they originated from the Coho Salmon Captive Broodstock Hatchery Program. This program began stocking coho in local streams in 2004. Two wild coho smolts have been captured in the Estuary in 2005 and 2009. No wild coho were found in 2010.

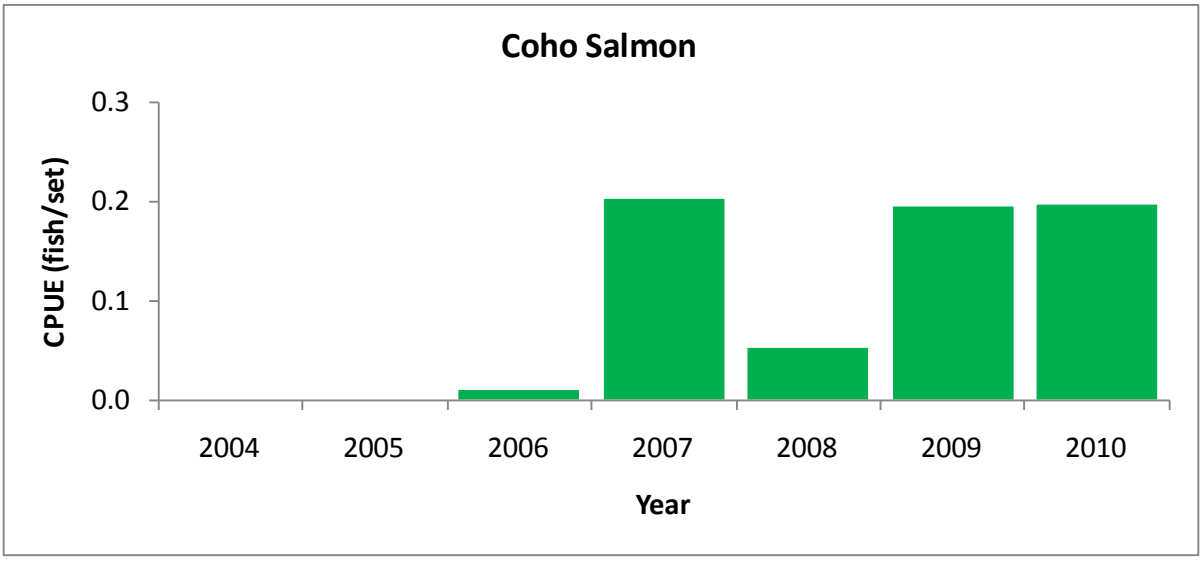


Figure 4.4.12. Relative abundance of coho salmon smolts captured by beach seine in the Russian River Estuary. Samples are catch per unit effort (CPUE) from 96 to 300 seine sets yearly from May to October.

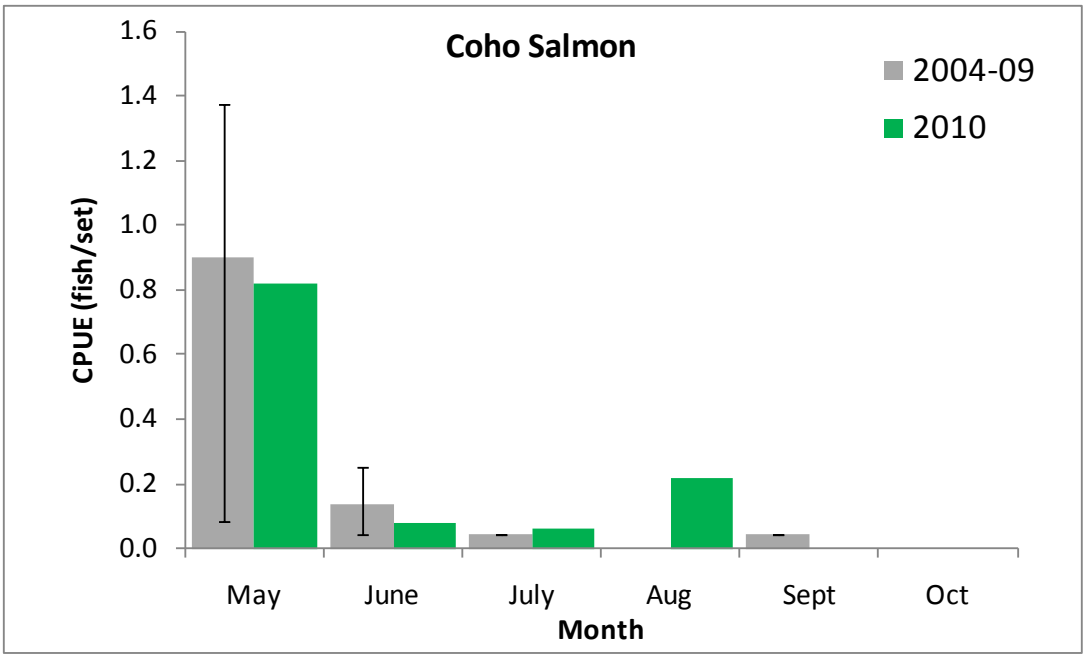


Figure 4.4.13. Seasonal abundance (CPUE) of coho salmon smolts captured by beach seine in the Russian River Estuary, 2004-2010. Seining events consisted of 21 to 50 seine sets approximately monthly. October surveys began in 2010. Data from 2004 to 2009 was averaged and whiskers indicate minimum and maximum values.

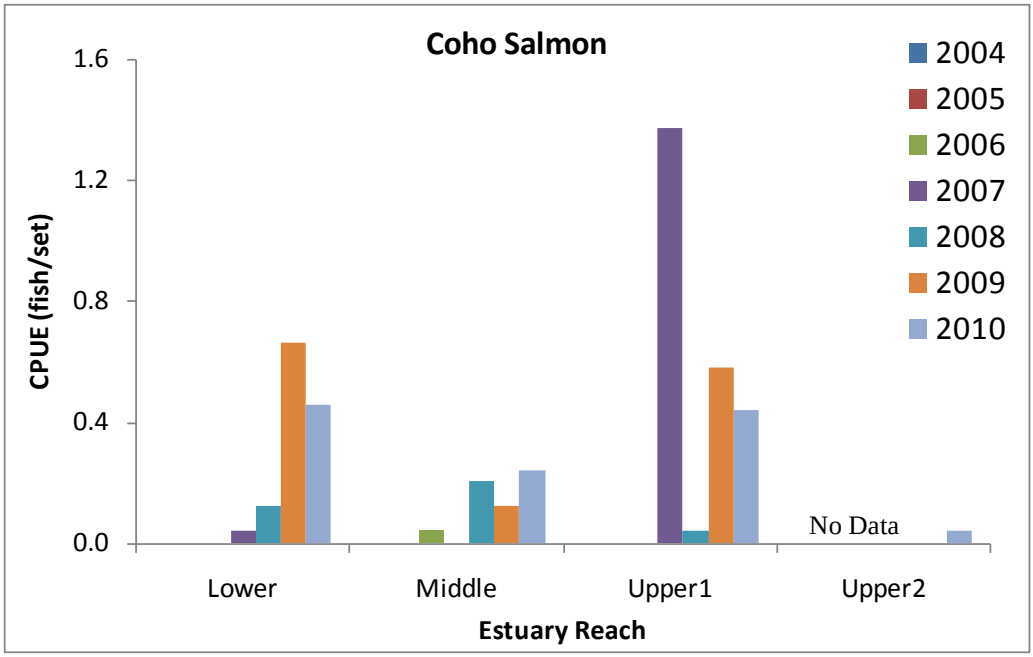


Figure 4.4.14. CPUE of coho salmon smolts in the Russian River Estuary, 2004-2010. Fish were sampled by beach seine consisting of 96 to 300 sets annually. No surveys were conducted in the Upper2 Sub-Reach (Casini Ranch and Moscow Bridge stations) from 2004 to 2009.

American Shad

American shad is an anadromous sportfish, native to the Atlantic coast. It was introduced to the Sacramento River in 1871, and within two decades, was abundant locally and had established populations from Alaska to Mexico (Moyle 2002). Adults spend from 3 to 5 years in the ocean before migrating upstream to spawn in the main channels of rivers. Juveniles spend the first year or two rearing in rivers or estuaries.

The annual abundance of American shad in the Estuary has ranged from 0.3 fish/set in 2005 to 24.3 fish/set in 2006 (Figure 4.4.15). The high capture rate in 2006 is largely from a single seine set when 1,540 juveniles were netted. During 2010, the shad CPUE was 2.9 fish/set. The seasonal occurrence of juvenile American shad followed a recurring seasonal pattern. They first appeared in relatively large numbers in July and the catch usually peaked in August. Shad were distributed throughout the Estuary but were most abundant in the Upper1 Sub-Reach where slightly brackish waters occur (Figure 4.4.16).

Topsmelt

Topsmelt are one of the most abundant fish in California estuaries (Baxter et al. 1999) and can tolerate a broad range of salinities and temperatures, but are seldom found in freshwater (Moyle 2002). They form schools and are often found near the water surface in shallow water. Sexual maturity is reached in 1 to 3 years and individuals can live as long as 7 to 8 years. Estuaries are used as nursery and spawning grounds and adults spawn in late-spring to summer.

Topsmelt are one of the most abundant fish in the Russian River Estuary, especially in brackish water areas. The abundance of topsmelt in the Estuary has been decreasing since a peak in 2006 with a CPUE of 13.4 fish/set (Figure 4.4.17). The CPUE in 2010 was 1.5 fish/set. The catch of topsmelt peaked in July and August. Topsmelt were distributed in the Lower and Middle Reaches, where brackish water conditions are common, and were seldom captured upstream where tidal influences are low (Figure 4.4.18). The highest occurrence of topsmelt was in the Middle Reach in 2006 with a CPUE of 32.9 fish/set. During 2010, the highest CPUE was in the same reach at 7.4 fish/set.

Starry Flounder

Starry flounder range from Japan and Alaska to Santa Barbara in coastal marine and estuarine environments. In California, they are common in bays and estuaries (Moyle 2002). This flatfish is usually found dwelling on muddy or sandy bottoms. Males mature during their second year and females mature at age 3 or 4 (Baxter et al. 1999). Spawning occurs during winter along the coast, often near the mouths of estuaries. Young flounders spend at least their first year rearing in estuaries. They move into estuaries during the spring and generally prefer warm, low-salinity water or freshwater. As young grow, they shift to using brackish waters.

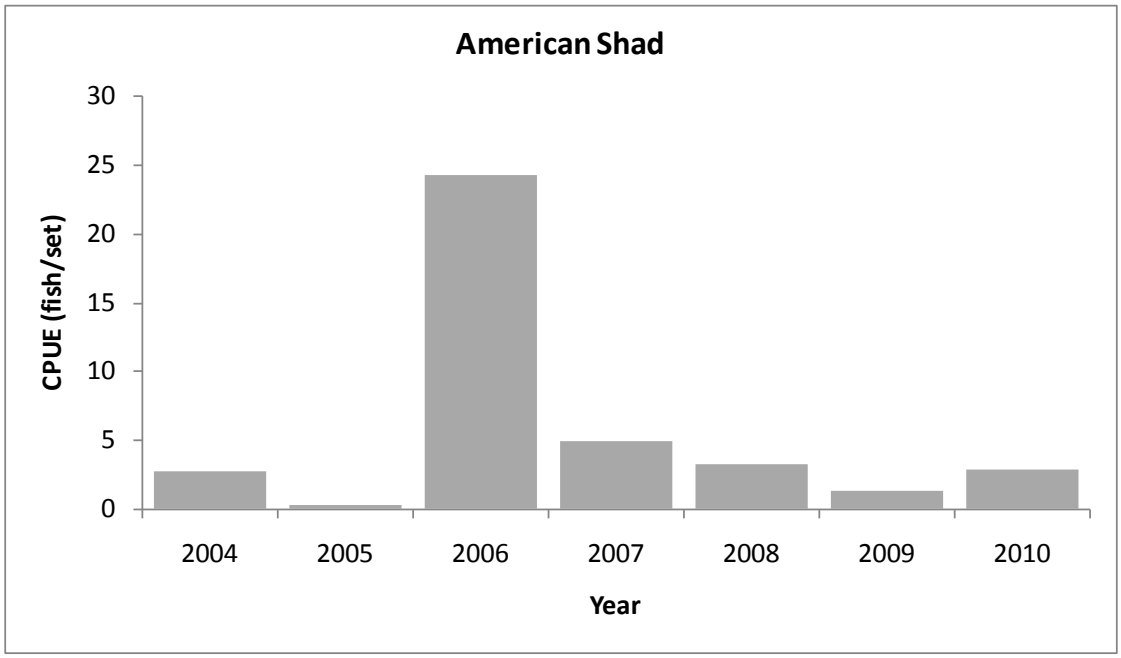


Figure 4.4.15. Relative abundance of juvenile American shad captured by beach seine in the Russian River Estuary. Samples are catch per unit effort (CPUE) from 96 to 300 seine sets yearly from May to October.

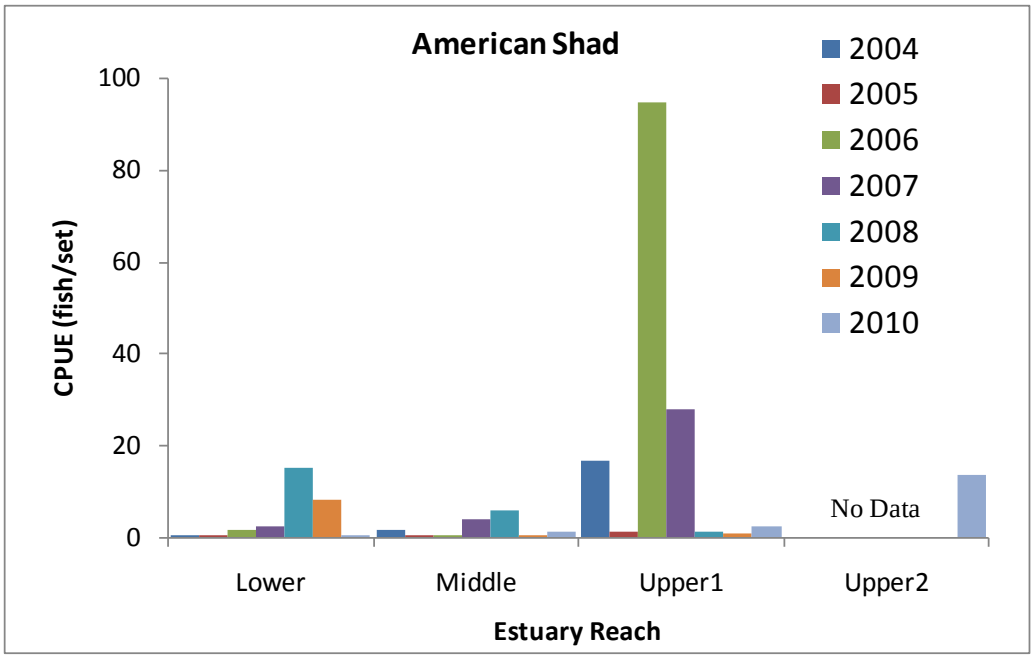


Figure 4.4.16. CPUE of juvenile American shad in the Russian River Estuary, 2004-2010. Fish were sampled by beach seine consisting of 96 to 300 sets annually. No surveys were conducted in the upper Estuary during 2004 and 2009.

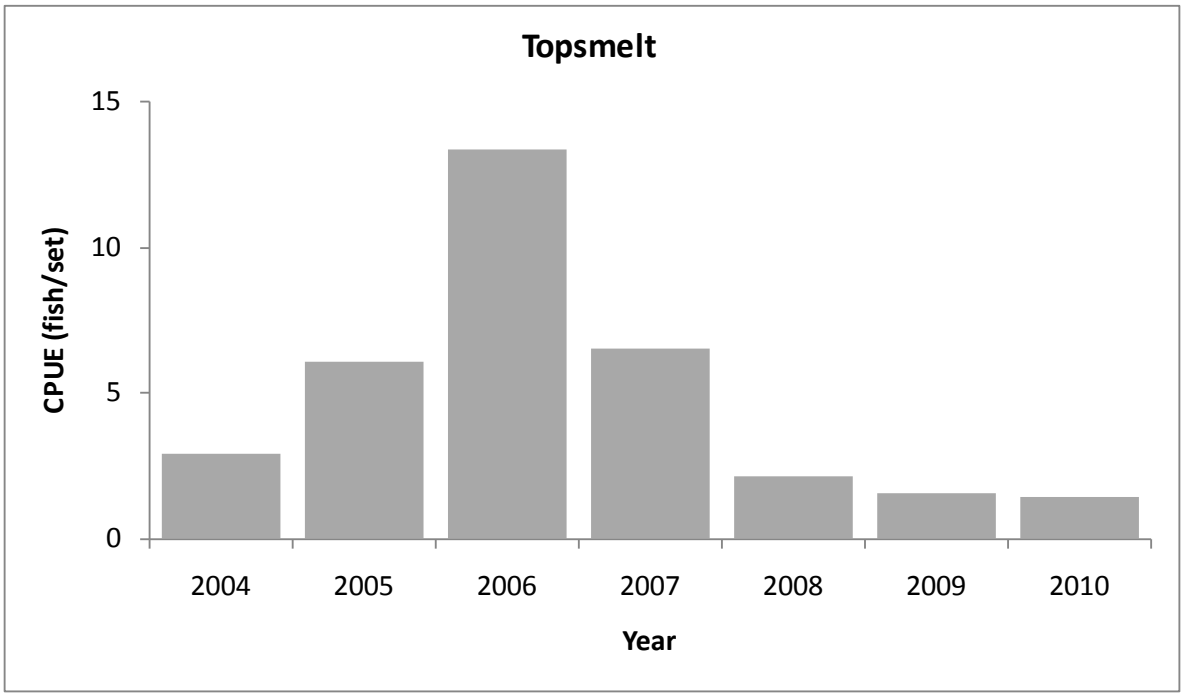


Figure 4.4.17. Relative abundance (CPUE) of topsmelt captured by beach seine in the Russian River Estuary. Samples are from 96 to 300 seine sets yearly from May to October.

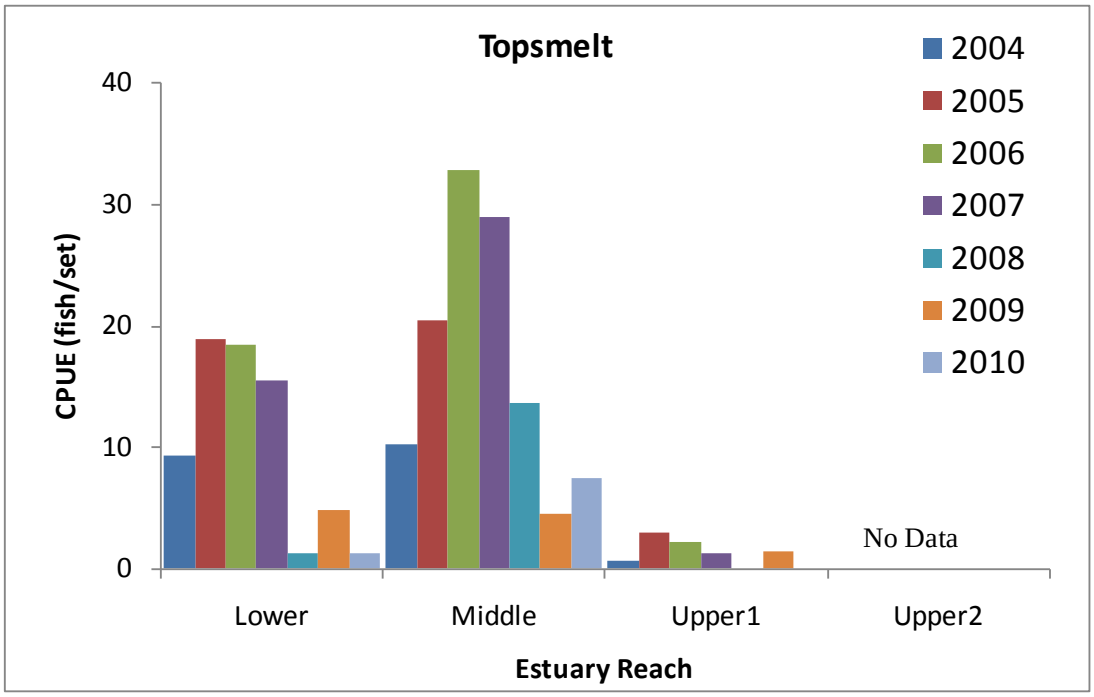


Figure 4.4.18. CPUE of topsmelt in the Russian River Estuary, 2004-2010. Fish were sampled by beach seine consisting of 96 to 300 sets annually. No surveys were conducted in the upper Estuary during 2004 and 2009.

The abundance of juvenile starry flounder in the Estuary has generally decreased since 2004 (Figure 4.4.19). Juvenile flounder have been at relatively low abundance since 2006. Seasonal changes in river outflow in combination with changing ocean conditions likely affect the strength of year classes (Baxter et al. 1999). The Estuary appears to be utilized primarily by young-of-the-year fish where most flounder captures are less than 100 mm fork length. The seasonal occurrence of starry flounder was typically highest in May and June, and then gradually decreased through September when few were caught. Starry flounder were distributed throughout the Estuary ranging from the River Mouth in the Lower Reach, with cool seawater conditions, to the Upper Reach, with warm freshwater (Figure 4.4.20). Starry flounder have been detected as far as Austin Creek at the upstream end of the Estuary (Cook 2006).

Conclusions and Recommendations

Fish Sampling - Beach Seining

The results of fish surveys from 2004 to 2010 found a total of 50 fish species from marine, estuarine, and riverine origins. The distribution of species was strongly influenced by the salinity gradient in the Estuary that is typically cool seawater near the mouth of the Russian River and transitions to warmer freshwater at the upstream end. Exceptions to this distribution pattern were anadromous and generalist fish that occurred throughout the Estuary regardless of salinity levels.

Although beach seining is widely used in estuarine fish studies, beach seines can only be used effectively near shore in relatively open water habitats free of large debris and obstructions that can foul or snag the net. Consequently, there is inherent bias in seine surveys (Steele et al. 2006). By design, our seining stations were located in areas with few underwater obstructions (i.e., large rocks, woody debris, etc) and this likely influenced our assessment of fish abundance and habitat use. However, the spatial and temporal aspects of our sampling do allow comparison among reaches and years.

To increase the statistical power to detect temporal and spatial differences in abundance for salmonids, Russian River Estuary beach seining efforts was intensified in 2010, as required by the Russian River Biological Opinion. The new fish sampling method included seining 25 sites in the Lower Estuary and 25 sites in the Upper Estuary that doubled the survey effort over previous study years.

Although the seining effort was doubled in 2010, the fish species composition remained similar as past years. This suggests that the past seining effort was adequate to inventory species present in the Estuary. There were four new fish species detected in the Estuary in 2010; however, three species were freshwater-residents known from the Russian River. The detection of these freshwater fish was likely attributable to high river flows during spring 2010 that maintained fresher conditions in the Estuary into the summer months. The fourth new species, a poacher, was likely a marine vagrant.

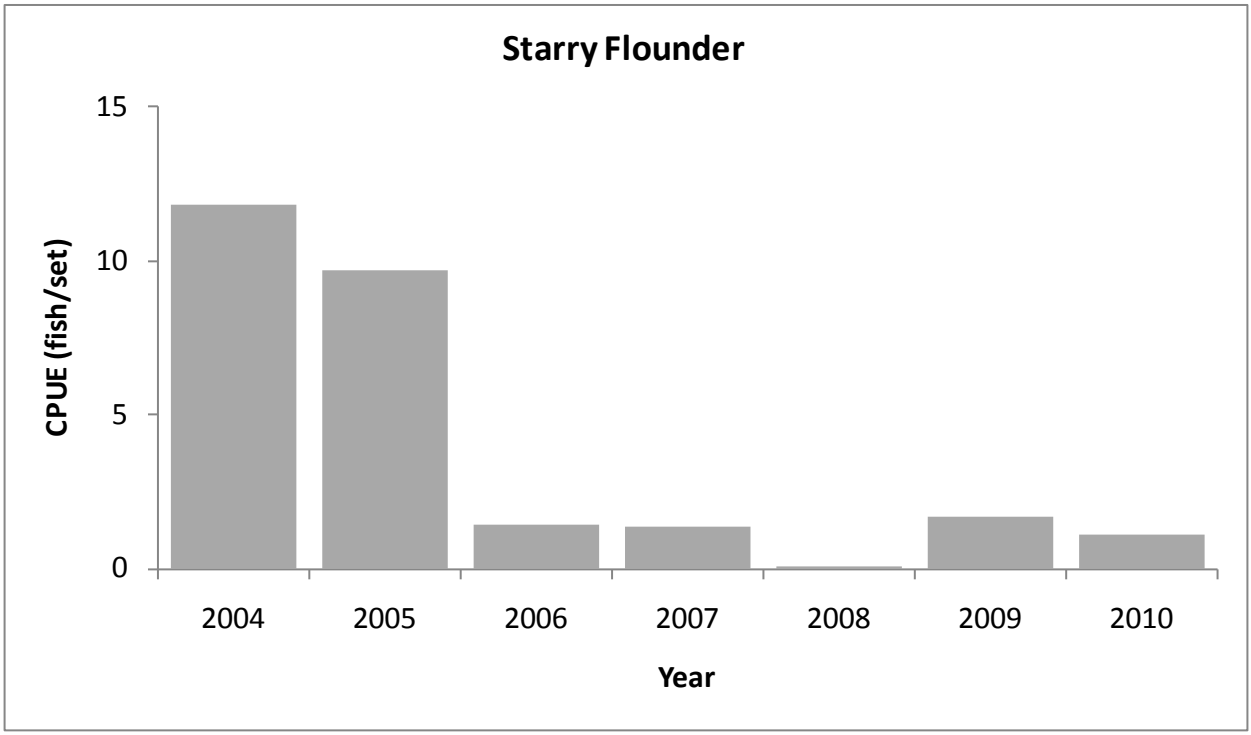


Figure 4.4.19. Relative abundance of juvenile starry flounder captured by beach seine in the Russian River Estuary. Samples are catch per unit effort (CPUE) from 96 to 300 seine sets yearly from May to October.

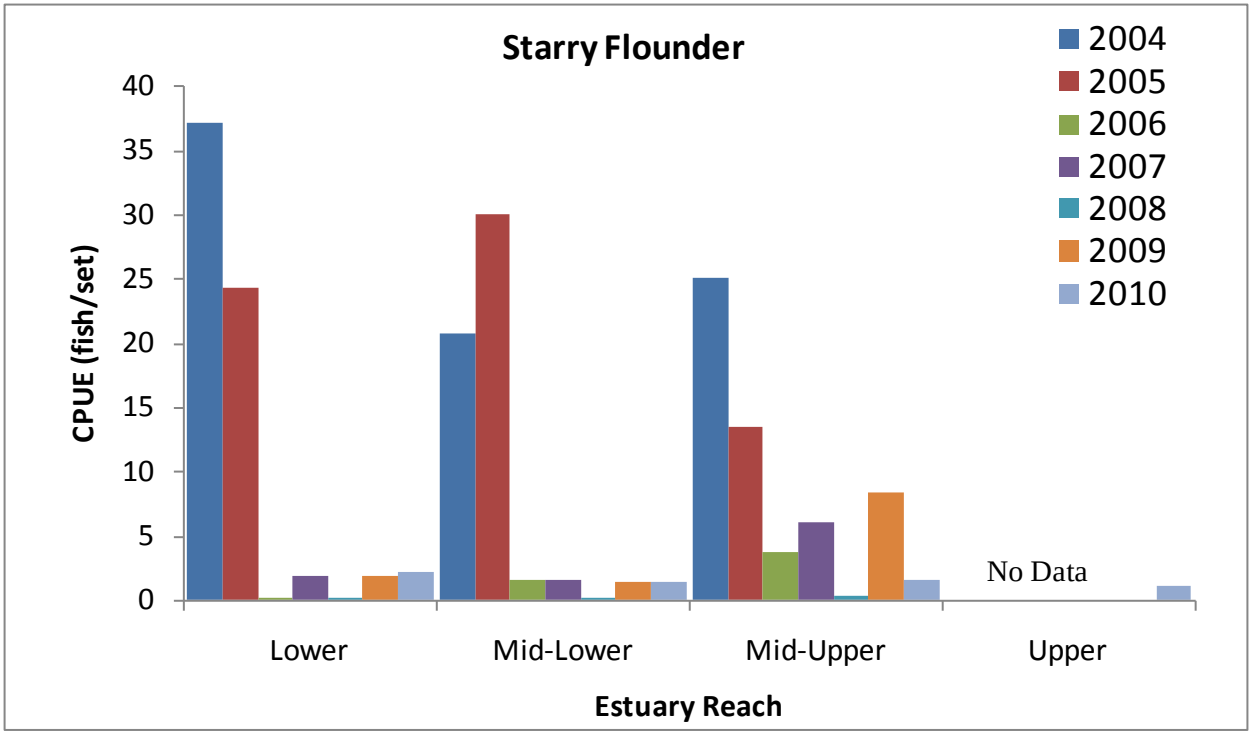


Figure 4.4.20. CPUE of juvenile starry flounder in the Russian River Estuary, 2004-2010. Fish were sampled by beach seine consisting of 96 to 300 sets annually. No surveys were conducted in the upper Estuary during 2004 and 2009.

The distribution and abundance of salmonids in the Estuary differed spatially, temporally, and by species. Steelhead were captured from May to October during each study year. Also, PIT-tagged steelhead showed strong site fidelity to specific sites in both the Upper and Lower Reaches of the Estuary. This indicates that steelhead rear in the Estuary under current river mouth management conditions. The synthesis in Chapter 10 provides a discussion about trends in abundance but the fluctuation in abundance of steelhead annually is likely attributed to the variability in adult spawner population size (i.e. cohort abundance), residence time of young steelhead before out-migration, and schooling behavior that affects susceptibility to capture by seining. Chinook salmon smolts spent less than half the summer rearing in the Estuary and were usually absent after July. Based on the detection of these smolts at most seining stations, they appear to use most estuarine habitats as they migrate to the ocean. In comparison, steelhead were found during the entire summer and were usually found in the Upper Reach of the Estuary. However, there are sites in the Middle and Lower Estuary (e.g., Jenner Gulch confluence) where steelhead are consistently found. There have been relatively low, but increasing, numbers of coho salmon smolts in the Estuary since studies began in 2004. Most coho were caught early in the season and were hatchery-born fish.

4.5 Crab and Shrimp Trapping

Trapping surveys were used to determine the relative abundance and distribution of macro-invertebrates in the Estuary. These surveys focused on marine species, began in 2004, and have been conducted annually.

Methods

Six permanent trap stations were distributed between the Russian River mouth in the Lower Reach and 6.4 km (4.0 mi) upstream in the Upper1 Sub-Reach (Figure 4.4.1). Traps were set approximately every 4 weeks from June to September/October annually. One shrimp trap and one crab trap baited with fish parts were located at each station. Traps were deployed in deep water during the morning and retrieved 24 hours later. Captured invertebrates were identified to species, measured, and released. Age classes of Dungeness crabs (*Metacarcinus* [*Cancer*] *magister*) were separated by an evaluation of size frequency data. For age class determination, we used ranges of carapace widths to incorporate summer growth of a cohort. Age class and carapace width categories were: age 0+/young-of-the-year (<60-75 mm); age 1+ (60-75 mm to 90-100 mm); and adult (≥90-100 mm).

Results

Our trapping studies have documented 8 freshwater and marine species in the Estuary (Table 4.5.1). Signal crayfish (*Pacifasticus leniusculus*) and red swamp crayfish (*Procambarus clarkii*) are both freshwater, non-native, invasive species that occur in the Upper Estuary. The most commonly encountered species were Dungeness crab and bay shrimp (*Crangon stylirostris*). Fish seining surveys commonly captured bay shrimp at fish seining stations from the Lower Reach to Upper1 Sub-Reach. Other marine macro-invertebrates found since 2004 include hairy rock crab (*Cancer jordani*), yellow shore crab (*Hemigrapsus oregonensis*), spot shrimp (*Pandalus platyceros*), and the invasive European green crab (*Carcinus maenus*).

Table 4.5.1. Macroinvertebrates trapped in the Russian River Estuary, 2004-2010. Each reach contained two trapping stations comprised of a crab and shrimp trap. Captures are from monthly trap events from June to September. *Incidentally captured during fish seining surveys.

		Year		Estuary Reach 2010			
Habitat	Species	2004-2008	2009	Lower	Middle	Upper1	Total Catch
Freshwater	signal crayfish	X	X				0
Freshwater	red swamp crayfish	X					0
Marine/ estuarine	Dungeness crab	X	X	111	87		198
Estuarine	bay shrimp	X					*
Estuarine	European green crab	X					0
Marine	hairy rock crab	X					0
Marine	yellow shore crab	X					0
Marine	spot shrimp	X					0

Dungeness crab prefer sandy to sandy-mud bottoms and range from the intertidal zone to depths greater than 100 m. Adult Dungeness crabs spawn in the open ocean. The shrimp-like larvae are planktonic and drift with offshore currents (Morris et al. 1980). Larvae metamorphose into juvenile crabs from April to June and have a similar appearance as adults. Juveniles are bottom dwellers and rear in near-shore coastal waters, including estuaries (Wild and Tasto 1983). At least 2 years of age is required for sexual maturity.

The Estuary is utilized by several age classes of Dungeness crab, although abundance has varied by year (Figure 4.5.1). The use of the Estuary by rearing juveniles was relatively high in 2004 (13.6 crab/trap) and since then the abundance of juveniles has been low. Although juvenile crabs appear nearly absent during several years, hundreds to thousands of age 0+ crabs where caught during 2006 to 2010 during fish seining surveys, suggesting that young crabs use shallow water habitats in the Estuary. Adults were consistently trapped in relatively low numbers over most study years. The captures of Dungeness crab were typically low in June and then increased during August or September. Dungeness crabs were only found in the Lower and Middle Reaches of the Estuary (Figure 4.5.2). Adults were caught mostly in the Lower Reach near the Russian River mouth where seawater occurs. Young-of-year (age 0+) crabs were most abundant in the Middle Reach were brackish and seawater occurs.

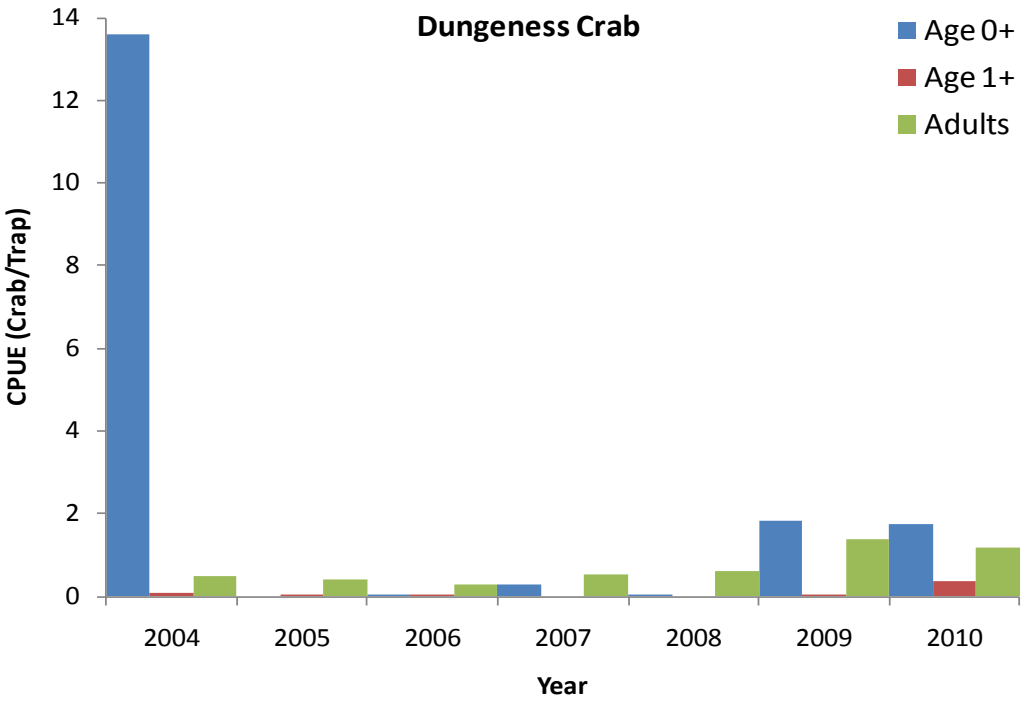


Figure 4.5.1. Annual abundance of Dungeness crab in the Lower, Middle, Upper1 reaches of the Russian River Estuary, 2004-2010. Six stations consisting of a crab and shrimp trap each were sampled monthly from June to September/October. Age classes are based on carapace widths.

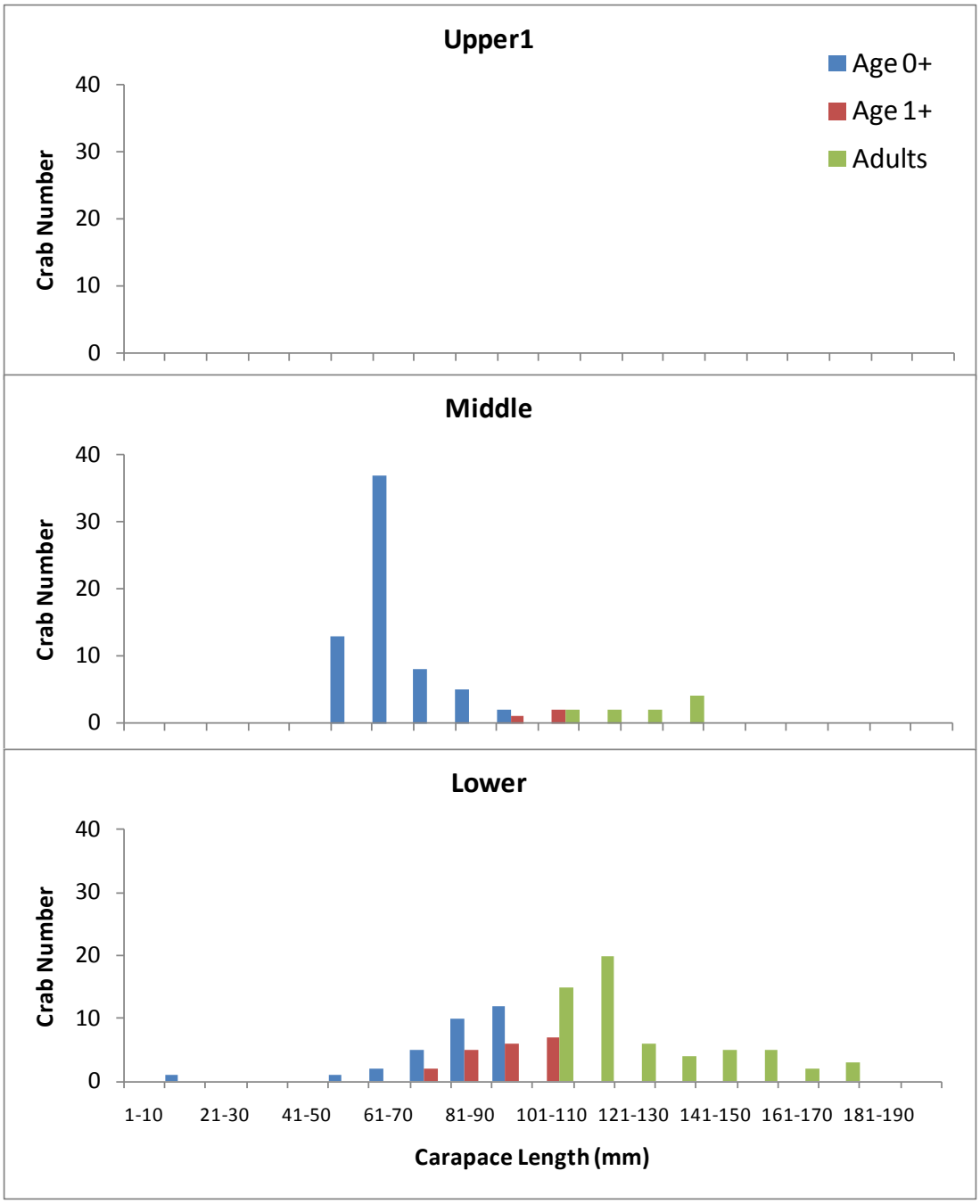


Figure 4.5.2. Abundance of Dungeness crab in the Russian River Estuary during 2010. Each reach contained two stations each comprised of a crab and shrimp trap. Captures are from monthly trap events from June to September/October. Age classes are based on season and carapace size.

Conclusions and Recommendations

Crab and Shrimp Surveys

The Russian River Estuary has shown a bust or boom pattern of abundance for rearing juvenile Dungeness crabs. Since 2004, the river mouth has been predominantly open during the spring suggesting that access to the Estuary does not affect the annual change in abundance of juvenile crabs. Changing winter ocean temperatures and currents, and low ocean productivity, are likely important factors. These ocean conditions can affect larval Dungeness crab survival and migration to inshore areas and estuaries.

The distribution of Dungeness crab appears to be restricted to portions of the Estuary with strong tidal influence. Adults are found in full strength seawater in the Lower Estuary. Juveniles utilize brackish water in the Lower and Middle Reaches. Our trap stations were positioned in the deepest water at a site with usually high salinities. Shoreline areas with brackish water, which may provide suitable rearing habitat for juvenile crabs, were under sampled. Beach seining for fish was conducted in shallow brackish areas and often detected large numbers of juvenile crabs. This disparity suggests a vertical separation (as a result of water stratification) by crab age group in the Estuary. Trap sampling and water quality monitoring along a cross-sectional profile may elucidate preferred habitat conditions of crab age groups. This new sampling method may provide insight on the distribution of rearing Dungeness crab during flooded lagoon periods.

References

Baxter R., K. Hieb, S. DeLeon, K. Fleming, and J. Orsi. 1999. Report on the 1980-1995 fish, shrimp, and crab sampling in the San Francisco Estuary, California. California Department of Fish and Game. Technical Report 63.

Cook, D. G. 2004. Russian River estuary flow-related habitat project, survey methods report 2003. Santa Rosa, (CA): Sonoma County Water Agency. 15 p.

Cook, D. G. 2005. Russian River estuary fish and macro-invertebrate studies, 2004. Santa Rosa (CA): Sonoma County Water Agency. 26 p.

Cook, D. G. 2006. Russian River estuary fish and macro-invertebrate studies, 2005. Sonoma County Water Agency.

Day, J.W., C.A.S. Hall, W.M. Kemp, and A. Yáñez-Arancibia. 1989. Estuarine ecology. New York: John Wiley and Sons.

ENTRIX, Inc. 2001. Russian River biological assessment. September 29, 2004. Prepared for U.S. Army Corps of Engineers and Sonoma County Water Agency.

Fuller, J. and D. Manning. 2005. Residence time and migratory behavior of juvenile steelhead in the Russian River estuary. 2005 project proposal. Santa Rosa (CA): Sonoma County Water Agency.

Heckel, M. 1994. Russian River estuary study 1992-1993. Prepared for Sonoma County Department of Planning and California State Coastal Conservancy.

Horne, A.J. and C.R. Goldman. 1994. Limnology. Second Edition. McGraw Hill.

Martini-Lamb, J., J. Church, D. Cook, J. Fuller and D. Manning. 2005. Russian River estuary sandbar breaching monitoring plan. Santa Rosa (CA): Sonoma County Water Agency.

Merritt Smith Consulting. 2000. Biological and water quality monitoring in the Russian River estuary, 1999. Fourth annual report. March 24, 2000. Prepared for Sonoma County Water Agency.

Morris, R. H., D. P. Abbott, and E. C. Haderlie. 1980. Intertidal invertebrates of California. Stanford: Stanford University Press. 690 p.

Moyle, P. B. 2002. Inland fishes of California. University of California Press. Pp. 502.

National Marine Fisheries Service. 2005. Biological and conference opinion for Clean Water Act Section 404 permit for Russian River estuary breaching activities conducted 2005-2010. May 20, 2005. File number 151422SWR04SR9206.

Sonoma County Water Agency and Merritt Smith Consulting. 2001. Biological and water quality monitoring in the Russian River estuary, 2000. Fifth annual report. June 21, 2001. Santa Rosa (CA): Sonoma County Water Agency.

Sonoma County Water Agency. 2011. Russian River biological opinion status and data report 2009-10. February 28. Santa Rosa (CA): Sonoma County Water Agency.

Steele, M. A., S. C. Schroeter, and H. M. Page. 2006. Experimental evaluation of biases associated with sampling estuarine fishes and seines. Estuaries and Coasts 29:1172-1184.

USGS (U.S. Geological Survey). 2007. USGS National Water Information System, USGS 11467000 Russian R Nr Guerneville CA. http://waterdata.usgs.gov/nwis

Wild, P. W., and R. N. Tasto (Department of Fish and Game). 1983. Life history, environment, and mariculture studies of the Dungeness crab, *Cancer magister*, with emphasis on the central California fishery resource. Fish Bulletin 172. 349 p.

5: Dry Creek Habitat Enhancement, Planning, and Monitoring

5.1 Dry Creek Habitat Enhancement

The Biological Opinion contains an explicit timeline that prescribes a series of projects to improve summer and winter rearing habitat for juvenile coho salmon and steelhead in Dry Creek (Table 5.1.1). During the initial three years of implementation, 2008 to 2011, the Water Agency is charged with improving fish passage and habitat in selected tributaries to Dry Creek and the lower Russian River. The status of those efforts is described in Chapter 6 of this report. For the mainstem of Dry Creek, during this initial period, the Water Agency is directed to perform fisheries monitoring, develop a detailed adaptive management plan, and conduct feasibility studies for large-scale habitat enhancement and a potential water supply bypass pipeline.

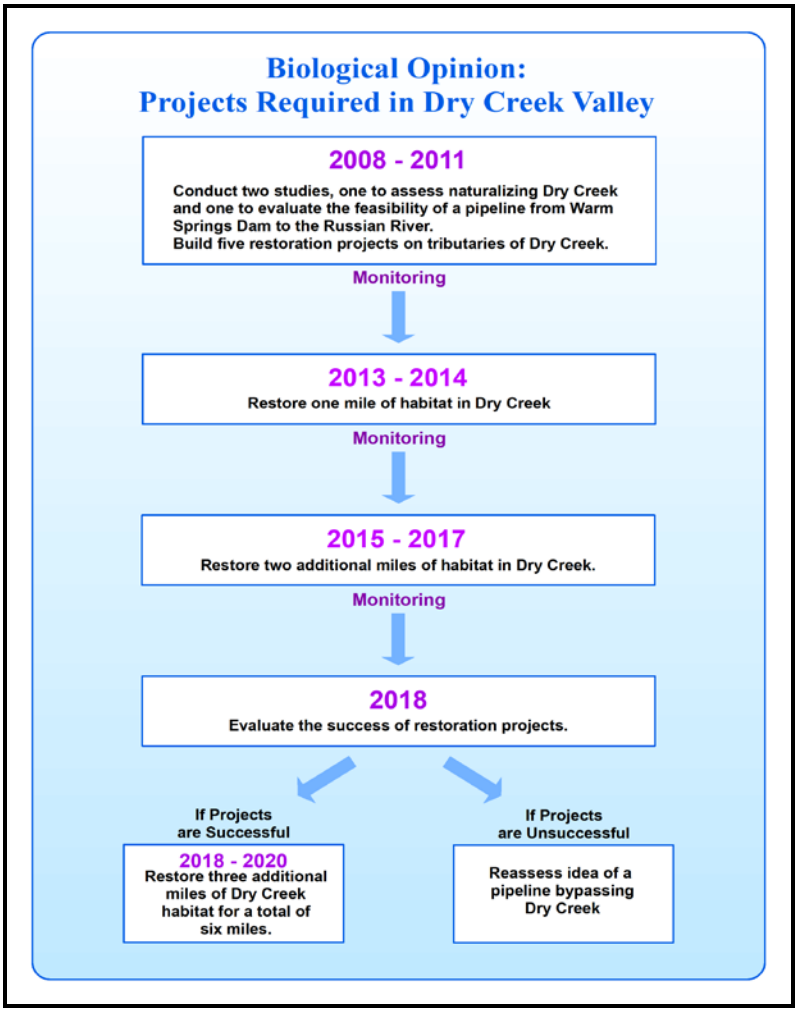


Figure 5.1.1. Timeline for implementation of Biological Opinion projects on Dry Creek.

Habitat Enhancement Feasibility Study

The Water Agency regulates summer releases from Warms Springs Dam along a 14 mile reach of Dry Creek from Lake Sonoma to the Russian River. This abundant, cool, high quality water has tremendous potential to enhance the Russian River's coho and steelhead population but it flows too swiftly to provide maximum habitat benefit. By modifying habitat conditions to create refugia from high water velocities along 6 miles of Dry Creek, NMFS and DFG assert that water supply releases can continue at current discharge levels of approximately 100 cubic feet per second (cfs) and potentially historic discharge levels up to 175 cfs.

To plan large scale enhancement of the Dry Creek channel, the Water Agency has retained Inter-Fluve, Inc. to conduct extensive field surveys and produce a series of reports detailing habitat enhancement opportunities along Dry Creek. Interfluve's work is being conducted in three phases: 1) inventory and assessment of current conditions; 2) feasibility assessment of habitat improvement approaches; and 3) conceptual design of habitat approaches deemed feasible. The phase 1 and 2 reports have been submitted to date.

During 2010, Interfluve developed the Phase 2 Draft Habitat Enhancement Feasibility Study Report (Appendix C-1). The report was released to the public in May 2011 and identifies 45 potential areas for construction of low velocity habitat with depth and cover characteristics conducive to rearing juvenile coho salmon and steelhead. These potential habitat enhancement areas capitalize on Dry Creek's current condition (described in a report released in 2009, see Manning and Martini-Lamb 2011) and are not designed to return Dry Creek to its historic condition.

The opportunities identified in the draft report are distributed throughout the 14 mile length of Dry Creek. However, different reaches of Dry Creek present unique geomorphic and hydrologic constraints and Interfluve divided the stream into three segments. In the upper reach (mile 11 to 13.7), the influence of Warm Springs Dam on streamflow, substrate, and channel dimensions is most pronounced. The stability of this reach provides opportunities for long lasting "constructed" habitat features such as side channels, backwaters, and log structures. In the lower reach between Westside Road Bridge and the confluence with the Russian River (mile 0 to 3), conditions are amenable to constructing projects designed to let natural river processes develop habitat over time. The middle reach between Pena Creek and Westside Road (mile 3 to 11), has opportunities for both constructed habitat and river process based approaches.

The study identified 45 sites amenable to the construction of backwater pools, alcoves, side channels, enhanced main channel pools, and constructed riffles. By total stream length, the upper, middle, and lower reaches described above contain, 1.6, 5, and 2.1 miles of habitat enhancement opportunities, respectively. of proposed a ranking scheme for the 45 project opportunity sites that incorporates geomorphic risk (i.e., the risk of fill, scour, or large scale channel movement that could affect the longevity of a project), quantity of potential habitat benefit, and landowner willingness. The next step in the feasibility study process, to be completed in 2011, is development of conceptual designs, cost estimates, and rankings for each of the 45 project opportunity sites.

Demonstration Project

As described in the Public Outreach Chapter of this report, the Water Agency must engage a diverse group of stakeholders to implement the Biological Opinion. Dry Creek is held almost entirely in private ownership and Water Agency staff must work in concert with landowners of more than 170 parcels to study, plan, and construct habitat enhancements. The Biological Opinion's 5 year timeline prior to construction of the first mile of habitat enhancement acknowledges this challenge and the depth of study, planning, and environmental compliance required for implementation. A forward looking group of property owners along a one mile stretch of the stream near Lambert Bridge, in the middle of Dry Creek Valley, approached the Water Agency with the opportunity to advance the schedule and demonstrate habitat enhancement techniques in their reach of the stream. The Water Agency has welcomed this opportunity, and worked throughout 2010 to develop the Dry Creek Habitat Enhancement Demonstration Project.

The Demonstration Project has four goals and objectives:

1. Maximize the general ecological lift to the reach to the extent practicable within the current geomorphic and hydraulic function of the stream,
2. Increase the availability of high quality summer rearing and winter refugia habitat for salmonids (specifically coho and steelhead), given the current physical function of the system,
3. Stabilize areas of problem erosion using techniques that also enhance habitat conditions for fish, and
4. Demonstrate enhancement techniques that may be utilized elsewhere in Dry Creek in order to meet the habitat requirements of the Biological Opinion.

Inter-Fluve is working simultaneously on the habitat enhancement study for the full 14 mile length of Dry Creek and detailed engineering designs for the demonstration mile. In early 2010, Inter-Fluve produced a 10 percent conceptual design that described enhancement techniques and their potential location along the one-mile reach (Manning and Martini-Lamb 2011). In close consultation with NMFS and DFG, Inter-Fluve advanced the engineering design to the 30 percent complete phase in 2010 and 60 percent complete phase during the first half of 2011 (Appendix C-2, 60% Design Report). Water Agency staff prepared a CEQA Initial Study and Mitigated Negative Declaration for the Demonstration Project and released it for public comment on June 3, 2011. During the remainder of 2011, Interfluve will advance the design to the 90 percent complete phase, Water Agency staff will work with property owners to obtain necessary easements for construction and maintenance, and submit permit applications to regulatory agencies. The project is proceeding toward construction in summer 2012.

Adaptive Management and Monitoring Plan

A multi-entity effort to develop an adaptive management framework (AMF) for validating the effectiveness of habitat enhancement in mainstem Dry Creek is currently underway. The group is facilitated by ESSA Technologies Ltd. (an independent consulting firm from Vancouver Canada) and it consists of the Sonoma County Water Agency, NMFS, CDFG, USACE and Inter-Fluve, Inc. The Water Agency intends to use the AMF developed through this process as the basis for the adaptive management plan described in the Russian River Biological Opinion. The plan will include criteria and approaches for evaluating project implementation (implementation monitoring), changes in habitat (effectiveness monitoring) and biological responses (validation monitoring).

During 2010, ESSA is held a series of workshops with the agencies, including USACE, to build the decision trees and guidelines for a state-of-art adaptive management plan. Planning for work in the Demonstration Project mile is being used to develop an adaptive management framework that can be applied to subsequent phases of the Dry Creek Habitat Enhancement Project. The final AMF will be completed in 2011.

Pipeline Bypass Feasibility Study

The Dry Creek Bypass Pipeline Feasibility Study is being conducted to evaluate the feasibility of constructing a raw water pipeline that would bypass flows from Warm Springs Dam around Dry Creek to the Russian River. Should 3 miles of the habitat enhancements efforts described above prove ineffective by 2018, the Water Agency must draw upon the results of the feasibility study to advance planning and construction of a bypass pipeline (Figure 5.1.1). The three primary components being evaluated are the pipeline inlet structure, the pipeline route, and an outlet structure. Additionally, the study is evaluating the potential to increase hydroelectric generation capacity. Objectives of the study are to identify uncertainties and potentially significant issues associated with the proposed bypass pipeline, develop and evaluate project alternatives including construction costs, and identify the preferred project alternative.

Throughout 2010, Engineering firm HDR, Inc., evaluated multiple variations on three primary pipeline routes: 1) the Northern Route, WSD to the Russian River , near Geyserville; 2) Central Route, WSD to confluence of the Russian River and Dry Creek via the Dry Creek Valley; and 3) a Southern Route that would extend to the Water Agency's facilities at Mirabel. HDR also identified alternatives for the inlet structure and multiple locations for an outlet structure.

The Draft Dry Creek Bypass Pipeline Feasibility Report was submitted in March of 2011 and released to the public in May 2011 (Appendix C-3). The preferred alternative consisted of a 72 inch diameter pipe with a Headbox inlet structure, a central route down Dry Creek Road to Kinley Road with an outlet structure consisting of a riverbank outfall adjacent to the 101 bridge, upstream of the confluence of Dry Creek and the Russian River. Estimated cost of the project is $141.5 million (2011 dollars). However, because three miles of habitat enhancement are required in Dry Creek prior to the 2018 decision about pursuit of a pipeline option, the habitat enhancement costs must be included in the minimum expense for a pipeline option. When estimated habitat enhancements are factored in, the pipeline cost is $162 million. Upon review of the document by Water Agency staff, key stakeholders in Dry Creek Valley, including the Water Agency's water contractors, a Final Feasibility Report will be completed by August, 2011.

5.2 Dry Creek Downstream Migrant Trapping

To validate the effectiveness of Dry Creek habitat enhancements and inform the adaptive management process, the Water Agency is conducting a number of salmonid monitoring activities in Dry Creek. One of these efforts is the operation of a rotary screw trap on Dry Creek to monitor population trends in juvenile coho salmon, steelhead, and Chinook salmon. The downstream migrant trapping effort began in 2009 with plans to continue until at least 2018. 2010 represents the second year of downstream migrant trapping data on Dry Creek.

Methods

A rotary screw trap with a 1.5 m diameter cone was anchored to the West Side Road bridge, located 3.3 km upstream from the confluence of Dry Creek and the Russian River (Figure 5.2.1). Weir panels were installed adjacent to the rotary screw trap in order to divert downstream migrating salmonids into the trap that may have otherwise avoided the trap.

Fish handling methods and protocols used in 2010 were similar to those used in 2009 (see Manning and Martini-Lamb 2011). Fish captured in the trap were identified to species and enumerated. A subsample of each species was anesthetized and measured for fork length each day, and a subsample of salmonid species was weighed each week. With the exception of Chinook, all fish were released downstream of the first riffle located downstream of the trap. Each day, up to 50 Chinook smolts ($\geq$50 mm) were finclipped and released approximately 100 m upstream of the trap for the purpose of estimating population abundance using program DARR (Bjorkstedt 2005). Finclipped fish that were recaptured in the trap were noted and released downstream (the lengths and weights of recaptured fish were not recorded a second time). We did not attempt to estimate the population size of steelhead parr (we define steelhead parr as including age-0 and older non-smolts) or smolts moving past the trap site and instead we simply report the trap catch. Based on trapping results from 2009, trap efficiency and numbers were too low to attempt to estimate trapping efficiency for steelhead smolts (Manning and Martini-Lamb 2011). An assumption of the mark-recapture model underlying DARR is that marked fish are available for recapture. Because steelhead parr are not necessarily motivated to move downstream (like smolts), attempting to estimate efficiency in the same way as Chinook represents a likely violation of that assumption.

We also installed and fished fry traps at Westside Road (river km 3.2) just downstream of the rotary screw trap site and at Yoakim Bridge just upstream of Yoakim Bridge (river km 17.1). Each trap consisted of a funnel on the upstream end fashioned by attaching rubber flaps to a lid of a five gallon plastic bucket. A slit was cut into the lid and the rubber flaps were inserted through the slit and tied off in the shape of a funnel. The lid was then snapped onto a perforated five gallon plastic bucket and the bucket was anchored to the stream bottom so that the funnel end faced upstream. Two fry traps at each at Yoakim Bridge and Westside Road were installed on 5/5. Traps were fished throughout the period at both sites with the exception of weekends and during periods of high flows until they were removed on 6/11. Traps were checked in the morning each day the traps fished.

Figure 5.2.1. Photograph of the rotary screw trap on Dry Creek located beneath the Westside Road bridge in Healdsburg, 2009.

Results

Because of high flows in Dry Creek, we were unable to install the rotary screw trap until April 21. The trap was checked daily during operation from April 22 until it was removed on August 31 (Figure 5.2.2).

Estimated average weekly capture efficiency for Chinook smolts ranged from just under 3% to over 23% (Figure 5.2.3) resulting in an estimated population size of 86,594 (95% CI: ± 17,425). Based on that estimate, May 23 marked the point at which one-half of the Chinook population had migrated past the rotary screw trap (Figure 5.2.4).

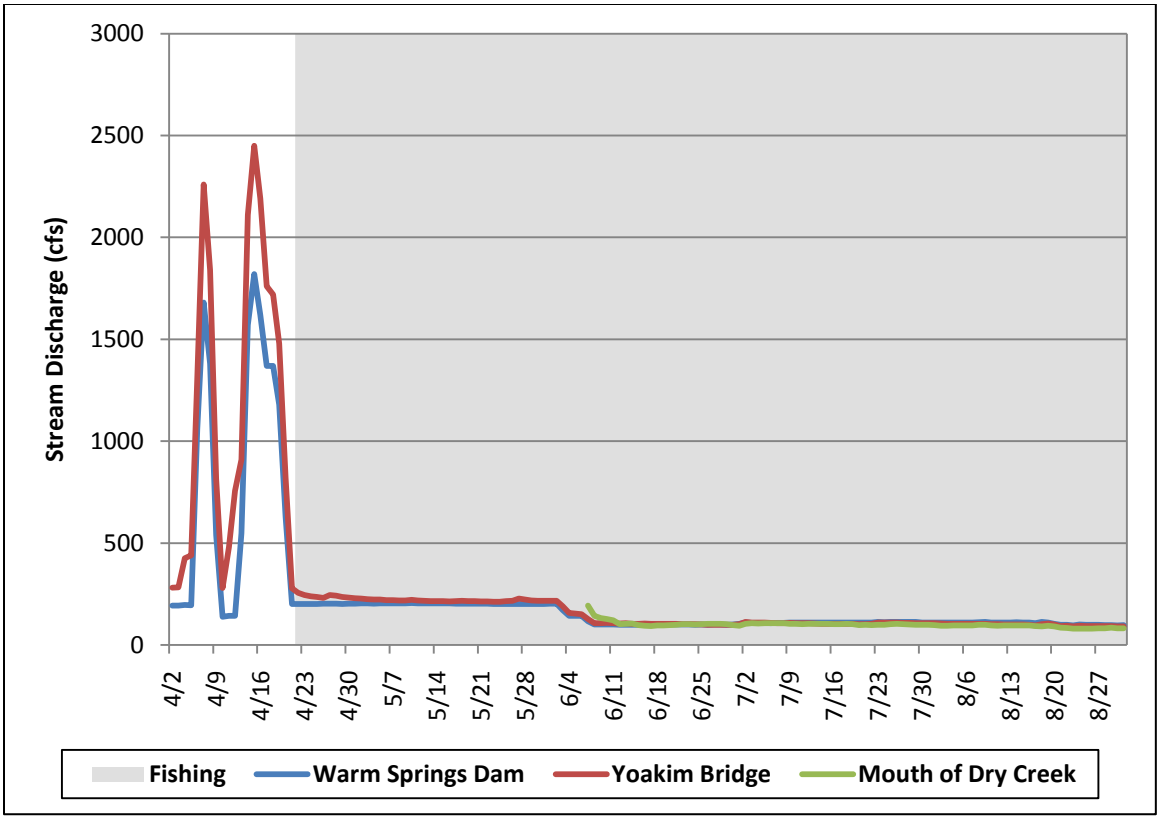


Figure 5.2.2. Releases from Warm Springs Dam (USGS gauge 11465000), discharge at Yoakim Bridge (USGS gauge 11465200), discharge at the mouth (USGS gauge 11465350) and the days the Dry Creek rotary screw trap fished, 2010. Note that the gauge at the mouth is a low flow gauge and is only valid for discharges <200 CFS.

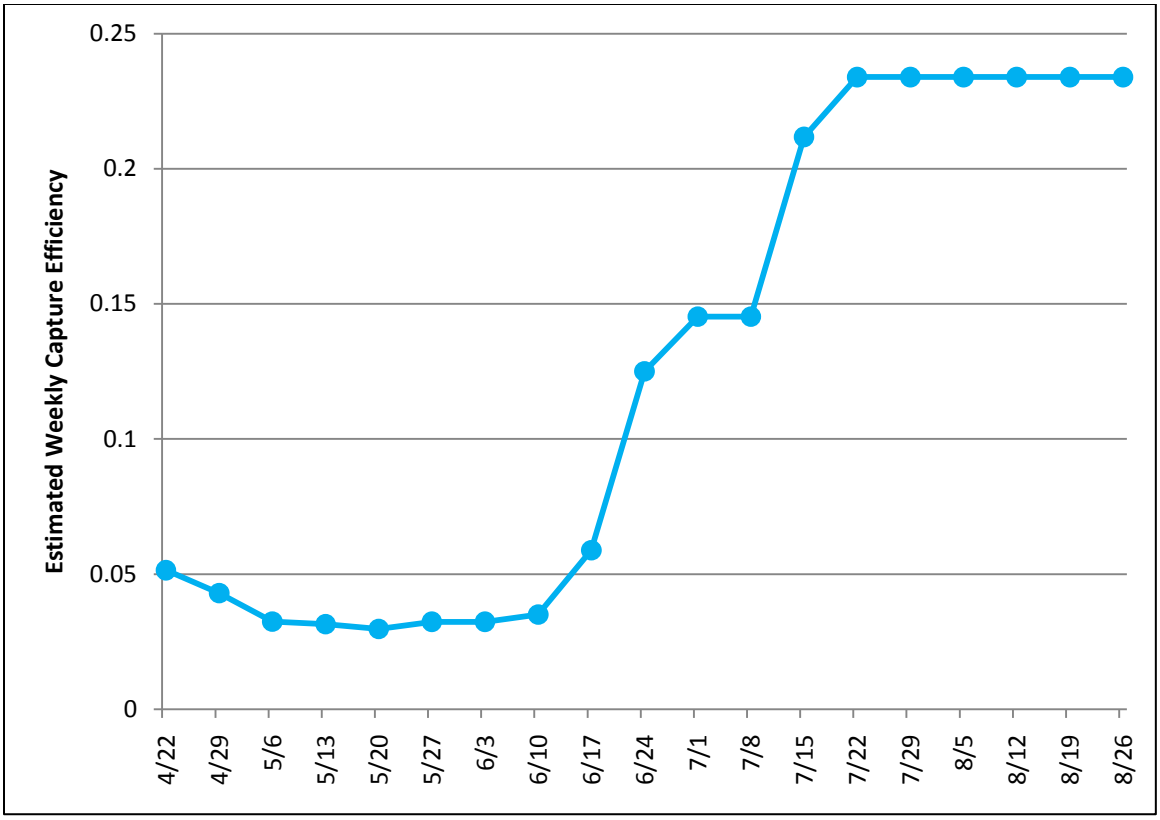


Figure 5.2.3. Weekly estimated capture efficiency and estimated overall average weekly capture efficiency for Chinook salmon at the Dry Creek rotary screw trap, 2010.

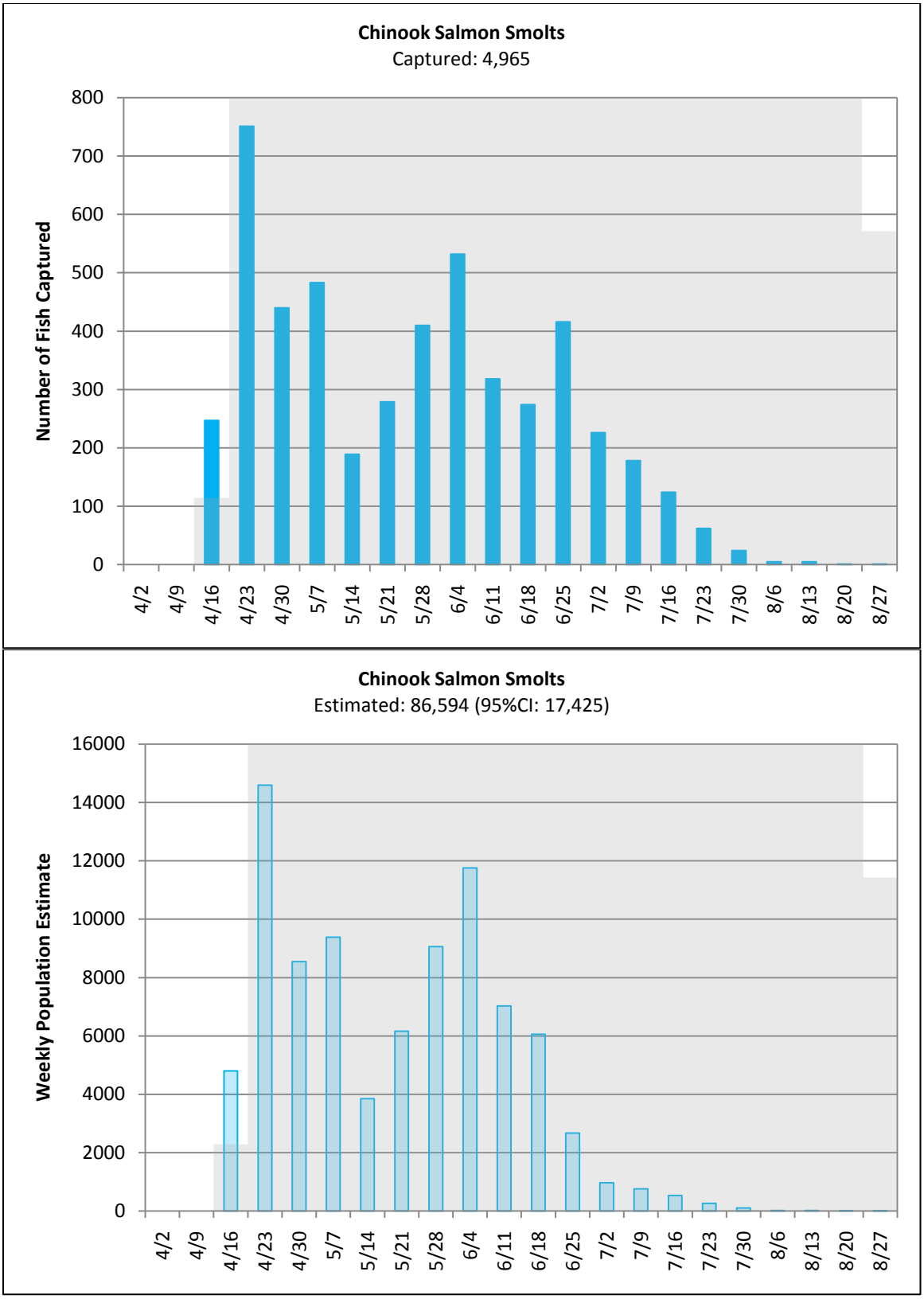


Figure 5.2.4. Weekly trap catch and population estimate of Chinook salmon smolts in the Dry Creek rotary screw trap, 2010. Note that because of high flows the trap was not installed until 4/21 (the week of 4/16).

Only 33 steelhead smolts were captured in 2010; we suspect that at least part of the reason for this low number was the relatively late installation of the trap relative to the steelhead smolt migration season. Steelhead parr capture peaked in late-June with a season total of 2,049 (Figure 5.2.5); in early July the catch of steelhead parr began to diminish.

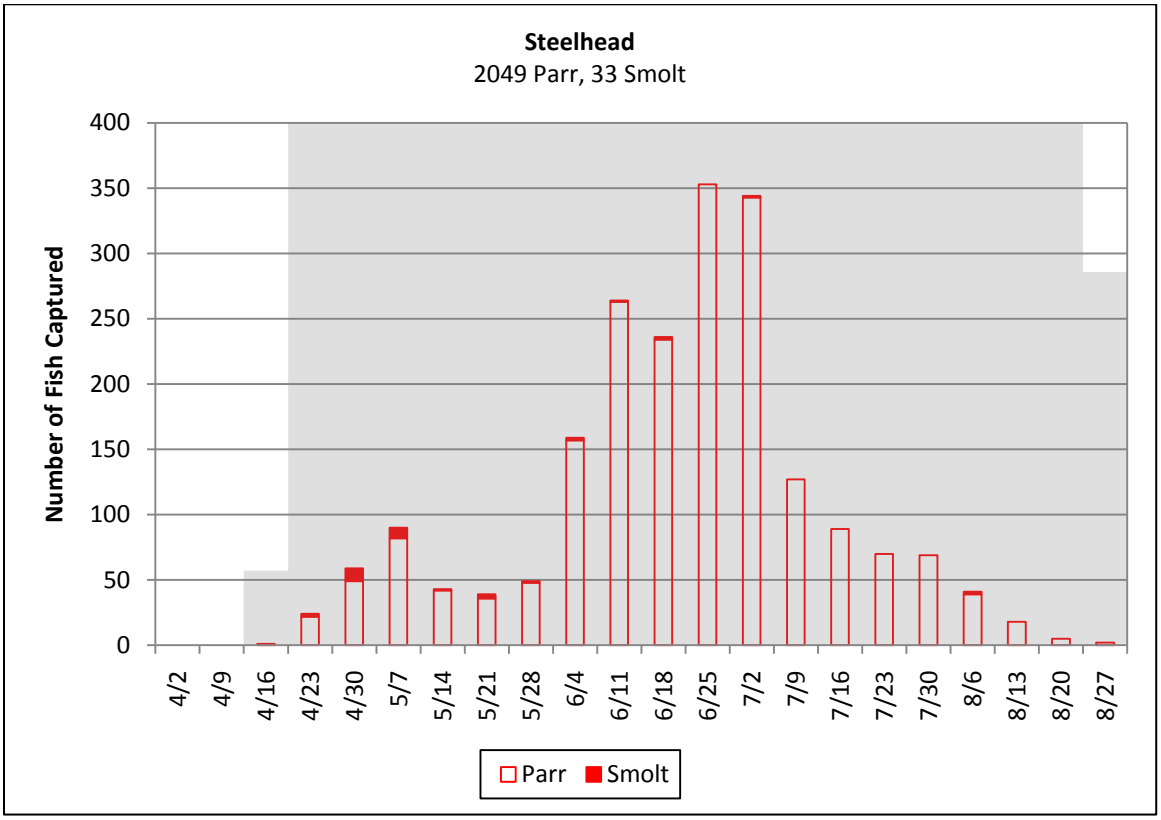


Figure 5.2.5. Weekly trap catch of juvenile steelhead in the Dry Creek rotary screw trap, 2010. Note that because of high flows the trap was not installed until 4/21 (the week of 4/16).

Coho were the least abundant of the 3 salmonid species captured; only 22 (19 hatchery-origin and 3 non-fin-clipped) were caught during the trapping season (Figure 5.2.6).

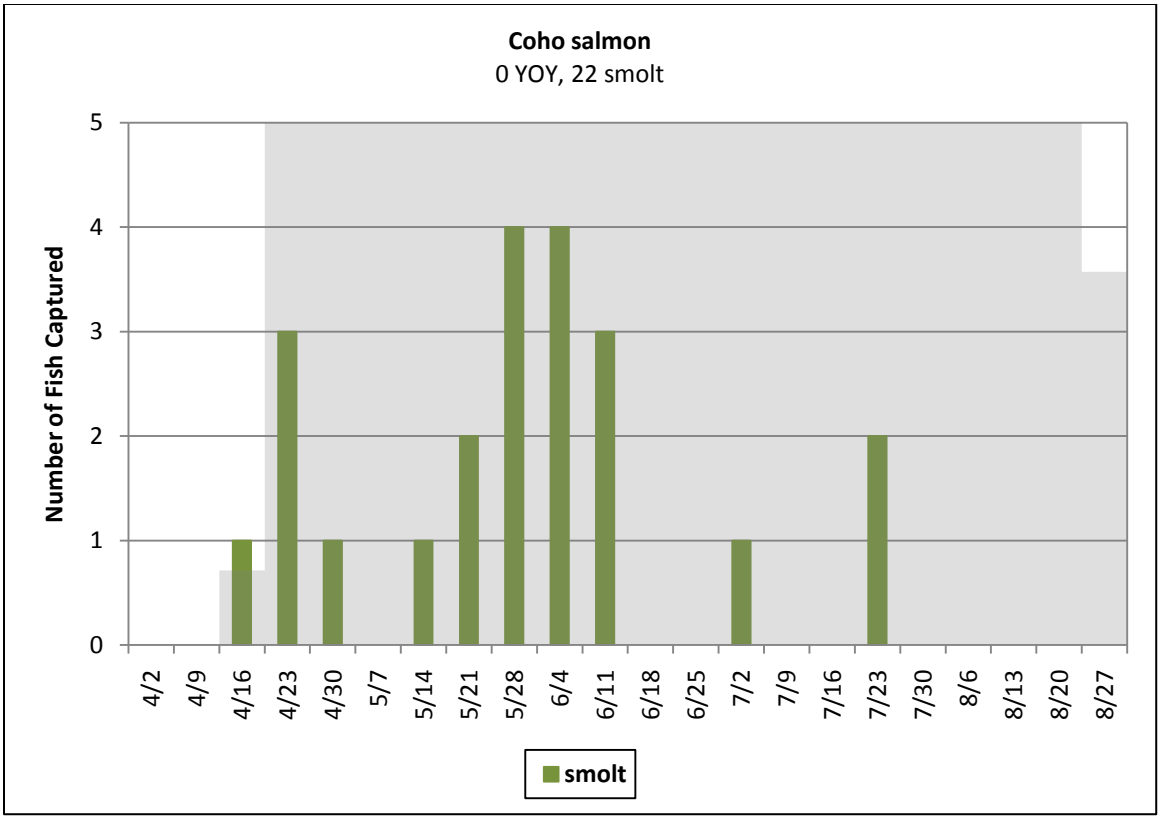


Figure 5.2.6. Weekly trap catch of coho smolts in the Dry Creek rotary screw trap, 2010. Note that because of high flows the trap was not installed until 4/21 (the week of 4/16).

The weekly sizes of Chinook smolts (Figure 5.2.7) and steelhead parr (Figure 5.2.8) showed a generally increasing trend over the season. In addition to salmonids, individuals representing 18 non-salmonid species were captured.

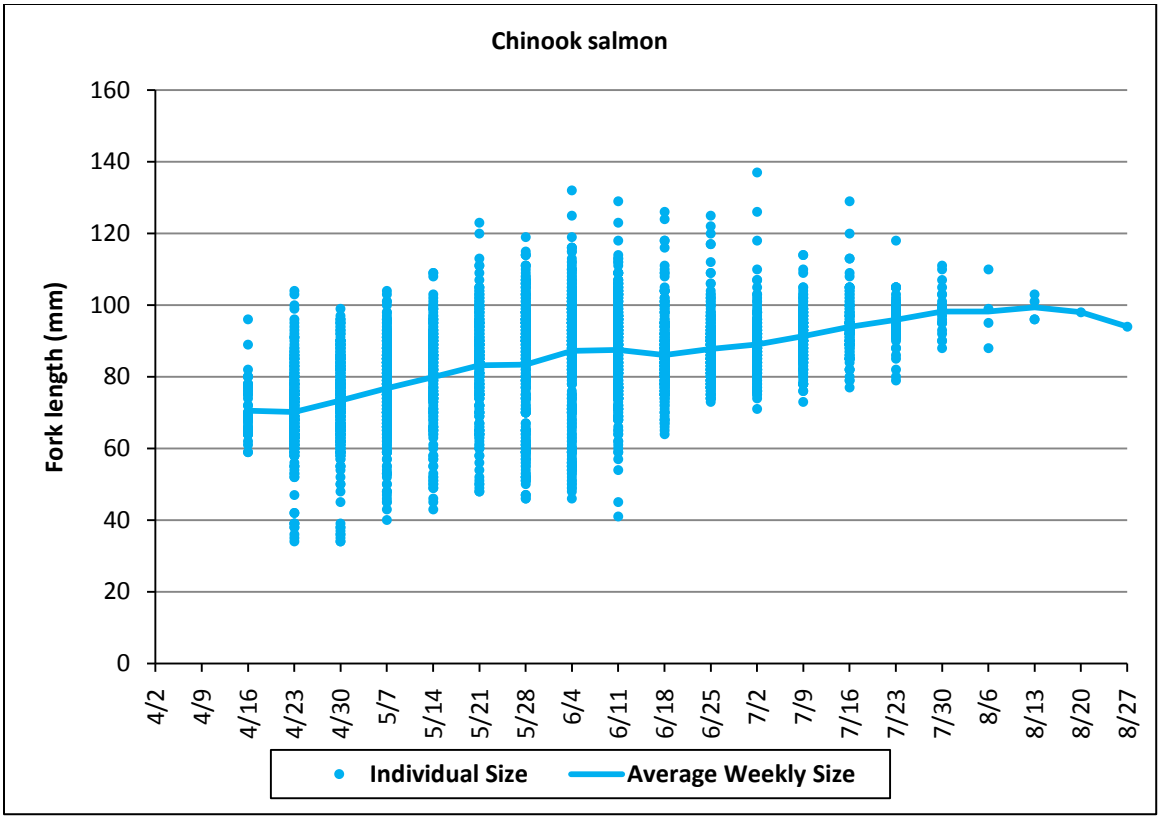


Figure 5.2.7. Fork lengths of Chinook salmon smolts captured in the Dry Creek rotary screw trap by week, 2010.

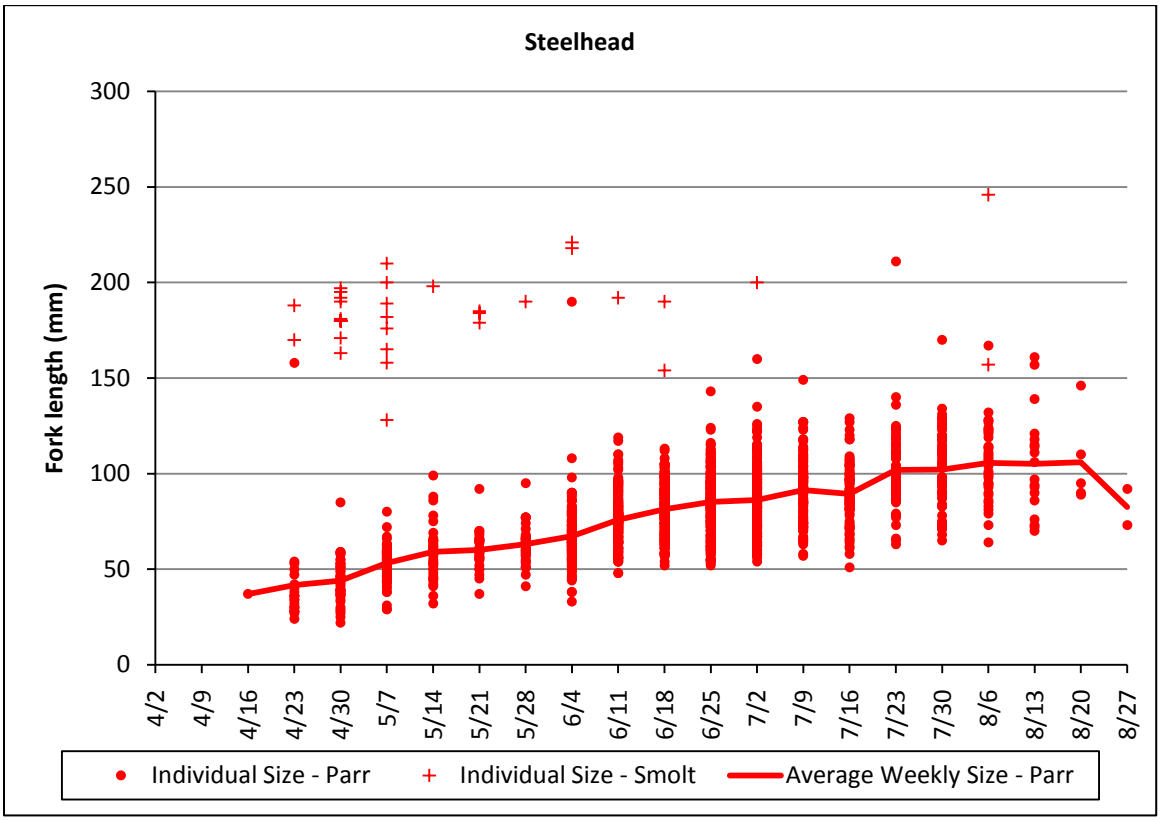


Figure 5.2.8. Fork lengths of juvenile steelhead captured in the Dry Creek rotary screw trap by week, 2010.

The fry traps at Yoakim Bridge were fished for 17 days at each site (Westside Road and Yoakim Bridge). Capture of salmonid fry at the traps was low with 37 captured at Yoakim Bridge and 6 captured at Westside Road. As in 2009, we observed dozens of fry milling about on the stream margins on several occasions. All fry captured appeared to be in good condition with no mortality observed. We were unable to identify individuals to species given their small size (sizes were generally in the 25-35 mm range).

Conclusions

The population estimate of Chinook salmon smolts on Dry Creek in 2010 (86,595 ±8,890) was 57% lower than the population estimate in 2009 (203,491 ±22,785) (Figure 5.2.9). At least part of this difference can be explained by the later installation date in 2010 (April 21) as compared to 2009 (April 6); however, late winter/early spring flows in Dry Creek were much higher in 2010 as compared to 2009 (Figure 5.2.10) leading us to suspect that high discharges at a critical time in Chinook fry development and/or emergence may also be partly responsible. The capture of steelhead parr in the trap in 2010 (2,049) was also much lower than in 2009 (5,226). Some of this difference may be explained by the low adult steelhead return in 2008-09 and 2009-10 as evidenced by returns to the two Russian River fish collection facilities (Figure 5.2.11). The adult steelhead cohorts in 2008-09 and 2009-10 represent the two lowest returns since 1992 when both Warm Springs and Coyote were online.

Although we have only collected two years of downstream migrant trapping data on Dry Creek thus far, the collective evidence support the conclusion that a host of abiotic and biotic factors, as well as conditions influencing sampling efficacy and timing, are and will continue to be challenges in our efforts to validate the success of eventual habitat enhancement measures in Dry Creek.

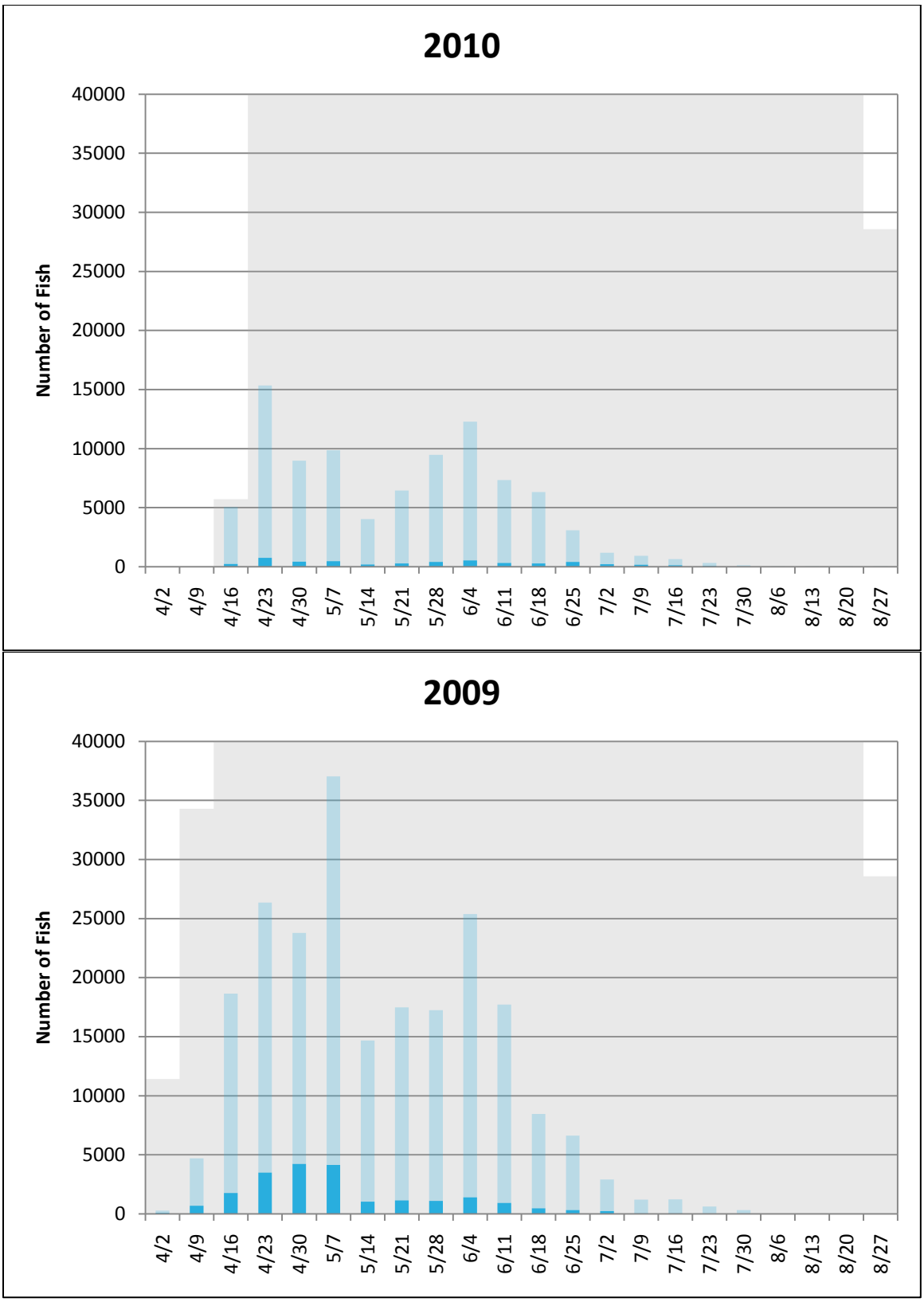


Figure 5.2.9. Weekly trap catch and population estimate of Chinook salmon smolts in the Dry Creek rotary screw trap in 2010 (upper panel) and 2009 (lower panel). Because of high flows in 2010, the trap was installed on 4/21 (the week of 4/16) which is 15 days later than the trap was installed in 2009.

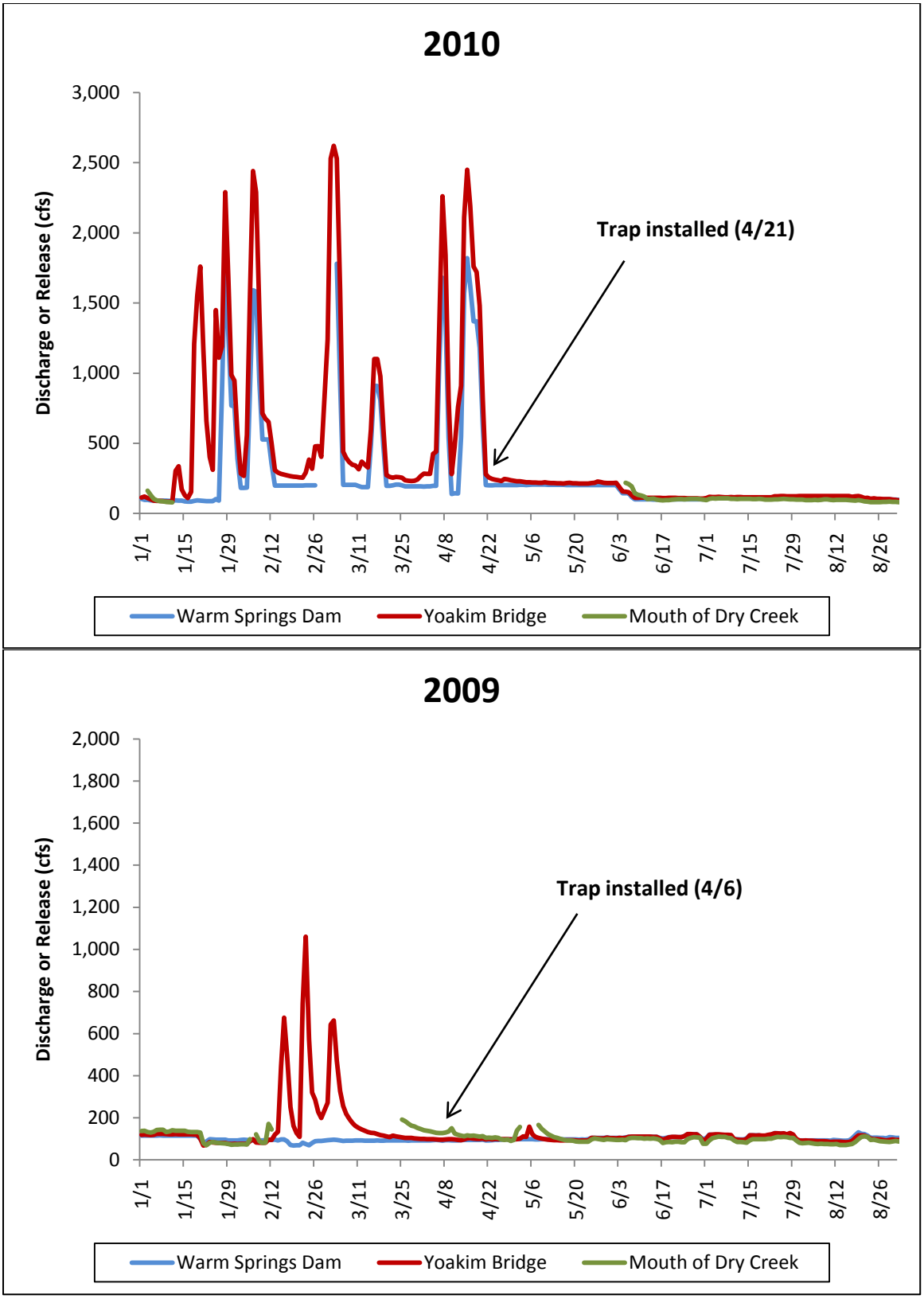


Figure 5.2.10. Releases from Warm Springs Dam (USGS gauge 11465000), discharge at Yoakim Bridge (USGS gauge 11465200), and discharge at the mouth (USGS gauge 11465350) in 2009 and 2010. Note that the gauge at the mouth is a low flow gauge and only shows discharges <200 cfs.

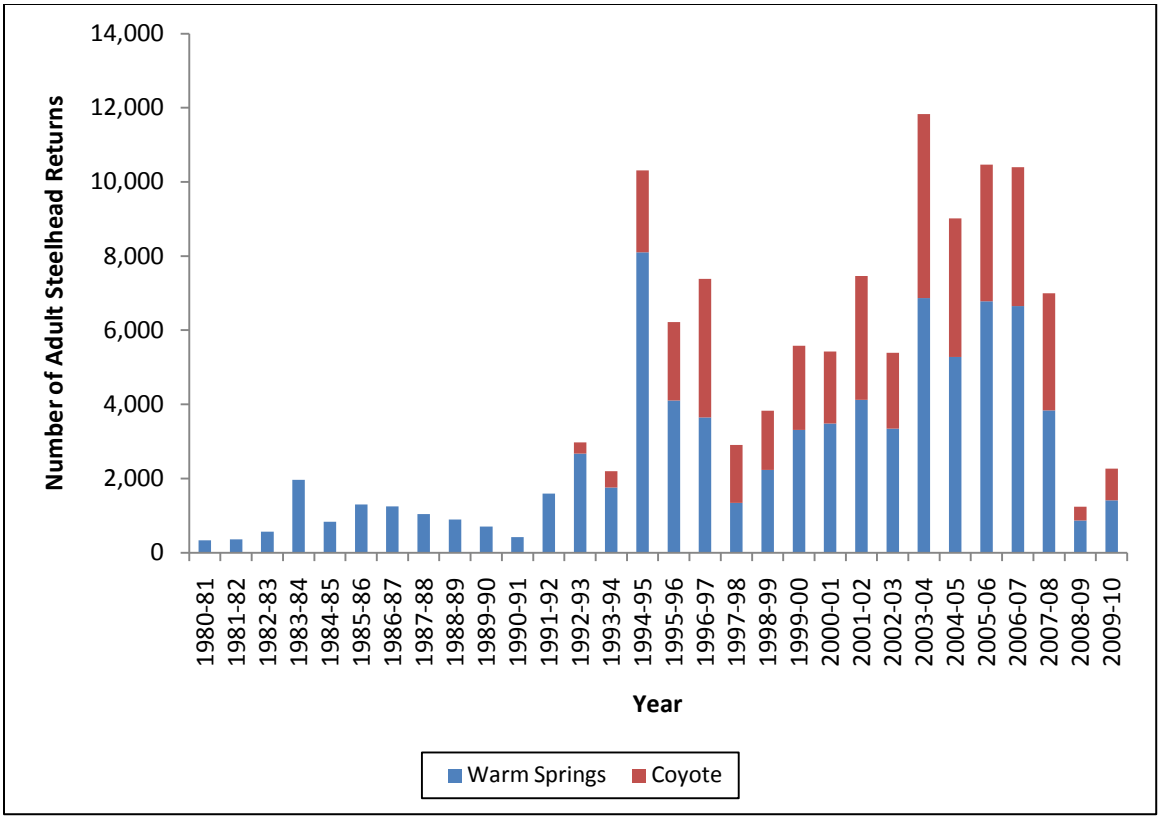


Figure 5.2.11. Number of adult steelhead returns to Russian River rearing facilities, 1980-2010.

References

Bjorkstedt, E.P. 2005. DARR 2.0: updated software for estimating abundance from stratified mark-recapture data. NOAA Technical Memorandum NMFS-SWFSC-368. 13 p.

5.3 Juvenile Salmonid Sampling

In the Russian River Biological Opinion Status and Data Report Year 2009-10 (Manning and Martini-Lamb 2011), the Water Agency outlined six possible metrics that could be considered for validation monitoring of juvenile salmonids with respect to eventual habitat enhancements in the mainstem of Dry Creek: habitat use, abundance (density), size, survival, growth, and fidelity. A major focus of validation monitoring to date in Dry Creek has been on evaluating the feasibility of sampling methods to accurately estimate each of those metrics while simultaneously attempting to understand how limitations in sampling approaches may affect our ability to validate project success. These same validation metrics and associated limitations and uncertainties have been discussed and are being incorporated into the adaptive management plan described above. Despite the focus in 2008 and 2009 on the feasibility of sampling methods, data collected during those years will be incorporated into the larger data set to validate the success of eventual habitat enhancements.

Several noted authors in the field of habitat enhancement advocate the idea of comparing a set of reference or control sites to treatment sites in order to decouple the confounding effects of non-

treatment variables (see Roni 2005 and references therein). Along with others, they recommend before-after, control-treatment (BACT) designs. Such designs have been effectively used in systems to assess the benefits to stream salmonid populations related to natural channel design restoration (Baldigo and Warren 2008), augmentation of winter habitat (Solazzi et al. 2000) and placement of large woody debris (Cederholm et al. 1997; Solazzi et al. 2000). Based on this and similar work, the current draft of the AMF outlines three spatial scales of validation monitoring for juvenile salmonids for mainstem Dry Creek: site/feature, reach and entire mainstem. The draft further suggests the appropriate target life stage and temporal scale of monitoring for each spatial scale (Table 5.3.1).

Table 5.3.1. Proposed target life stages, validation metrics, spatio-temporal scale and monitoring tools for validation monitoring in mainstem Dry Creek.

Spatial scale	Target life stage	Target metric(s)	Temporal scale	Primary monitoring tool(s)
Site/feature	Juvenile (non-smolt)	Habitat use, abundance (density), size, growth	Post-construction	Snorkeling, electrofishing, PIT tags and antennas
Reach	Juvenile (non-smolt)	Abundance (density), size, survival, growth, fidelity	Pre-construction (baseline) vs. post-construction	Electrofishing, PIT tags and antennas
Mainstem Dry Creek[11]	Smolt	Abundance	Ongoing to capture long-term trend	Downstream migrant trap, PIT antennas

The Water Agency has been collecting baseline validation monitoring data for juvenile salmonids since 2008. In 2008 the focus was at the site scale, while in 2009 and 2010 the focus was at the reach scale with limited sampling at the site scale. We plan to continue our focus on the reach scale until habitat enhancements are implemented; at the time we plan to shift our focus to the site scale. Pre-construction data that is currently being collected at the reach scale will be used to assist in understanding the magnitude of differences in target metrics among reaches that arise from non-treatment variables (e.g., the effects of marine survival on subsequent juvenile density) as opposed to treatment variables (e.g., the effects of habitat enhancement on subsequent juvenile density). For example, consider the following hypothetical scenario. During the pre-construction period the average density in a non-treatment reach (control) is 10% lower than the average density in a reach that is targeted for eventual habitat enhancement (treatment). Now imagine that during the post-construction period density is 25% higher in the treatment reach as compared to the control reach. From that, we could infer that 15% of that difference (25%-10%) is because of habitat enhancement. Site-scale data could be collected and used in a similar way to compare densities in newly-enhanced habitats as compared to adjacent non-enhanced habitats.

In the current section, we summarize our results for 2010 and then place those findings in the context of validation monitoring results from 2008 and 2009. Along the way, we attempt to highlight the necessary assumptions of the approaches we employed in 2010 and suggest whether those approaches may prove beneficial as a way to help inform the larger question of whether eventual habitat enhancements in mainstem Dry Creek are successful.

[11] Monitoring data from the downstream migrant trap is covered in a separate section of this report.

Methods

In 2010, we continued the focus began in 2009 of sampling at the reach scale by making multiple electrofishing passes through relatively long stream sections in an attempt to characterize validation metrics for each reach. However, as in 2008 and 2009, we also sampled shorter sections within the stream section that has been targeted for the first mile of habitat enhancements in mainstem Dry Creek (the "demonstration" reach). Though all of the stream sections sampled in 2010 were similar to those sampled in previous years (Figure 5.3.1), there were important differences in some of the sampling approaches that allowed us to estimate additional metrics as compared to 2008 and 2009.

Reach-scale sampling. Because a significant sampling focus during the pre-construction period is at the reach scale, we need to first define those reaches. To accomplish this we considered that because hydro-geomorphic conditions are an important contributor to habitat characteristics, we could use the same reaches defined by Inter-Fluve (2011) in Dry Creek. Those reaches are: the lower reach (Dry Creek mouth to just downstream of the lowest grade control sill; river km 0.00 to 4.83), the middle reach (just downstream of the lowest grade control sill to the confluence of Pena Creek; river km 4.83 to 11.00) and the upper or "tailwater" reach (river km 11.00 to 22.00).

This sampling involved capturing individual juvenile steelhead ≥60 mm in one contiguous section of each reach that could be sampled with a backpack electrofisher in July, PIT-tagging them, bounding the downstream end of each section with a PIT antenna array from July to early autumn and re-sampling the same sections in each reach late September/early October. Each antenna array consisted of either one antenna (upper reach) or two antennas in close proximity to one another (middle and lower reaches). For PIT-tagged fish that were captured in July then again in autumn (i.e., recaptured), we calculated over-summer growth rates (mm of change in fork length per day). By using the multistate-robust-design model in program MARK (White and Burnham 1998), we estimated over-summer survival and emigration. Fall re-sampling actually consisted of two passes through each section so that abundance could be estimated using the Petersen mark-recapture model after adjusting for fish emigrating from the section between the mark and recapture events (core sampling approach). Therefore, for each section in each reach we estimated true survival, emigration and abundance (density) as well as growth rates for fish ≥60 mm fork length in July.

The choice of contiguous stream sections in each reach to sample was limited because of low sampling gear efficacy and unsafe wading conditions in particularly deep or swift habitat. In the upper reach, we sampled a 183 m long section extending from river km 19.12 to 19.29; in the middle reach, we sampled a 251 m long section extending from river km 9.48 to 9.73; in the lower reach, we sampled a 526 m long section extending from river km 2.80 to 3.33 (Figure 5.3.1). Within each section, the location of capture for each individual was recorded to the nearest 46 m.

Site-scale sampling. Site-scale sampling involved defining two sites within the demonstration reach, then sampling each site with a backpack electrofishing unit in early autumn followed 2-3 days later by a recapture pass through each section. Based on past experience with failure of structures to temporarily close the section in mainstem Dry Creek (Manning and Martini-Lamb 2011), we did not attempt to close sections to fish exit between passes. Because of this, unless we assume geographic closure during the period between the mark and recapture events, abundance estimates at these sites may be biased by an unknown amount. In 2009 we suggested "core-sampling" as a way of evaluating this assumption over relatively longer sections (Manning and Martini-Lamb 2011); however, because

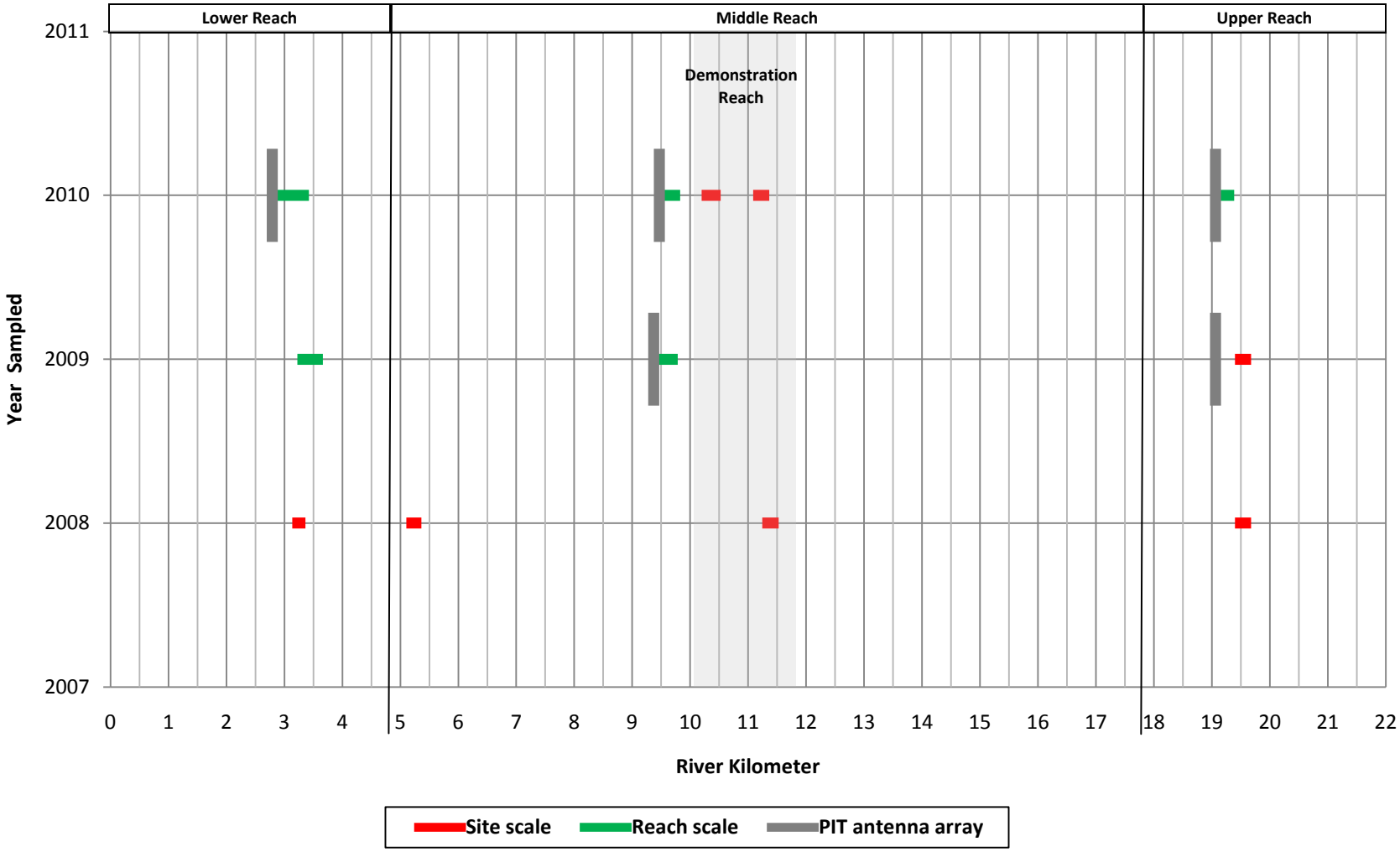


Figure 5.3.1. Years sampled and river kilometer (from the mouth) where juvenile steelhead populations were sampled in mainstem Dry Creek, 2008-2010. Line length for each site is scaled to the length of stream sampled. Data collected at the site scale were analyzed using mark-recapture (either a multiple-pass depletion or Petersen model) and reach scale data collected in 2009 was analyzed with the core-sampling approach (see Manning and Martini-Lamb 2011 for details) while reach scale data collected in 2010 was analyzed with the multistate-robust-design model using program MARK (White and Burnham 1998). The gray-shaded area indicates the stream section that has been targeted to receive the first mile of habitat enhancements ("demonstration reach").

available PIT readers were being used in other locations for reach-scale monitoring we were unable to evaluate this assumption at these sites.

Results

Densities of juvenile steelhead ranged from less than 0.05 fish/m^2 to 0.17 fish/m^2. Overall, densities in 2010 appeared to be slightly lower than densities in 2009 and significantly lower than densities observed in 2008 (Figure 5.3.2).

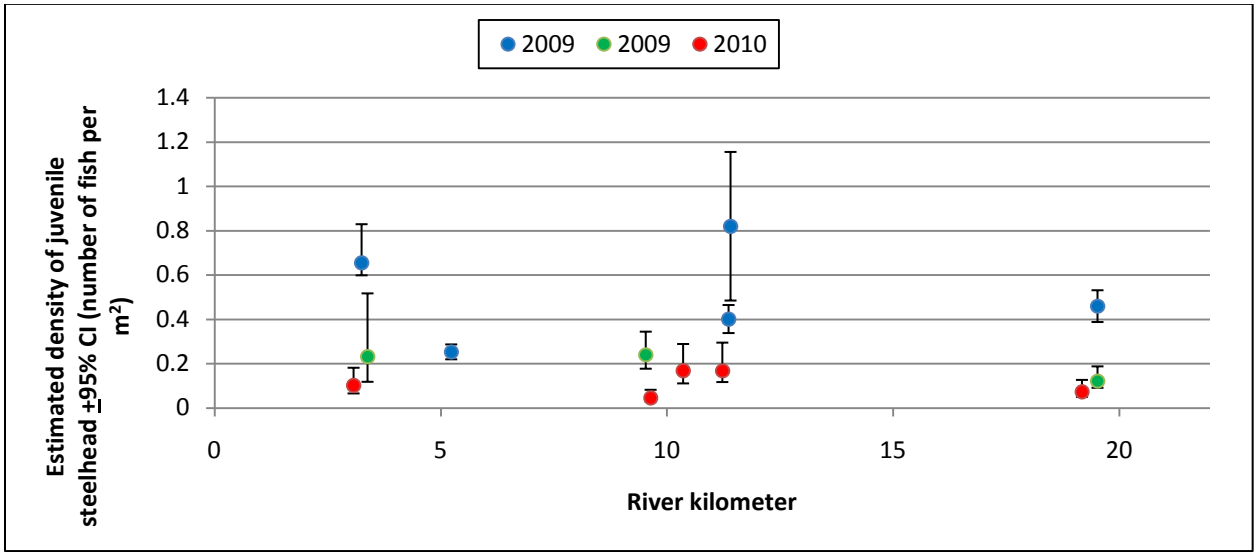


Figure 5.3.2. Estimated density of juvenile steelhead in the mainstem Dry Creek, 2008-2010. Estimates are from a variety of approaches all based on mark-recapture models.

In 2010, our study design allowed us to use a mark-recapture model that facilitates simultaneous estimates of over-summer survival and emigration for juvenile steelhead in our three reach-scale monitoring sections. Survival estimates varied between 0.16 (middle reach) and 0.33 (upper reach) and emigration varied between 0.06 (middle and upper reaches) and 0.11 (upper reach) (Figure 5.3.3).

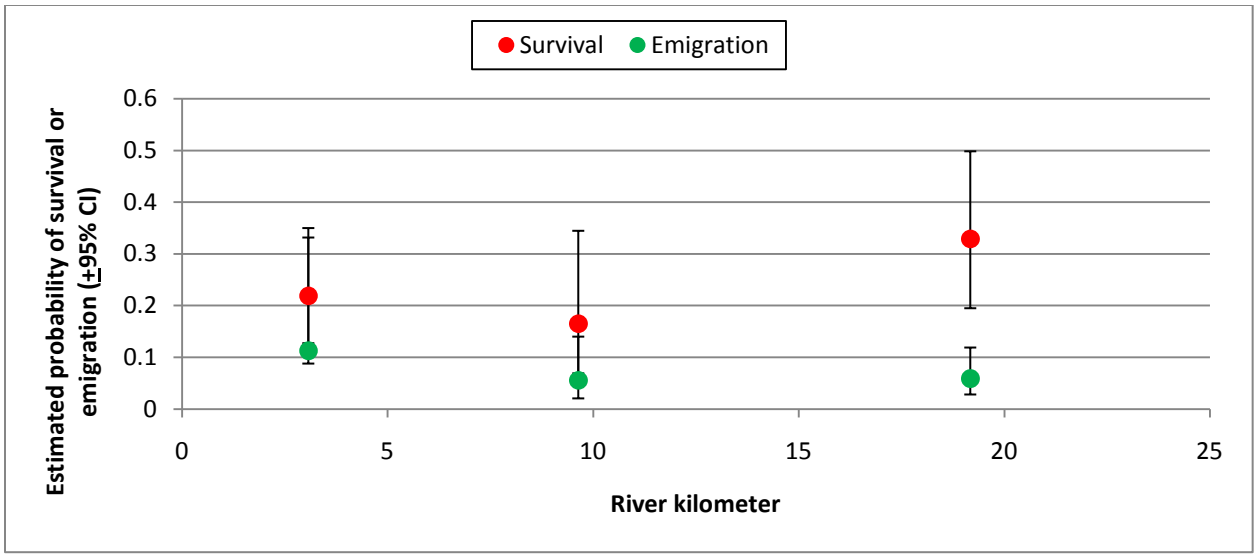


Figure 5.3.3. Estimated survival and emigration of juvenile steelhead from mainstem Dry Creek, 2010.

Growth was significantly lower in the upper reach as compared to the middle and lower reaches (Figure 5.3.4). These data help to explain a similar trend in size data (smaller-sized fish in the upper reach) evident in data from 2008 and 2009 as well (Manning and Martini-Lamb 2010).

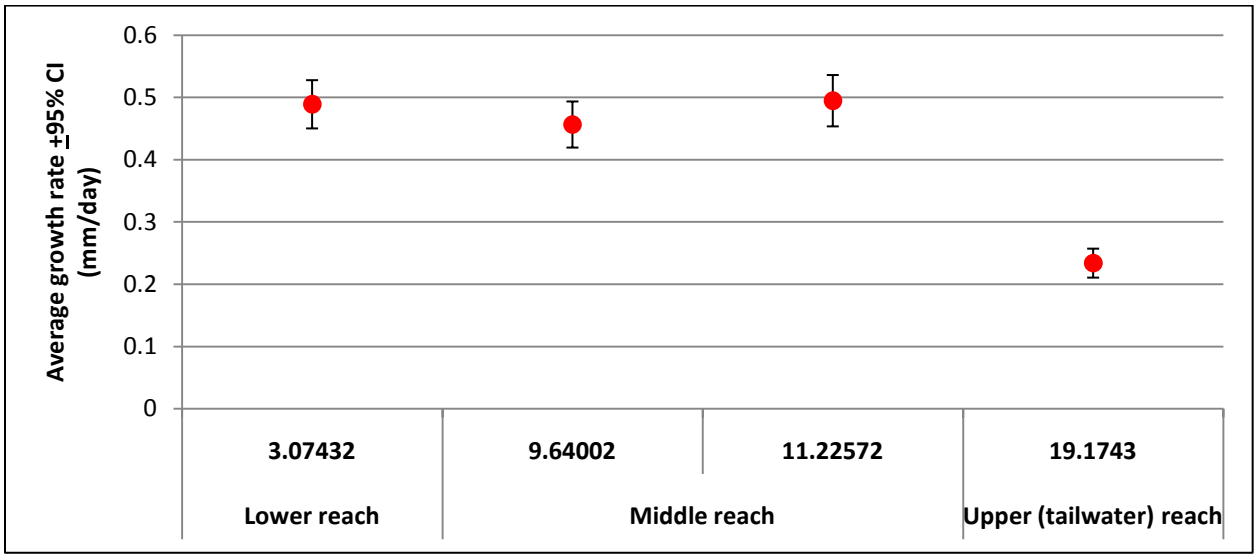


Figure 5.3.4. Estimated growth rates of juvenile steelhead from mainstem Dry Creek, 2010. Estimates are from individual growth rates calculated as the change in fork length (mm) per day of PIT-tagged fish between initial tagging in July and recapture in late September/early October.

Conclusions and Recommendations

In 2010, we made significant progress towards developing the basis necessary for a workable validation monitoring component to the adaptive management plan described in the Russian River Biological Opinion. If data at the reach scale are collected using approaches similar to those employed by the Water Agency in 2010, we are confident that we will continue to build a data set that will be useful for helping to distinguishing population responses to target treatment variables as opposed to non-target variables. After much focus in 2008 and 2009 on evaluating methods and approaches, the data gathered in 2010 can be applied to inform the AMF process. Furthermore, this approach develops a suite of estimates (density, survival, fidelity/emigration and growth) from which we can more fully evaluate the possible interactions and/or trade-offs among metrics (e.g., is there a relationship between survival and size or growth).

To date, the estimates of population metrics developed by the Water Agency illustrate that there is decided variability among years as well as among reaches in mainstem Dry Creek. Although the data thus far are for steelhead, the approaches shown should work equally well when applied to juvenile coho. However, as we continue to develop and implement validation monitoring in Dry Creek, we must simultaneously explore the assumptions necessary to apply our selected approaches and interpret the data we gather from those approaches. We provide the following framework as a way to make those assumptions explicit.

In 2011 we recommend continuing the reach-scale validation monitoring approaches applied in Dry Creek in 2010. In addition, we recommend continuation of efforts to develop approaches for monitoring at the site/feature scale so that once habitat enhancements are implemented we are prepared to immediately begin to evaluate fish responses to those projects.

Table 5.3.2. Target metrics, approaches and limitations for reach-scale validation monitoring in mainstem Dry Creek[12].

Target metric	Approach	Limitation	Recommended solution	Comments
Abundance (density)	Depletion/mark-recapture	Geographic closure assumption difficult to satisfy in Dry Creek	"Core" sampling (Manning and Martini-Lamb 2010)	none
Survival and fidelity/emigration	Multistate mark-recapture model	Must assume fish that were available for capture at time 1 are available at time 2- this may be difficult if fish remain in reach but move to an area that is inaccessible to sampling because of depth, velocity, etc.	none	May still be valid to use if making relative comparisons within the same reach over multiple years
Survival and fidelity/emigration	Multiple PIT antenna array	If fish are leaving the reach past the antenna site but are not swimming through the detection field of the antenna array, efficiency estimates may be biased high	Install mesh panels to guide fish through antenna array	none
Growth	Recapture of Previously PIT-tagged fish	none	none	none

[12] This is not meant to be an exhaustive list of approaches, limitations or solutions; rather it is intended to form the basis for continuing discussion of efforts by the Dry Creek adaptive management plan working group facilitated by ESSA to develop an adaptive monitoring plan for evaluating habitat enhancements in mainstem Dry Creek.

References

Baldigo, B. P. and Warren, D. R. 2008. Response of fish populations to natural channel design restoration in streams of the Catskill Mountains, New York. North American Journal of Fisheries Management 28: 954-969.

Cederholm, C. J., Bilby, R. E., Bisson, P. A., Bumstead, T. W., Fransen, B. R., Scarlett, W. J., and Ward, J. W. 1997. Response of juvenile coho salmon and steelhead to placement of large woody debris in a coastal Washington stream. North American Journal of Fisheries Management 17: 947-963.

Inter-Fluve. 2010. Fish Habitat Enhancement Feasibility Study Dry Creek Warm Springs Dam to the Russian River, Sonoma County, CA for Sonoma Water County Agency, Santa Rosa CA (Draft prepared: March 11, 2011).

Manning, D.J., and J. Martini-Lamb, editors. 2011. Russian River Biological Opinion status and data report year 2009-10. Sonoma County Water Agency, Santa Rosa, CA. 200 p.

Roni, P. 2005. Monitoring stream and watershed restoration. American Fisheries Society. Bethesda, MD.

Solazzi, M. F., Nickelson, T. E., Johnson, S. L., and Rodgers, J. D. 2000. Effects of increasing winter rearing habitat on abundance of salmonids in two coastal Oregon streams. Canadian Journal of Fisheries and Aquatic Sciences 57: 906-914.

Sonoma County Water Agency (Water Agency). 2009. Proposed juvenile salmonid monitoring in Dry Creek: Russian River Biological Opinion Implementation – Draft. February 10, 2009.

White, G. C. and Burnham, K. P. 1999. Program MARK: survival estimation from populations of marked animals. Bird Study 46: 120-139.

6: Tributary Habitat Enhancements

One component of the reasonable and prudent alternative (RPA) identified in the Biological Opinion is the enhancement of salmonid rearing habitats in tributaries to Dry Creek and the Russian River. A total of ten potential tributary enhancement projects are listed in the Biological Opinion with the requirement that the Water Agency implement at least five of these projects by the end of year 3 of the 15 year period covered by the Russian River Biological Opinion. The five projects that the Water Agency intends to complete are 1) Grape Creek Habitat Improvement Project; 2) Willow Creek Fish Passage Enhancement Project; 3) Grape Creek Fish Passage Project; 4) Wallace Creek Fish Passage Project; and 5) Crane Creek Fish Passage Access Project. The Water Agency entered into an agreement with the Sotoyome Resource Conservation District on December 16, 2008 to coordinate and implement the Grape Creek Habitat Improvement Project, Mill Creek Fish Passage Project, and the Crane Creek Fish Passage Access Project. In December 2010, after efforts to secure landowner access for the Mill Creek Fish Passage Improvement Project were unsuccessful, the Water Agency abandoned efforts on the Mill Creek Fish Passage Improvement Project and directed the Sotoyome Resource Conservation District to move forward with the Crane Creek Fish Passage Access Project. The Water Agency is coordinating with the County of Sonoma Department of Public Works, Permit and Resource Management Department, CDFG, and NMFS on the design and implementation of the Grape Creek Fish Passage Project and the Wallace Creek Fish Passage Project. On January 26, 2011, the Water Agency provided $100,000 to Trout Unlimited towards the construction of the Willow Creek Fish Passage Enhancement Project.

Grape Creek Habitat Improvement

Phase 1

The Grape Creek Phase 1 portion of the project consisted of installing 8 complex log and boulder structures along a 1,200 foot reach of Grape Creek upstream of the Wine Creek Road Crossing (Figure 6.1). Implementation of this work took place in July and August of 2009. All areas where vegetation was disturbed by heavy equipment were replanted with native plants prescribed by restoration staff from the RCD. Additional plantings were also installed per the request of DFG, and permission of the landowner, in areas outside the active construction area in an effort to eventually expand the width of the riparian area. A total of 248 native trees and shrubs were planted along this reach of the project. During 2010, maintenance and weeding of the plantings was conducted. General observations of the log structures during and after high creek flows of 2010-2011 have not shown any changes or failures in any of the Phase 1 reach structures. The first post-construction monitoring efforts are scheduled to occur during the summer of 2011.

Figure 6.1. Grape Creek – Phase 1. In-Stream Large Woody Debris Structure Example

Phase 2

The Grape Creek Phase two portion of the project consisted of installing nine complex log and boulder structures and two bank layback areas along a 700 foot reach of Grape Creek upstream of the West Dry Creek Road Crossing (Figure 6.2). Implementation of this work took place over two construction seasons, in 2009 and 2010. Construction began in early October 2009 and was cut short due to rain. Revegetation took place in January 2010. In February 2010, portions of one structure (Site 5) were removed as an emergency measure to avoid bank erosion on the opposite bank as a result of the structure's movement during high flows. Construction resumed in late August 2010, with heavy equipment work completed in the first week of September, and final touches placed on erosion control in early October. The remaining vegetation was installed in early 2011 when the soil is sufficiently moist. General observations of the log structures during and after high creek flows of 2010-2011 have not shown any changes or failures in any of the Phase 2 reach structures. The first post-construction monitoring efforts are scheduled to occur during the summer of 2011.

The pre-construction and project implementation monitoring report for Phase 1 and Phase 2 of the Grape Creek Habitat Improvement Project is attached as Appendix D-1.

Figure 6.2. Grape Creek – Phase 2. Large Woody Debris and Bank Layback Example.

Willow Creek Fish Passage Enhancement Project

Willow Creek is a tributary to the lower Russian River that once supported an abundant subpopulation of coho salmon. The creek continues to support significant potential spawning and rearing habitat; however, access to that habitat is blocked by impassable road culverts and a shallow braided channel that passes through forested wetland. To implement the Willow Creek Fish Passage Enhancement Project, the Water Agency has contributed $100,000 in funding to Trout Unlimited towards the removal of a complete barrier in Willow Creek. On October 19, 2010, the Water Agency's Board of Directors approved the funding agreement with Trout Unlimited for the Willow Creek Fish Passage Enhancement Project. The $100,000 in funding was provided by the Water Agency to Trout Unlimited on January 26, 2011. Attached in Appendix D-2 is a copy of a letter from the National Marine Fisheries Service describing the project and confirming that the provision of funds to Trout Unlimited constitutes completion of the Water Agency's obligation for implementing the Willow Creek Fish Passage Enhancement Project.

Grape Creek Fish Passage Project

The Grape Creek Fish Passage Project consists of the modification of a concrete box culvert where Grape Creek flows under West Dry Creek Road (Figure 6.3). As part of the permit review and design approval process, the National Marine Fisheries Service noted that the project design did not meet their maximum allowable 0.5-foot drop height for barrier passage. In October 2010, the Water Agency proposed re-designing the project to cut into the culvert bottom instead of placing curbs on top of the culvert bottom in order to meet the 0.5-foot maximum drop height requirement. Because the culvert-bottom is a structural portion of the bridge and culvert, cutting into the culvert bottom substantially increases the design complexity and costs of implementing the project. Between October 2010 and March 2011, the Water Agency coordinated with the Sonoma County Department of Public Works on the proposed re-design of the project. In April 2011, National Marine Fisheries Service indicated that the proposed re-design provided by the Sonoma County Department of Public Works was acceptable. Because of the increased complexity and costs to implement the revised project, the new design will require the Water Agency to solicit bids from a general construction contractor as opposed to performing the work with a Water Agency maintenance crew as was originally planned. Putting the project out to bid requires detailed project drawings and construction specifications. The Water Agency is in the process of obtaining a consultant to prepare the project construction drawings and specifications. It is anticipated that the project will be advertised for construction bids during the summer of 2011. Depending on weather conditions, the project could be constructed in the fall of 2011 and is progressing toward completion.

Figure 6.3. Grape Creek Fish Passage Project – Flat culvert invert proposed for modification.

Wallace Creek Fish Passage Project

The Wallace Creek Fish Passage Project consists of the modification of a concrete box culvert where Wallace Creek flows under Mill Creek Road (Figure 6.4). Engineering designs have been completed for the Wallace Creek Project. The National Marine Fisheries Service has approved the engineering designs for the project. The County of Sonoma Permit and Resource Management Department has submitted permit applications and has coordinated site visits with CDFG, USACE, and the North Coast Regional Water Quality Control Board. The Water Agency is continuing to work on obtaining the necessary landowner permissions for constructing the project. There are three landowners within the project area. The Water Agency has obtained permission from one of the landowners, is in negotiations with a second landowner, and has not been able to illicit any response from the third landowner. If the necessary landowner permissions are obtained, the project will be advertised for construction during the summer of 2011 and progressing toward completion.

Figure 6.4. Wallace Creek Fish Passage Project – Flat culvert invert proposed for modification.

Crane Creek Fish Passage Project

The Water Agency originally intended to implement the Mill Creek Fish Passage Project. The Mill Creek Fish Passage Project required landowner permission from two property owners in order to design and construct the project. One of the property owners was willing to enter into an agreement to allow the project to move forward; however, the second landowner gave multiple indications that they would allow the project to move forward, but ultimately failed to sign any access agreements to allow project design to move forward. Multiple attempts at obtaining the neccessary permissions from this landowner were made by the Stoyome Resource Conservation District and NFMS. Still seeing no progress with this landowner, the Water Agency directed the Sotoyome Resource Conservation District in December 2010 to abondon its efforts on the Mill Creek Fish Passage Project and instead implement the Crane Creek Fish Passage Access Project (Figure 6.5). The Crane Creek Fish Passage Access Project consists of the removal of a barrier to fish passgae caused by a bedrock outrcropping at the lower end of Crane Creek near its confluence with Dry Creek. The proposed project design developed by Prunuske Chatham, Inc., consists of creating a series of step pools through the bedrock outrcropping to create sufficient depth and flow to allow fish passage. The project design is currently being reviewd by the National Marine Fisheries Service. If design approval is obtained, and there are no landowner concerns with the project design, construction of the project is expected to occur during the fall of 2011.

Figure 6.5. Crane Creek Fish Passage Access Project. Bedrock outcropping.

7: Coho Salmon Broodstock Program Enhancement

The Biological Opinion and Consistency Determination require the Water Agency to increase production of smolts from the Russian River Coho Salmon Broodstock Hatchery Program (Coho Program). The Coho Program is located at the Don Clausen Fish Facility (Warm Springs Hatchery) at the base of Lake Sonoma on Dry Creek. Initiated in 2001, this innovate program is a multi-partner effort involving USACE, CDFG, NMFS, University of California Cooperative Extension (UCCE), Pacific States Marine Fish Commission (PSMFC), and the Water Agency. Native Russian River coho salmon and neighboring Lagunitas (Olema) Creek coho salmon stock are bred according to a genetic matrix (provided by NMFS Southwest Fisheries Science Center) and progeny are released to more than 15 streams in the Russian River watershed. Fish are released in spring as fry, in fall as fingerlings, and during winter and early spring as smolts. The Biological Opinion requires USACE to fund most hatchery operations and monitoring but also requires to the Water Agency to provide resources to CDFG to produce 10,000 coho smolts for release directly to Dry Creek.

In spring 2010, the Water Agency purchased 15 tanks for the Coho Program and they were installed by USACE in fall 2010. These tanks were operational by January of 2011, and have since been used to increase space for juvenile rearing, as well as holding for adult returns, and for the streamside acclimation tank used on Dutch Bill Creek. The Water Agency also hired a technician in spring 2010 and she began work full time at the hatchery in summer 2010. The technician's primary duties at the hatchery include daily feeding and cleaning, seasonal inventories of Broodstock, and special projects as they relate to the spawning, rearing, and release of all coho salmon Broodstock and progeny.

In 2010 the Broodstock program initiated streamside acclimation and smolt release to the suite of release strategies used to introduce fish to tributaries. The Water Agency's technician, Francis Hourigan, played a principal role in developing and implementing streamside acclimation techniques. One such special project was a cooperative assignment with a PSMFC employee in which an imprinting tank was fabricated and installed at Westminster Woods on Dutch Bill Creek. This tank used a pump to circulate creek water through the tank, and was used to hold three groups of 2,000 coho smolts for three to four weeks at a time - allowing them time to imprint on Dutch Bill Creek. The technician has also assisted the lead biologist in program data processing and annual report writing.

The current release plan for Coho Program smolts includes more than 10,000 fish for release into Dry Creek (Table 7.1).

Table 7.1. Russian River Coho Program 2010-11 planned smolt releases (B. White, PSMFC, personal communication).

Release Date(s)	Release Stream	# Released	Mean Fork Length (mm)	Mean Weight (g)	Tagging Strategy
6/14/10	Green Valley Creek	508	66 ± 5	3.4 ± 1.0	PIT only
6/15/10	Mill Creek	1,648	66 ± 5	3.5 ± 1.0	PIT only
6/15/10	Palmer Creek	824	66 ± 6	3.5 ± 1.1	PIT only
6/16/10	Grape Creek	1,017	66 ± 5	3.5 ± 1.0	PIT only
6/17/10	Purrington Creek	1,018	83 ± 7	7.1 ± 1.7	Snout + Adipose CWT
6/17/10	Dutch Bill Creek	1,019	76 ± 6	5.8 ± 1.5	Snout + Adipose CWT
6/22/10	Freezeout Creek	2,008	82 ± 8	6.9 ± 2.1	Snout CWT
6/22/10	Sheephouse Creek	3,009	78 ± 7	6.2 ± 1.8	Snout CWT
6/23/10	Gray Creek	7,026	82 ± 12	7.4 ± 2.6	Snout CWT
6/24/10	Thompson Creek	3,006	83 ± 8	7.0 ± 2.3	Snout CWT
6/24/10	Gilliam Creek	3,014	78 ± 13	6.3 ± 3.3	Snout CWT
	Spring Release Total:	***24,097***			
10/14/10	Walker Creek	5,140	94 ± 9	10.2 ± 3.1	Snout CWT
10/18/10	Freezeout Creek	3,140	100 ± 9	12.6 ± 3.6	Snout CWT
10/18/10	Sheephouse Creek	4,126	98 ± 7	12.0 ± 2.7	Snout CWT
10/19/11	Thompson Creek	3,330	97 ± 9	11.4 ± 3.4	Snout + Adipose CWT

Release Date(s)	Release Stream	# Released	Mean Fork Length (mm)	Mean Weight (g)	Tagging Strategy
10/19/10	Gilliam Creek	5,070	97 ± 12	11.4 ± 4.6	Snout + Adipose CWT
10/21/10	Dutch Bill Creek	10,543	97 ± 11	11.2 ± 4.1	Snout CWT
10/26-10/28 & 11/2/2010	Mill Creek	28,654	97 ± 8	11.2 ± 2.6	Snout CWT (+ 1,496 PIT)
10/29/10	Green Valley Creek	7,933	98 ± 10	12.3 ± 4.2	Snout CWT (+ 2,307 PIT)
11/3/10	Palmer Creek	6,092	98 ± 10	11.7 ± 3.7	Snout + Adipose CWT (+ 1,567 PIT)
11/4/10	Devil Creek	5,077	98 ± 10	11.8 ± 3.8	Snout + Adipose CWT
11/9 & 11/10/2010	Porter Creek	12,424	96 ± 6	10.7 ± 2.1	Snout CWT
11/11/10	Grape Creek	3,303	101 ± 10	12.8 ± 4.0	Snout CWT (+ 895 PIT)
11/16/10	E. Austin Creek	14,697	100 ± 10	12.2 ± 3.7	Snout + Dorsal CWT
	Fall Release Total:	***109,529***			
4/1/11	Mill Creek	5,952	126 ± 10	23.9 ± 6.5	Snout + Dorsal CWT (+ 1,200 PIT)
4/4/11	Green Valley Creek	4,986	129 ± 10	24.8 ± 5.9	Snout + Dorsal CWT (+ 1,199 PIT)
4/5/11	Dutch Bill Creek	1,228	123 ± 13	22.5 ± 6.8	Snout + Dorsal CWT (+ 285 PIT)
4/27/11	Dutch Bill Creek	1,998	125 ± 11	23.7 ± 6.1	Snout + Dorsal CWT (+ 400 PIT)
5/16/11	Dutch Bill Creek	2,000	133 ± 11	26.6 ± 6.9	Snout + Dorsal CWT (+ 473 PIT)
4/20/11	Dry Creek	10,738	129 ± 13	24.5 ± 7.6	Snout CWT (+ 2,999 PIT)
	Smolt Release Total:	***26,902***			
	2010-11 (BY09) Release Total:	***160,528***			

8: Wohler-Mirabel Water Diversion Facility

The Water Agency diverts water from the Russian River to meet residential and municipal demands. Water is stored in Lake Sonoma and Lake Mendocino, and releases are made to meet downstream demands and minimum instream flow requirements. The Water Agency's water diversion facilities are located near Mirabel and Wohler Road in Forestville. The Water Agency operates six Ranney collector wells (large groundwater pumps) adjacent to the Russian River that extract water from the aquifer beneath the streambed. The ability of the Russian River aquifer to produce water is generally limited by the rate of recharge to the aquifer through the streambed. To augment this rate of recharge, the Water Agency has constructed several infiltration ponds. The Mirabel Inflatable Dam (Inflatable Dam) raises the water level and allows pumping to a series of canals that feed infiltration ponds located at the Mirabel facility. The backwater created by the Inflatable Dam also raises the upstream water level and submerges a larger streambed area along the river. Three collectors wells, including the Agency's newest and highest capacity well, are located upstream of Wohler Bridge. These wells benefit substantially from the backwater behind the Dam.

8.1 Mirabel Fish Screen and Ladder Replacement

To divert surface water from the forebay of Mirabel Dam, The Water Agency operates a pump station on the west bank of the river. The pump station is capable of withdrawing 100 cfs of surface flow through two rotating drum fish screens in the forebay. The fish screens have been functioning since the dam was constructed in the late 1970's. However, they fail to meet current velocity standards established by NMFS and DFG to protect juvenile fish. The Biological Opinion requires the Water Agency to replace the antiquated fish screens with a structure that meets modern screening criteria. In 2009, the Water Agency employed the engineering firm of Prunuske Chatham, Inc. to prepare a fish screen design feasibility study. The report was completed in December 2009 (Appendix E-1).

The feasibility study was conducted to develop a preferred conceptual design that meets many of the project objectives while ensuring that the fish screening facilities adhere to contemporary fish screening design criteria. A Technical Advisory Committee composed of the Sonoma County Water Agency, NMFS, and CDFG provided guidance in refining the objectives and identifying alternatives. Six concept alternatives were evaluated for meeting the project objectives. Schematic designs and critical details were developed for these concept alternatives to assess physical feasibility and evaluate alternatives relative to the objectives. The preferred concept design alternative was

determined through an interactive evaluation and was selected because it meets or exceeds the project objectives.

The preferred concept design alternative includes a new intake with an inclined flat plate fish screen system, an oversized screen for increased bypass flow control and capacity, and a bypass fishway in the form of a vertical slot fish ladder. It also includes a fish viewing chamber with a window which will allow for real-time monitoring along with excellent education and outreach opportunities. The preferred conceptual design alternative will be a significant improvement for the water supply system and ecosystem protection. This alternative best meets the project objectives and is considered feasible for construction.

The estimated construction cost of the preferred conceptual design alternative is in the range of $3.5M to $4.0M. The construction cost estimate is not a total project cost. Other project costs will be considered in the next phase of project planning and design.

The next step of the project is to begin detailed environmental evaluation and engineering design of the preferred conceptual design alternative. In 2010, the Water Agency solicited qualifications from engineering firms, and a list of qualified consultants was created from the responses. The Water Agency selected HDR Engineering (HDR) because of its demonstrated experience with this type of work and the strength of their proposed project manager, who has a proven track record with fish passage and screening projects. The Water Agency and HDR entered into an Agreement for Engineering Design Services for the Mirabel Fish Screen and Fish Ladder Replacement Project in June of 2011. The work will include preliminary engineering, geotechnical analysis, hydraulic modeling, development of final construction contract drawings as specifications, and engineering support during bidding and construction. The design process will include consultation with a Technical Advisory Committee comprised of members of the Water Agency's engineering and fisheries biologist staff, HDR's design team, NMFS and CDFG.

Because the fish ladder enhancement identified in the feasibility study is not required by the Biological Opinion, the Water Agency applied for funds from DFG's Fishery Restoration Grant Program in 2010 to help defray costs associated with fish ladder design. The Director of DFG awarded the grant to the Water Agency in February 2011. A series of steps required by CDFG including agreements and correspondence between the Water Agency's Board of Directors and CDFG, were publicly noticed and approved in April 2011. CDFG contracting requirement precluded incurring expenses on the project until these steps were complete. The Water Agency received grant funding from CDFG in May 2011.

8.2 Wohler Infiltration Pond Decommissioning

The Wohler Infiltration Ponds 1 and 2 (originally built to assist with water supply operations) are located on the east side of the Russian River at the Water Agency's Wohler facility. The Decommissioning Project is part of the Reasonable and Prudent Measure (RPM) 6 Terms and Conditions (Item C), in which the Water Agency is required to decommission or modify Infiltration Ponds 1 and 2 to prevent fish entrapment in the ponds during flood events.

The proposed project consists of decommissioning the off-channel Wohler Infiltration Ponds 1 and 2 by removal of two manual valves each located adjacent to the ponds and grading each pond at a slope of 1 percent toward the river. A 1% slope will allow the ponds to fill with water during flood events but will allow them to drain at the same rate as the receding river. The proposed project will prevent entrapment of salmonids in the ponds after flood events and will meet the requirements of the Biological Opinion. In addition, the Water Agency will perform periodic maintenance of each infiltration pond. The grade will be checked by Water Agency staff and will be re-graded as necessary in order to maintain the appropriate drainage.

During 2010, the Water Agency received all necessary state and federal agency permits to allow construction during the low-flow season (June 15- October 31, 2011), when the infiltration ponds are dry.

8.3 Mirabel Fisheries Monitoring

2010 marked the 11th year that fishery studies have been conducted at the Wohler-Mirabel site. Although this report details the findings of the 2010 sampling season, data from previous years will be included (where appropriate) to provide historical context. Fisheries studies at Mirabel Dam were developed in cooperation with the National Marine Fisheries Service and the California Department of Fish and Game to assess the potential for the dam to adversely impact listed species through: 1) altering water temperature and water quality in the lower river, 2) impeding downstream migration of juveniles, 3) impeding upstream migration of adults, and 4) altering habitat to favor predatory fish. The results of the initial 5-year study found that the dam likely resulted in an approximate 0.5°C increase in water temperature above what would have been expected without the dam in place (Chase *et al.* 2005), and that out-migrating juvenile steelhead experienced a short delay in passing the dam (Manning *et al.* 2007). Adult upstream migrating salmonids where not impeded by the dam (Chase *et al.* 2005). In addition, predator populations appeared to be balanced and large aggradations of predatory fish were not observed during August electrofishing surveys (Chase *et al.* 2005). The initial 5-year study concluded that the small increase in summer water temperatures were unlikely to impact salmonids since the average temperatures in the Wohler Pool were naturally in excess of 20.0°C, thus the Wohler Pool likely provides

limited rearing habitat during the low flow summer months. Changes in the dam configuration (forming a V-notch to increase depth and velocity over the dam – see Manning *et al.* 2007 for details) significantly reduced the delay experienced by out-migrating steelhead smolts. Since 2005, the studies have focused on providing a long-term record of adult Chinook salmon escapement and juvenile salmonid emigration, as well as collecting basic life history information on all salmonids migrating past the Inflatable Dam.

Mirabel Downstream Migrant Trapping

The Water Agency has collected juvenile emigration data below the Inflatable Dam since 2000. Two rotary screw traps are generally fished below the dam from approximately April 1 through mid-July (depending on annual flow conditions). Data collected includes run timing, species composition, relative abundance, age, and size at emigration.

Methods

The rotary screw trap site is located approximately 60 m downstream of the Inflatable Dam. In 2010, two rotary screw traps (one 1.5-m diameter and one 2.5-m diameter) were operated. Fish captured by the screw traps were netted out of the live well and placed in an insulated ice chest supplied with freshwater. Aerators were operated to maintain DO levels in the ice chest. Prior to data collection, fish were transferred to a 19-liter bucket containing water and Alka-seltzer, which was used as an anesthetic. Fish captured were identified to species and measured to the nearest mm (FL). After data collection, fish were placed in a bucket containing fresh river water. Dissolved oxygen levels in the recovery buckets were also augmented with aerators to insure that the DO level remained near saturation. Once equilibrium was regained, the fish were released into the river downstream of the screw traps. In accordance with Water Agency's NMFS Section 10 Research Permit, once water temperatures exceeded 21.1˚C, fish were not anesthetized, but were netted from the live well, identified, enumerated, and immediately released below the traps.

In 2010, a mark-recapture study was initiated on May 5 and conducted through July 15 in an attempted to estimate the number of juvenile Chinook salmon that emigrated past the dam. The study has been initiated each year since 2001 once the majority of juvenile Chinook salmon captured reach a minimum length of 60 mm FL (juveniles less than 60 mm FL are too small to mark safely). Chinook salmon captured in the traps were sub sampled, and up to 50 fish daily were marked with a caudal clip. Marked fish were held in an ice chest equipped with aerators, and transported and released approximately 0.8 km above the dam. The proportion of marked to unmarked fish captured in the traps was then used to calculate a weekly estimate of the number of Chinook smolts emigrating past the dam (Bjorkstedt 2000).

Towards the end of the 2010 sampling season, the position of the 2.5 and 1.5 meter traps were switched. The 2.5 meter trap has been traditionally operated on the east

side of the river, and the 1.5 meter trap has been fished on the west side of the river. The gravel bar in the middle of the river (located directly between the two traps) has slowly increased in size since it formed in 2001. The configuration of the larger island now deflects a greater percentage of the streamflow towards the west bank. The decreased flow along the east bank has resulted in the channel becoming too shallow (less scour) to be effectively sampled by the larger trap under low flow conditions. Conversely, the flow on the west side of the river has become deeper and wider (as a greater percentage of the streamflow is deflected toward that side of the river), making the 1.5 meter trap less efficient. Switching the traps had the benefit of placing the larger trap in the deeper, faster current along the west bank, while the smaller trap was appropriately sized to fish the shallower current along the east side of the river.

Results

Although this report details the findings of the 2010 sampling season, data from previous years will be included, where appropriate, to provide historical context. In 2010, the two rotary screw traps were operated for 74 days (Table 8.3.1). A total of 27 species including 11,461 individual fish were captured. The catch included 15 native species and the majority of individuals, 7,032, were three threespine stickleback (*Gasterosteus aculeatus*).

Chinook salmon

A total of 2,368 juvenile Chinook salmon were captured in 2010. Relatively few Chinook salmon were captured compared to previous years (Table 8.3.2). The low catch rate was likely related to both the late start to the sampling season and the operation of the traps, and likely does not reflect a decrease in the abundance of outmigration juvenile Chinook salmon (see Dry Creek out-migrant trapping data Section 5.2 in this report).

Prior to 2009, overall trapping efficiency has ranged from 6.3 to 11.4 percent. The overall trapping efficiency was 2.8 and 4.0 percent in 2009 and 2010, respectively. The low capture efficiencies observed in 2009 and 2010 are likely related to both the late date that the dam was inflated as well as changes in stream geomorphology. In 2010, capture efficiency increased significantly after the dam was inflated and the position of the traps was switched. For example, for the seven days prior to the dam inflation, the average daily catch for Chinook salmon was 14 fish/day. After the dam was fully inflated on June 18 and the traps were repositioned, the daily average catch rate for Chinook salmon increased to 82 fish/day.

Table 8.3.1. Summary of Mirabel Dam rotary screw operations from 2000 to 2009.

Year	Deployment date	End date	Dam Inflated	Dates on non-operation	Number of days operated
2000	April 8	June 29	May 2	April 18, 19	82
2001	April 20	June 7	April 21	April 22 May 28, 29	46
2002	March 1	June 27	April 16	April 16	118
2003	March 1	July 3	May 23	March 15 – 19 April 13 – 21; April 24- May 11 May 23	92
2004	April 1	July 1	April 8	April 8	91
2005	April 15	June 30	May 26	May 19-23; May 27 - 31	72
2006	May 4	May 24	May 11	May 12 - 15	18
2007	March 21	June 28	March 28	March 30 May 30	99
2008	March 20	June 26	April 11	April 11 – 13 May 17 – 18 June 10 June 16 June 24	104
2009	April 1	July 17	July 8	April 15 May 5-7 July 2, 9, 14	93
2010	May 4	July 16	June 11	--	74

Table 8.3.2. Weekly capture of Chinook salmon at the Wohler trapping site, 2000 – 2010.

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
26-Feb			45	332							
5-Mar			74	841							
12-Mar			319	89							
19-Mar			181	169				257	114		
26-Mar			797	346				940	80	6	
2-Apr	41		908	377	82			730	224	257	
9-Apr	158		757	176	115	446		564	100	236	
16-Apr	154	122	2,279	17	672	848		1,011	866	190	
23-Apr	204	720	2,992	60	1,911	618		759	1,161	159	
30-Apr	169	1,338	4,337	0	1,845	353		1,148	315	67	86
7-May	121	1,154	1,780	50	1,631	132	69	782	258	149	451
14-May	174	226	2,056	508	552	222	46	880	381	123	187
21-May	106	76	1,755	690	158	35	217	698	91	55	158
28-May	92	64	704	1,461	150	419	67	503	107	64	268
4-Jun	66	22	192	530	125	541		857	60	42	145
11-Jun	47		93	374	31	136		268	94	30	155
18-Jun	19		46	186	88	156		45	19	9	324
25-Jun	10		4	86	26	55		38	8	2	441
2-Jul				3						8	71
9-Jul										1	72
16-Jul										1	10
Total	**1,361**	**3,722**	**19,319**	**6,295**	**7,386**	**3,961**	**399**	**9,480**	**3,878**	**1,399**	**2,368**

Overall trap efficiency for Chinook salmon was 1.9 percent between May 7 and June 17. After June 17, trapping efficiency increased to 6.1 percent.

Because trap efficiency was low and inconsistent in 2010, we produced a population estimate with a wide confidence intervals. Based on the DARR estimator, the 2010 mark-recapture estimate was 109,540 (±47,463) juvenile Chinook salmon migrating past the trapping site (Table 8.3.3). This number should be viewed with caution because of the poor trap efficiency during the first half of the study period as well as the late start of the sampling season.

Based on sampling from 2000 to 2008, peak juvenile Chinook salmon emigration typically occurs between mid-April and mid-May. Although peak catches of Chinook salmon occurred during the second half of June in 2010, it is likely that the true peak of the run was missed. The weekly average measured fork length for Chinook salmon captured below the Inflatable Dam ranged from approximately 84.6 mm in early May to approximately 94.2 mm in mid-July (Figure 8.3.1).

Steelhead

For the season, 373 wild (natural origin) steelhead parr were captured, most of which were likely YOY based on length-frequency data (Figure 8.3.2, Table 8.3.4). In addition, forty-four wild origin steelhead smolts were captured between May 4 and June 15 in 2010 (Table 8.3.5). Based on previous data collection efforts at the Wohler-Mirabel fish trapping station, the steelhead migration season runs from at least March through June, with peak numbers occurring between mid-March and mid-May. Steelhead smolts ranged in length from 171 to 201 mm FL, averaging 184 mm FL overall. Since 2000, the average size of steelhead smolts has ranged from 161 to 185 mm FL.

Coho salmon

Coho smolts were captured between May 4 (first day of sampling) and July 11. For the season, 181 coho salmon smolts were captured (180 hatchery smolts and 1 wild smolt) (Table 8.3.6). Coho smolts ranged in length from 85 to 150 mm FL (Figure 8.3.3). Overall, for the 2010 trapping season, coho salmon smolts average 118 mm FL.

Table 8.3.3. Estimated number of juvenile Chinook salmon that passed the Mirabel Dam site, based on mark-recapture trap efficiency testing, from 2001 to 2009.

Year	Number marked	Number recaptured	Overall efficiency	Seasonal estimate[1]	95% CI
2000	N/A	N/A	N/A	N/A	N/A
2001	525	60	11.4	19,473	5,022
2002	2,778	253	9.1	225,135	37,028
2003	1,072	90	8.4	45,699	18,218
2004	1,631	120	7.4	91,352	17,652
2005	N/A	N/A	N/A	N/A	N/A
2006	N/A	N/A	N/A	N/A	N/A
2007	3,201	203	6.3	149,329	28,722
2008	1,321	88	6.7	43,774	16,768
2009	709	20	2.8	41,663	10,208
2010	1,881	76	4.0	109,540	47,463

[1]Includes fish captured outside of the mark-recapture study period

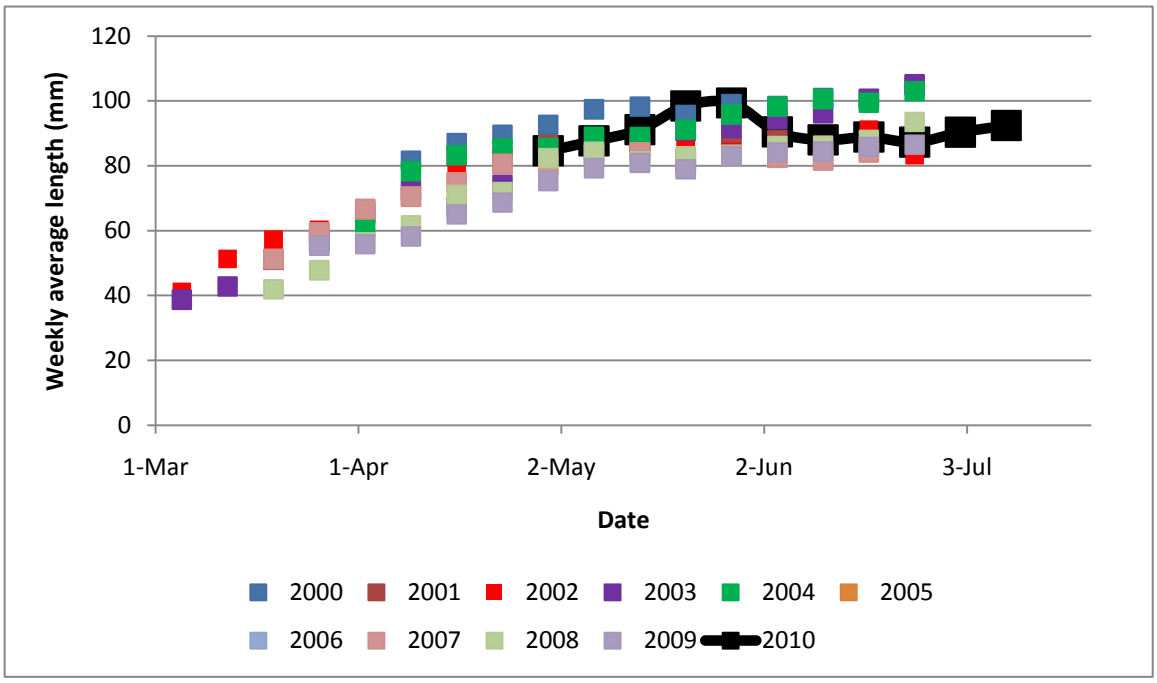


Figure 8.3.1. Weekly average fork lengths of Chinook salmon smolts measured at the Mirabel Dam trap site in 2010 (black line) compared to years 2000-2009.

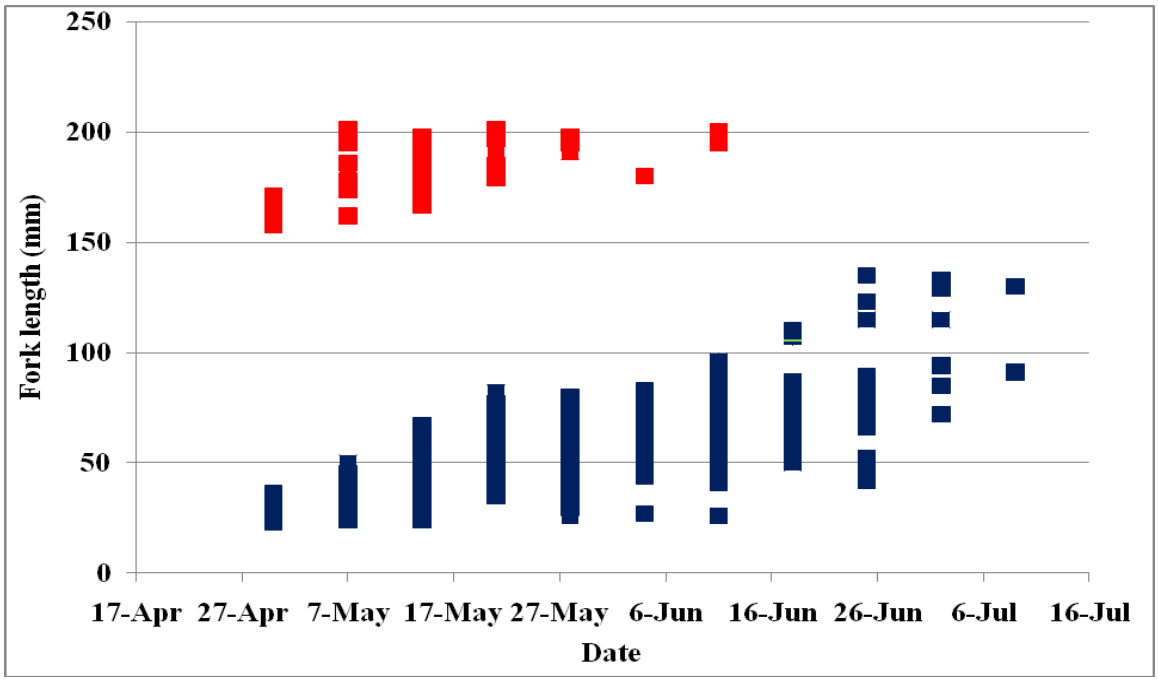


Figure 8.3.2. Length of steelhead captured in 2010, grouped by week of capture. Blue squares represent young-of-the-year (age 0+), green squares represent parr (age 1+), and red squares represent smolts (age 1-2+).

Table 8.3.4. Weekly catch of steelhead young-of the year (age 0+) and parr (age 1+) at the Mirabel Dam trapping site, 2000 – 2010.

	2000	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
26-Feb	0	0	0	1	0	0	0	0	0	0	
5-Mar	0	0	0	5	0	0	0	0	0	0	
12-Mar	0	0	1	3	0	0	0	0	0	0	
19-Mar	0	0	8	13	0	0	0	1	1	0	
26-Mar	0	0	3	67	0	0	0	27	7	0	
2-Apr	0	0	56	170	3	0	0	8	14	4	
9-Apr	3	0	51	132	14	86	0	12	35	4	
16-Apr	20	1	447	4	12	100	0	39	34	4	
23-Apr	33	17	81	20	16	97	0	136	74	8	
30-Apr	224	4	658	0	10	523	14	58	118	11	33
7-May	30	13	756	22	3	354	12	164	133	7	36
14-May	49	23	976	74	1	75	182	157	52	3	39
21-May	80	34	1315	246	1	25	26	185	101	8	81
28-May	74	32	806	223	2	110	0	173	59	6	60
4-Jun	102	26	467	55	2	136	0	684	76	2	26
11-Jun	40	0	164	29	1	40	0	176	50	8	41
18-Jun	58	0	60	28	10	29	0	5	26	4	22
25-Jun	50	0	1	2	7	9	0	22	10	4	25
2-Jul	0	0	0	1	0	0	0	0	0	1	8
9-Jul	0	0	0	0	0	0	0	0	0	0	2
16-Jul	0	0	0	0	0	0	0	0	0	0	
23-Jul	0	0	0	0	0	0	0	0	0	0	
Total	**763**	**150**	**5,850**	**1,095**	**82**	**1,584**	**234**	**1,847**	**790**	**74**	**373**

Table 8.3.5. Weekly catch of steelhead smolts at the Mirabel trapping site, 2000 – 2010.

	2000	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
26-Feb			1	4							
5-Mar			1	3							
12-Mar			38	5							
19-Mar			15	3				24	0		
26-Mar			24	39				99	1		
2-Apr			31	39	3			24	3	12	
9-Apr	19		33	18	14	0		25	0	5	
16-Apr	24	7	30		11	18		43	4	5	
23-Apr	24	16	23		14	9		61	8	2	
30-Apr	21	16	23		10	7	9	14	12	1	4
7-May	8	9	7		3	3	10	17	4	1	8
14-May	14	4	9	26	1	1	5	11	0	2	14
21-May	9	0	9	16	1	3	6	3	1	2	9
28-May	6	0	3	6	1	0		2	0	0	4
4-Jun	1	1	0	2	2	3		1	0	0	1
11-Jun	4		1	1	1	2		0	0	0	4
18-Jun	2		0	0	2	1		0	0	2	
25-Jun	2		0	0	0	1		0	0	0	
2-Jul										1	
9-Jul										0	
16-Jul										0	
23-Jul										0	
Total	**134**	**53**	**248**	**162**	**63**	**48**	**30**	**324**	**33**	**33**	**44**

Table 8.3.6. Weekly catch of coho salmon smolts at the Mirabel Dam trapping site, 2006 – 2010. Most fish were marked from the Russian River Coho Salmon Hatchery Broodstock Program.

	2006	**2007**	**2008**	**2009**	**2010**
26-Feb					
5-Mar					
12-Mar					
19-Mar		3	1		
26-Mar		1	6	4	
2-Apr		0	6	23	
9-Apr		2	2	35	
16-Apr		9	10	38	
23-Apr		8	16	33	
30-Apr	1	15	17	3	38
7-May	1	38	23	26	53
14-May	1	24	9	23	30
21-May	0	7	1	9	15
28-May		1	0	7	21
4-Jun		0	0	1	19
11-Jun		0	0	4	0
18-Jun		0	0	0	3
25-Jun		0	0	0	1
2-Jul				0	0
9-Jul				0	1
16-Jul				0	
Total	**3**	**108**	**91**	**206**	**181**

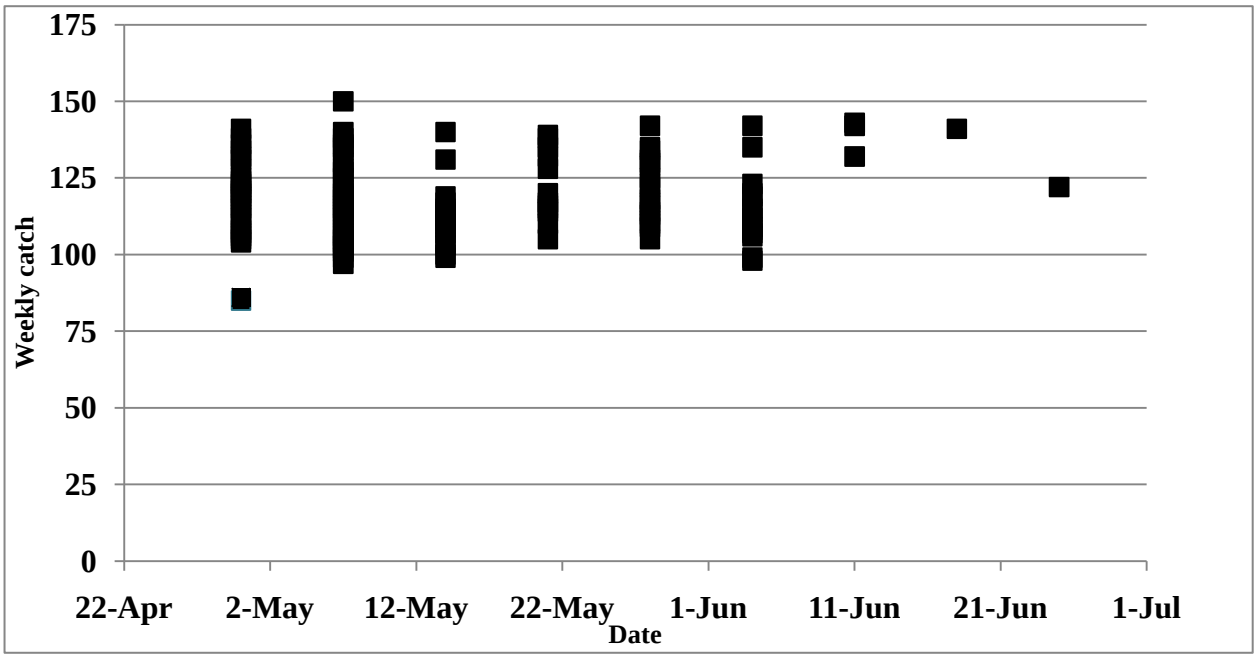


Figure 8.3.3. Lengths of coho salmon captured in 2010 grouped by week of capture.

Conclusions and Recommendations

The overall capture of all species in the rotary screw traps at Mirabel was lower compared to most years sampled. The reason for the lower catch was likely a combination of the late start to the season and the poor trapping efficiency experienced throughout the first half of the trapping season. The poor capture efficiencies experienced during the majority of the sampling season in 2010 limits conclusions that can be drawn from this year's data. However, the capture of juvenile coho released from the coho salmon broodstock program is encouraging.

This project is an essential component of the overall Russian River fisheries monitoring program and provides valuable information necessary for the management of all three listed species. Information collected at the Mirabel trapping site provides long term trends in smolt emigration past the Wohler-Mirabel facility, as well as insights into their life history strategies. The 2.5-m and 1.5-m traps were switched at the end of the 2010 sampling season. We will continue to fish the 2.5-m trap on the west side and the 1.5-m trap on the east side to test whether trap efficiency is affected by trap placement. In addition to trap positioning, efficiency also appears to be effected by the presence of dam. After dam inflation, both total catch and efficiency increased. We suspect that fish are concentrated in the dam forebay and may be disoriented as they pass through the v-notch at the dam crest and enter the plunge pool a short distance above the trap site. As these disoriented fish exit the plunge pool into high velocity riffles they are more susceptible to capture. Despite this potential disorientation, injury and mortality rates observed at the trap have been very low over the past 11 years and operation of the dam and trap is an effective method of gauging trends in salmonid outmigration.

Mirabel Fish Ladder Video Monitoring

The Inflatable Dam is approximately 4.0-meter high, 45-m wide, and when fully inflated forms a barrier to upstream migrating fish. To provide upstream passage, the dam is equipped with two Denil-type fish ladders. The dam is typically inflated from early spring through late fall, depending on water demand and streamflow, during the majority of the Chinook salmon migration period. During years with low rainfall in the fall and early winter, the dam may also be inflated during the beginning of the coho salmon and steelhead migration periods.

The video counting system has been in operation at the Inflatable Dam since 2000 (system testing was conducted in 1999, but few quantitative data were collected). The original objective of this study was to verify that anadromous salmonids were able to detect and ascend the fish ladders that provide passage around the dam. A secondary objective assessed the timing of migration and relative numbers of anadromous fish migrating upstream of the dam while it was inflated. Since the results of the original 5-year study demonstrated that anadromous fish were able to detect and ascend the ladders, the counting station has been operated primarily to document Chinook salmon escapement. The upstream migration period for Chinook salmon overlaps the time period when the dam is most likely to be inflated. Conversely, a large portion of the coho salmon and steelhead runs generally occur after the dam is deflated during the high flow period. Since the vast majority of Chinook salmon spawning habitat lies above the dam, the counting station provides a good estimate of the overall run in the Russian River. However, during periods of high turbidity (generally associated with high streamflows), the cameras are ineffective and some portion of the run is missed in most years. As a result, the numbers presented here should be viewed as minimum counts.

Methods

In 2010, passage of adult salmonids through the fish ladders was assessed using digital underwater video cameras from September 1 until December 5, when high stream flows resulted in the deflation of the dam for the season. Each year, metal housings (camera boxes) are installed at the upstream end of each fish ladder. Underwater cameras and lighting systems are located in the boxes, and are operated 24 hours a day, 7 days a week. Video data are stored on a hard drive located in a nearby building. Each morning, data stored on the hard drive are downloaded directly to the office where it is reviewed. Once viewed, the video footage is copied to 8 GB DVDs for archival purposes.

Fish were counted as moving upstream once they exited the upstream end of the camera box. For each adult salmonid observed, the reviewer recorded the species (when possible), date, and time of passage out of the ladder. During periods of low visibility it was not always possible to identify fish to species, although identification to family (e.g., Salmonidae) was often possible, and such fish were lumped into a general category called “unknown salmonid.” Fish that were identified as a salmonid, but could not be identified to species were partitioned into Chinook or steelhead in an attempt to

better estimate the number of each of these species observed in the fish ladders. Salmonids were partitioned by taking the proportion of Chinook salmon to steelhead identified in the ladder each day, and multiplying the number of salmonids by these proportions. On days when no salmonids could be identified to species, an average ratio from adjacent days was used to categorize the unidentified salmonids. This process was made easier by the fact that Chinook and steelhead runs only minimally overlap. The recent increase in the occurrence of coho salmon will require that they are considered in future estimates of salmonids migrating past the fish counting stations.

Results

In 2010, the cameras were in operations continuously from September 1 to December 5 (Table 8.3.7), excluding a five day period (October 28 – November 1) when the dam was deflated due to high flows. During the majority of the season, the image quality of the videos was sufficient to identify and count fish passing through the fish ladder. Video monitoring demonstrated that adult Chinook, coho, steelhead, and Pacific lamprey are able to locate and ascend the Mirabel fish passage facilities. Species observed in the last 10 years include, but are not limited to Chinook and coho salmon, steelhead, Pacific lamprey, American shad, Sacramento pikeminnow, hardhead, Sacramento sucker, smallmouth bass, common carp, and channel catfish. Most of the non-anadromous species were likely resident in Wohler Pool and were noted as "milling about" in the exit boxes, as opposed to migrating upstream or downstream through the fish ladders.

Table 8.3.7. Deployment and removal dates for the Mirabel underwater video system, 2000 – 2010.

Year	Date Deployed	Date Removed
2000	May 12	January 10 (2001)
2001	August 7	November 13
2002	August 12	December 11
2003	September 3	December 2
2004	August 1	December 8
2005	August 1	December 1
2006	August 14	November 26
2007	April 1	June 27
2007	August 15	December 15
2008	August 15	December 22
2009	August 15	December 16
2010	September 1	December 5

Unknown Salmonids

In 2010, 597 fish were categorized as an "unknown salmonid" (i.e., these fish possessed the general body shape of an adult salmonid, but could not be identified to species). Of these, 549 were portioned as Chinook salmon, and 48 were estimated to be steelhead.

Chinook

The date that the first Chinook salmon was observed during video monitoring ranged from August 20 to October 7 during the 11 years of video monitoring. In 2010, the first Chinook salmon was observed on September 24. The run began in earnest on October 5 when 653 Chinook were counted. Prior to this date, a total of 4 Chinook salmon had been observed. A second peak occurred between October 13th and 17th and appeared to be associated with a pulsed flow release from Coyote Valley Dam. A likely third peak However, high flows associated with the storm event forced the deflation of the dam from 28 October – 1 November resulting in a significant loss of data.

In 2010, 2,516 adult Chinook salmon (including "unknown salmonids") were counted at the Mirabel fish counting station. The number of adult Chinook salmon counted each year has ranged from 1,125 to 6,103 from 2000 through 2010 (Table 8.3.8). The deflation of the dam during late October likely resulted in a significant underestimate of the true Chinook salmon escapement to the river in 2010. At the time that the dam was being deflated, Water Agency staff observed large numbers of Chinook salmon jumping at the dam, indicating that a large pulse of fish was migrating upstream during this high flow event. The dam was re-inflated on November 1, but turbidity limited video operations for a few additional days. The mid-season high flow event occurred during the typical peak of the Chinook salmon run.

In 2010, the first Chinook salmon was observed at the counting station when the mean daily temperature (MDT) was 17.1°C, The first significant pulse of adult Chinook salmon occurred on October 4 (573 fish) at a MDT of 17.1°C. In 2010, 62 percent of the run occurred after the MDT declined below 15.5°C. However, as discussed above, several days of video monitoring were lost during the traditional peak of the Chinook salmon run. Had the fish migrating during this timeframe been counted, the percentage of fish migrating below a temperature of 15.5°C would have been substantially higher.

In 2010, the lowest flow recoded at USGS Hacienda Bridge Gauging Station (Hacienda gauge) after Chinook salmon were first observed at the fish counting station was 145 cfs. On October 4 when the first significant pulse of Chinook were detected passing the dam, flow measured 163 cfs. Streamflow did not appear to be effect migration in 2010.

Coho

In 2010, 38 coho salmon were identified on the video system. These images were reviewed by multiple fisheries biologist from the Water Agency, NMFS, and University of California Cooperative Extension (UCCE). The coho observed on the video system were adipose fin clipped indicating that they were returns from the Russian River coho salmon broodstock program. Monitoring by UCCE detected nearly 200 adult coho salmon spawning in Russian River tributaries during 2010 and many returned to Dry Creek and its tributaries above the Mirabel trap site. Some of these fish were not detected by our video system because they either passed upstream during a period when the dam was deflated or could not be positively differentiated from Chinook salmon.

Table 8.3.8. Weekly count of adult Chinook salmon at the Mirabel Dam fish ladders, 2000 – 2010. Dashes indicate that no sampling occurred during that week.

Week	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
1-Aug	0	0	0	--	0	0	--	--	--	--	--
8-Aug	0	0	0	--	0	0	--	--	--	--	--
15-Aug	0	0	1	--	0	0	0	0	0	0	--
22-Aug	1	0	8	--	0	1	0	0	0	0	--
29-Aug	0	3	7	2	1	2	0	0	1	0	0
5-Sep	9	1	18	7	1	5	0	0	0	0	0
12-Sep	38	7	19	20	3	11	2	0	1	0	0
19-Sep	23	12	65	23	8	13	3	0	14	0	3
26-Sep	50	17	1,223	181	16	20	7	1	65	0	1
3-Oct	31	240	113	146	42	34	120	7	122	21	669
10-Oct	115	51	628	515	51	114	255	38	109	394	896
17-Oct	81	10	272	232	585	403	531	28	11	362	154
24-Oct	466	300	153	532	2284	332	83	87	21	305	286[1]
31-Oct	63	661	505	2969	183	632	1169	250	243	75	95[2]
7-Nov	24	81	2,337	1289	1164	735	696	115	427	217	174
14-Nov	182	--	20	47	217	172	472	475	13	229	43
21 Nov	200	--	37	95	57	91	53	60	24	63	113
28 Nov	111	--	14	45	59	40	18	105	15	84	76
5-Dec	19	--	54	--	15	0	--	770	21	20	5
12-Dec	14	--	--	--	--	--	--	22	8	31	--
19-Dec	17	--	--	--	--	--	--	0	13	0	--
26-Dec	1	--	--	--	--	--	--	--	--	0	--
2-Jan	0	--	--	--	--	--	--	--	--	--	--
Total	**1,445**	**1,383**	**5,474**	**6,103**	**4,788**	**2,572**	**3,410**	**1,963**	**1,125**	**1,801**	**2,516**

[1]Dam was deflated for 3 days of this week

[2]Dam was deflated for 2 days of this week

Steelhead

Fall counts of steelhead have ranged from 56 to 513 since 2000, including 163 in 2010 (Table 8.3.9). Since the majority of the steelhead run in the Russian River occurs after Mirabel Dam is deflated, these counts are not representative of run size and cannot be used to compare steelhead runs between years. Steelhead were categorized by being of wild, hatchery, or unknown origin. Of the 108 steelhead that could be categorized by origin, 39 were identified as wild and 69 were identified as hatchery. In all years, few adult steelhead were observed prior to the last week of November.

Conclusions and Recommendations

Based on the results of video monitoring from 2000 through 2010, Chinook salmon and steelhead appear to successfully find and ascend the fish ladders around the Inflatable Dam. Relatively large numbers of adult fish of both species have been documented negotiating the ladders, and large numbers of salmonids have not been observed at the base of the dam.

The 2010 count of 2,516 Chinook salmon ranks 6 out of the 11 years surveyed to date. However, the run was likely significantly underestimated in 2010. Five full days (28 October – 1 November) of video surveillance were lost when the dam was deflated. After the dam was re-inflated, and flows were receding, turbidity caused poor visibility and limited the opportunity to count fish. A direct comparison of population size between years is limited because the sampling periods are not equal. Although the counting system is operated throughout the majority of the Chinook salmon run in most years, the date that the dam has been deflated has ranged from November 13 to January 10. Thus, the counts presented here should be viewed as minimum escapement.

Few Chinook salmon have been counted at the dam prior to October in any year sampled. Based on video monitoring, the typical Chinook salmon run in the Russian River begins in mid-September, peaks between the last week of October and mid-November, and ends in late December (Figure 8.3.5). In 2010, peak counts occurred during the first half of October, approximately 2 to 3 weeks earlier compared to other years. The first Chinook salmon was observed at Mirabel on September 24, and the first significant pulse of fish occurred on October 4 and 5 (653 fish). A second, larger, pulse of Chinook salmon was observed between October 13 and 15 (804 fish). The presence of these fish at the counting station coincided with a pulse flow release from Coyote Valley Dam. The USACE was required to increase storage in Lake Mendocino for the upcoming rainy season. This water was released as a pulse to simulate a rain event. Flows measured at the Hacienda gauge increased from 176 cfs on October 10 to 660 cfs on October 14 in response to the upstream releases. The immediate response in the number of Chinook salmon migrating past the Mirabel fish counting stations suggests that these fish were staging in the river prior to the release. The apparent earlier run timing of Chinook salmon in the 2010 is also partly explained by the fact that approximately one week of data was lost when the dam was deflated during an early

season storm that increased streamflows to over 3,000 cfs at the Hacienda gauge. Water Agency staff observed large numbers of Chinook salmon jumping at the dam as it was being deflated, suggesting that a large pulse of Chinook salmon were migrating during this flow event. Had it been possible to count these fish at the counting station, the run timing for Chinook would have been shifted towards the more typical late October/early November timeframe.

Although Chinook salmon have been observed migrating past the Mirabel Dam at temperatures ranging to 22.6°C, approximately 91 percent of the adult Chinook salmon have been observed at the fish counting station after the MDT declined below 17.1°C (SCWA unpublished data) (Table 8.3.10). Annually, between approximately 73 and 97 percent of the fish counted at the Mirabel Dam pass after the mean daily temperature (MDT) declines below 15.5°C. The 15.5°C threshold is significant because exposure of migrating adults to temperatures above this point can result in decreased survival of developing embryos (Hinze 1959, cited by DW Kelly and Associates and 1992).

The Mirabel video monitoring system continues to provide excellent data on Chinook salmon escapement to the Russian River. In addition, with the recent rebound in coho salmon numbers resulting from the coho broodstock program (see Chapter 7 in this report), the Mirabel Fish Counting Station is providing information on at least the first half of the their run. 2010 marks the second year that coho salmon have been observed migrating upstream during the fall spawning run. Although the numbers counted have been very low, the system misses a large segment of the available coho salmon spawning habitat, as well as a significant portion of the migration period.

Table 8.3.9. Fall steelhead counts at the Mirabel Dam fish counting station in the fall of 2000-2010.

Date	2000	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
8/1	0	0	0	0	0	0	0	0	--	--	--
8/8	0	0	0	0	0	0	0	0	--	--	--
8/15	0	0	0	0	0	0	0	0	0	0	--
8/22	0	0	0	0	0	0	0	0	0	0	--
8/29	0	0	0	0	0	0	0	0	0	0	0
9/5	0	0	0	0	0	0	0	0	0	1	0
9/12	0	0	0	0	0	1	0	0	0	0	0
9/19	0	0	0	0	0	0	0	0	0	0	0
9/26	0	0	0	0	0	0	0	0	0	0	0
10/3	1	0	2	0	0	1	0	0	2	0	0
10/10	0	0	0	1	0	2	0	1	1	9	8
10/17	0	0	3	0	1	3	0	0	0	19	8
10/24	2	0	1	2	6	3	1	0	1	1	0
10/31	2	0	3	0	0	2	0	0	9	2	5
11/7	1	0	18	4	3	12	6	0	5	8	2
11/14	7	--	10	18	14	9	25	4	15	2	22
11/21	11	--	1	17	34	21	--	15	4	12	36
11/28	56	--	9	36	97	14	--	194	35	18	72
12/5	43	--	55	--	52	--	--	46	18	33	10
12/12	178	--	--	--	--	--	--	--	112	51	--
12/19	87	--	--	--	--	--	--	--	55	--	--
12/26	24	--	--	--	--	--	--	--	--	--	--
1/2	45	--	--	--	--	--	--	--	--	--	--
1/9	56	--	--	--	--	--	--	--	--	--	--
TOTAL	513	**0**	**102**	**78**	**207**	**68**	**32**	**260**	**256**	**156**	**163**

[1]Wild, hatchery, and unknown origin combined.

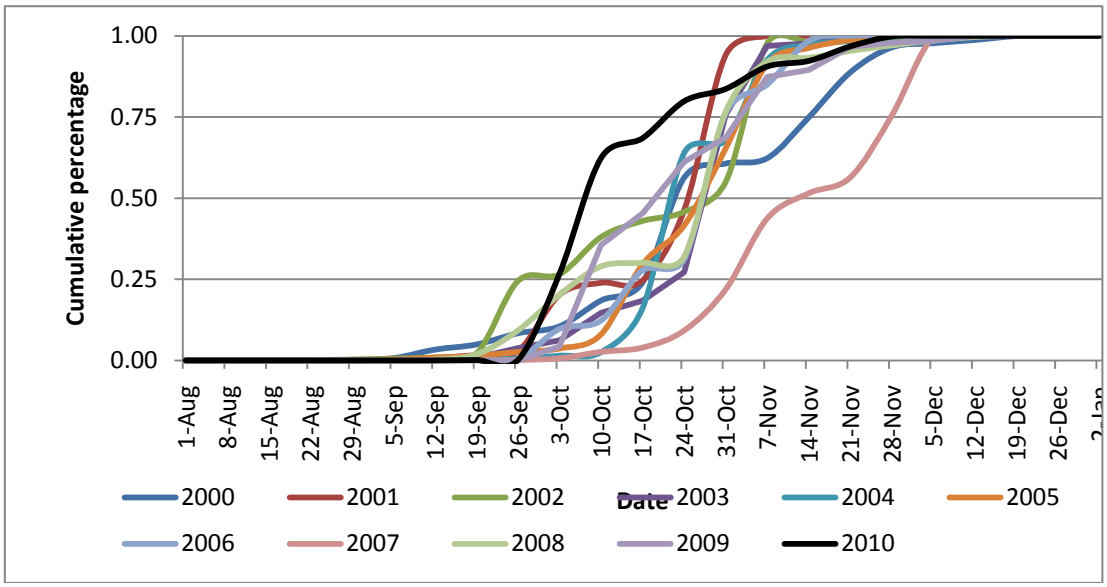


Figure 8.3.5. Cumulative percentage of the total number of adult Chinook salmon counted at the Mirabel Dam fish ladders each year from 2000 to 2010.

Table 8.3.10. Date that the mean daily water temperature declines below 17.1 and 15.5 and the percentage of the run that occurs after this date, 2000-2010.

Year	Date temp ≤ 17.1°C	Percentage of Chinook salmon counted on days when temp ≤17.1°C	Date temp ≤ 15.5°C	Percentage of Chinook salmon counted on days when temp ≤15.5°C
2000	Oct 11	86.5	Oct 22	76.4
2001	Oct 7	75.4	Oct 21	72.6
2002	Oct 9	97.7	Oct 16	59.4
2003	Oct 16	83.2	Oct 30	75.3
2004	Oct 10	98.4	Oct 13	96.7
2005	Oct 9	96.2	Oct 27	91.8
2006	Oct 11	99.6	Oct 18[1]	82.2[1]
2007	No data[2]	No data	No data	No data
2008	Oct 4	87.3	Oct 10	79.7
2009	Sept 30	93.9	Oct 28	62.2
2010	Oct 14	91.3	Oct 17	62.3

[1]Temperature pulled on October 18, 2006 when the MDT = 15.8°C. For this analysis it was assumed that the temperature would have declined below 15.5°C on October 19.
[2]Temperature probed failed, no temperature data collected in 2007.

References

Hinze, J. A. 1959. Annual report. Nimbus salmon and steelhead hatchery. Fiscal Year 1957-58. CDFG. Inland fish. Admin. Rept. 56-25.

9: Chinook Spawning Ground Surveys

Although not an explicit requirement of the Biological Opinion, the Water Agency has continued to perform spawning ground surveys for Chinook salmon in the mainstem Russian River and Dry Creek. This effort compliments the required video monitoring of adult fish migration and has been stipulated in temporary D1610 flow change orders issued by the State Water Resources Control Board to satisfy the Biological Opinion (see Pursue Changes to D1610 flow chapter of this report). The Water Agency began conducting Chinook salmon spawning surveys in fall 2002 to address concerns that reduced water supply releases from Coyote Valley Dam (Lake Mendocino) may impact migrating and spawning Chinook salmon (Cook 2003). Spawner surveys in Dry Creek began in 2003.

This report summarizes 2010 field studies that were curtailed due to poor conditions for detecting Chinook salmon redds. Hence, spawner surveys were only conducted in Dry Creek. Background information on the natural history of Chinook salmon and findings from 2002 to 2009 are presented in the 2009 Russian River Biological Opinion annual report (SCWA 2011). The primary objectives of the spawning ground surveys are to (1) characterize the distribution and relative abundance of Chinook salmon spawning sites, and (2) compare annual results with findings from previous study years.

Methods

Chinook salmon redd (spawning bed) surveys were conducted in the Russian River from fall 2002 to 2010. Typically, the upper Russian River basin and Dry Creek are surveyed (Figure 9.1). The study area includes approximately 114 km of the Russian River mainstem from Riverfront Park (40 rkm), located south of Healdsburg, upstream to the confluences of the East and West Forks of the Russian River (154 rkm) near Ukiah. River kilometer (rkm) is the meandering stream distance from the Pacific Ocean upstream along the Russian River mainstem and for Dry Creek the distance from the confluence with the Russian River upstream. In 2003, the study area was expanded to include 22 rkm of Dry Creek below Warm Springs Dam at Lake Sonoma to the Russian River confluence.

Chinook salmon spawner surveys were limited to Dry Creek in 2010. Performing spawner surveys are dependent upon suitable field conditions. Unfortunately, high flows at the onset of the 2010 Chinook salmon migration period prevented safe boating and increased water turbidity in the Russian River mainstem. Water conditions in Dry Creek, which receives releases from Lake Sonoma, had lower flows and clear water that was suitable to conduct spawner surveys.

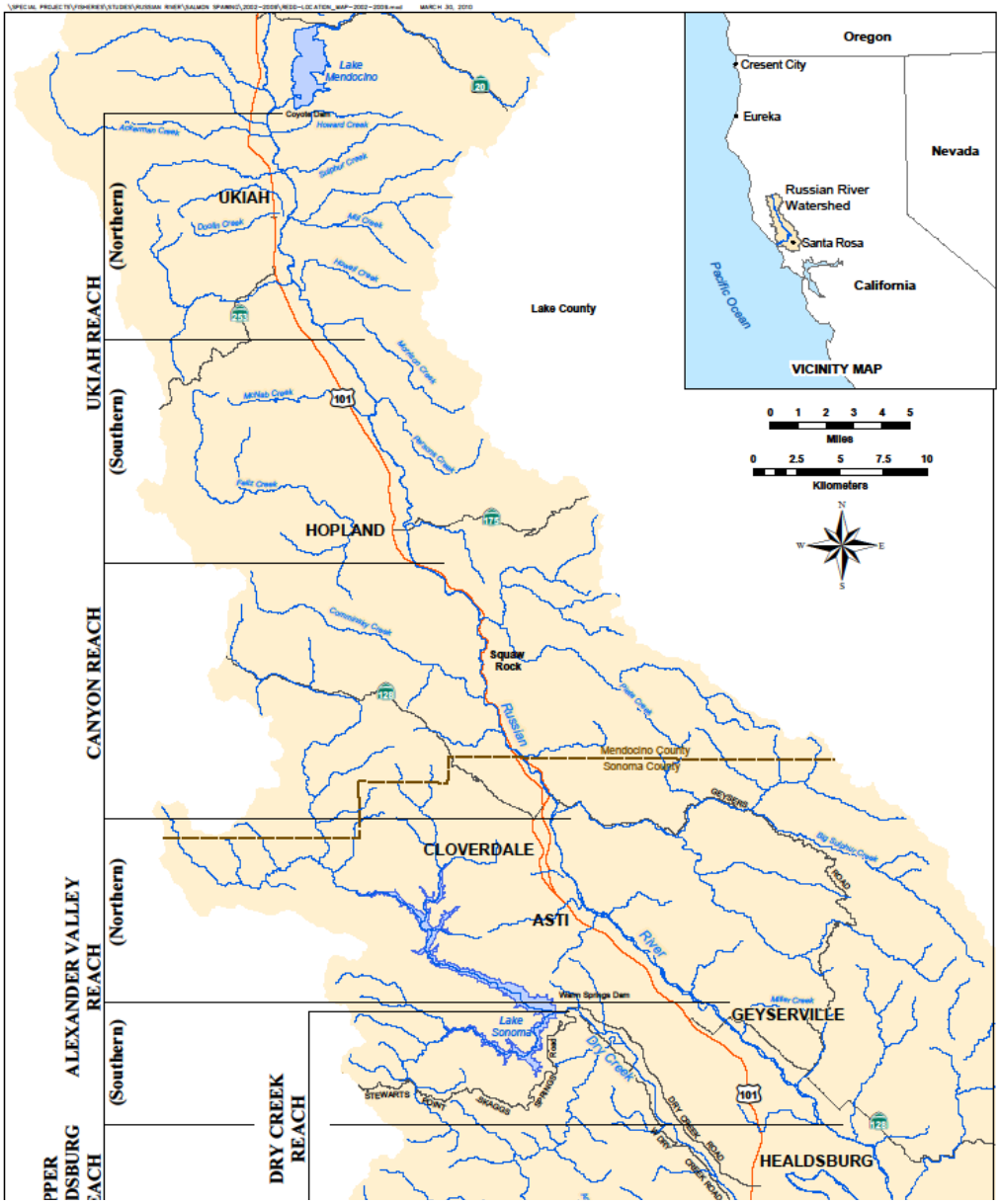


Figure 9.1. Chinook salmon spawning survey reaches. Only surveys in Dry Creek were completed in 2010.

Surveys were conducted to determine the distribution and relative abundance of Chinook salmon redds and the habitats utilized for spawning. The Dry Creek study area was surveyed once on November 15, 2010. A crew of 2 biologists in kayaks visually searched for redds along the streambed. The locations of redds were recorded using a global positioning system (GPS).

The number of redds counted during surveys is unlikely to be the actual number of redds constructed during the annual spawning period. Redd surveys were conducted after underwater video monitoring at the Mirabel inflatable dam fish ladder indicated a peak in migration activity (see Chapter 8.3). However, it is likely that additional redds were constructed after the single-pass survey of the study area. Additionally, identification of individual redds was difficult at high density spawning grounds because some redds were covered or obscured by overlapping redds. Chinook salmon may also spawn in low numbers in the larger tributaries located outside of the study area.

Results

Most of the Chinook salmon spawning typically occurs in the upper Russian River mainstem and Dry Creek (SCWA 2011), although the mainstem of the Russian River was not sampled in 2010. A total of 269 redds were found in Dry Creek in 2010 (Figure 9.2). This number was second highest only to 342 redds recorded in 2004.

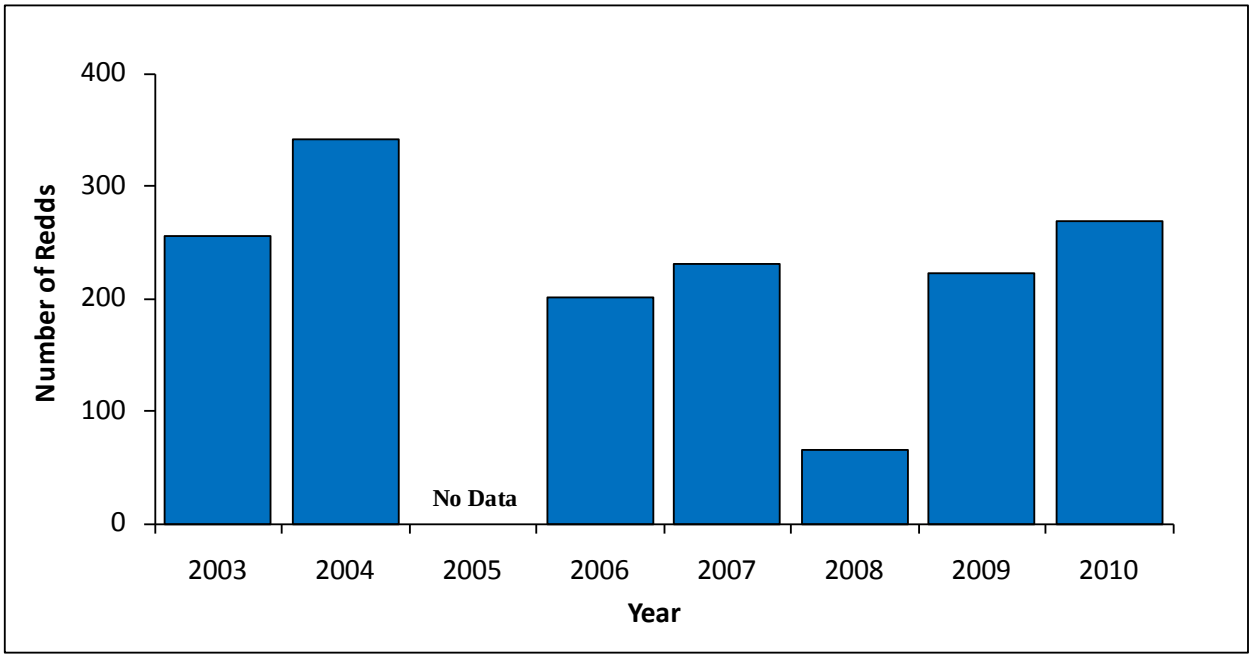


Figure 9.2. Chinook salmon redds in Dry Creek, 2002-2010. Redd counts are from single pass surveys. The 2008 value is a proportional estimate based on a partial survey of the reach.

The locations of Chinook salmon redds in Dry Creek were similar during the 8 years of study (see Appendix F-1). Redds were constructed at the tail ends of pools or heads of riffles with gravel to small cobble substrate. Due to faster water velocities from dam releases this preferred substrate is also found in fast flowing run habitats in Dry Creek and Chinook salmon redds were occasionally found in this habitat. Most of the suitable spawning for Chinook salmon is located in the upper reach of Dry Creek, which had the highest density of redds clustered at riffle sites. As many as 19 redds were observed at a single spawning site. Relatively few redds were detected in the lower reach of Dry Creek. The upper half of the Dry Creek reach contained greater than 80% of the redds annually, including 2010.

The overall frequency of redds in Dry Creek was 12.4 redds/rkm in 2010, which was second only to 2004 at 15.8 redds/rkm (Table 9.1). The highest frequency of redds in Dry Creek was always at the upstream terminus near Lake Sonoma. In the two river kilometers below Lake Sonoma 72 redds were observed (Figure 9.3). The highest report was in 2004 with 110 redds.

Conclusions and Recommendations

During 2005 and 2010 Chinook salmon spawner surveys were thwarted or curtailed due to poor sampling conditions. Although Chinook salmon spawner surveys could not be completed in the mainstem of the Russian River, the relatively high abundance of redds in Dry Creek and results of adult fish counts at the Mirabel Dam video monitoring station (Chapter 8 in this report) indicate that Chinook salmon were moderately abundant in the Russian River watershed during 2010. From 2003 to 2009 Dry Creek contributed between 21% to 45% of all redds recorded in the upper Russian River and Dry Creek study area (SCWA 2011).

Table 9.1. Chinook salmon redd frequencies in Dry Creek, 2002- 2010. *Survey either not completed or incomplete.

		Frequency (redd/rkm)								
Reach	**Reach (rkm)**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
Dry Creek	21.7	*	11.8	15.8	*	9.3	10.6	3.0	10.3	12.4

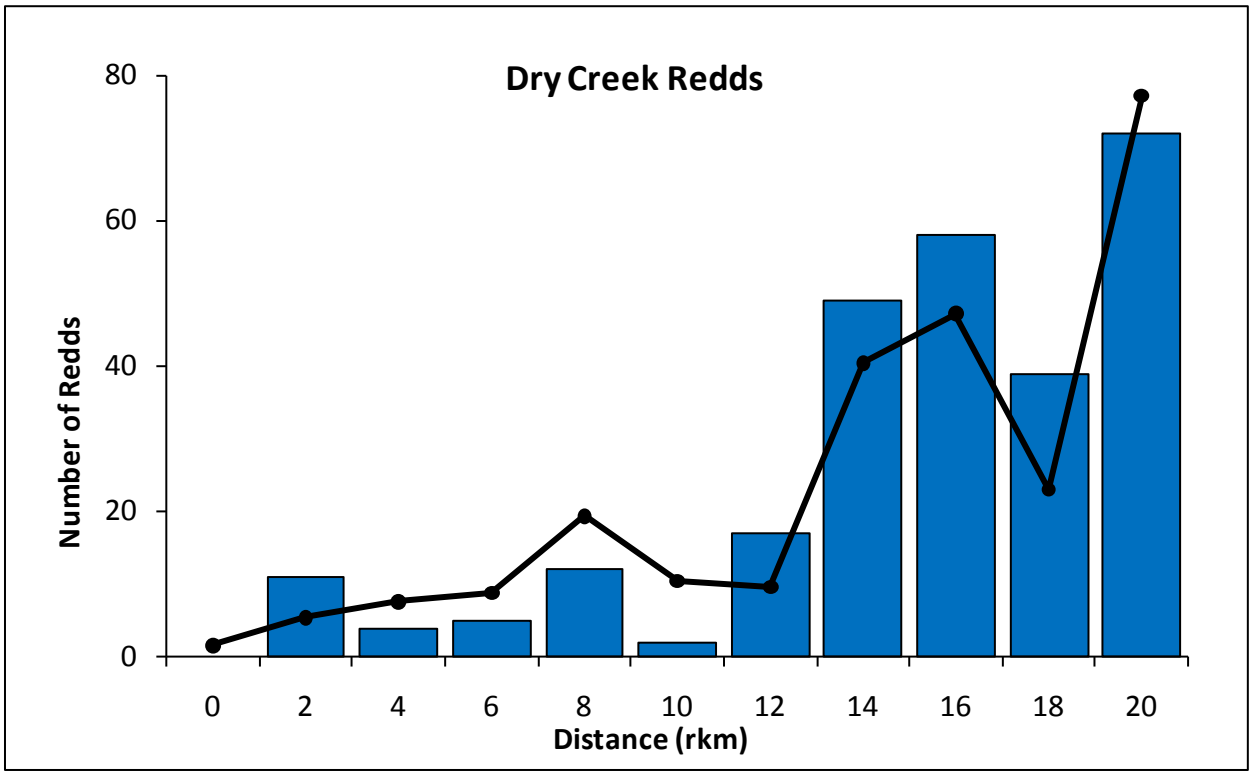


Figure 9.3: Chinook salmon redds in Dry Creek, 2010. Number of redds are grouped in 2-rkm intervals. River distances extend from the Dry Creek confluence with the Russian River (0 rkm) to Warm Springs Dam at Lake Sonoma (22 rkm). The black line is the average number of redds between 2003 and 2009.

References

Cook, D. (Sonoma County Water Agency). 2003. Chinook salmon spawning study, Russian River, fall 2002. 9 p. Santa Rosa, (CA): Sonoma County Water Agency.

Sonoma County Water Agency. 2011. Russian River biological opinion status and data report 2009-10. February 28. Santa Rosa (CA): Sonoma County Water Agency.

10: Synthesis

As has been outlined in portions of this report leading to this chapter, the Sonoma County Water Agency has collected a variety of fish and water quality monitoring data relevant to fulfilling the overall objectives in the Russian River Biological Opinion. The objectives specific to this synthesis chapter are to relate these data by (1) illustrating the spatial and temporal extent of monitoring activities; and (2) presenting and discussing currently emerging trends in juvenile salmonid abundance, growth and movement in streams encompassed by the RPA.

Sampling Methods and Spatial Extent

In 2010 we collected data from a broad spatial and temporal extent in the Russian River Basin. We begin by illustrating the spatial (Figure 10.1a, b) and temporal extent (Figure 10.2) of our sampling in 2010. Between April 16 and December 5, we collected fish data from 23 sites in the Russian River Basin. We also conducted spawner surveys on 137 km of stream length in the mainstem Russian River and Dry Creek. Sites, gear types, and target life stages monitored included: downstream migrant trapping with rotary screw traps on Dry Creek, the mainstem Russian River at Wohler-Mirabel and Austin Creek as well as a funnel net on Dutch Bill Creek and Green Valley Creek (operated by UCCE); operation of an underwater video camera and PIT antenna to detect both PIT-tagged and non-PIT-tagged salmonids near the upstream extent of the estuary in Duncans Mills; juvenile salmonid sampling using beach seining at ten fixed locations in the estuary; juvenile sampling using electrofishing, PIT tags and PIT antennas at multiple sites in Dry Creek; adult Chinook surveys using underwater video at Wohler-Mirabel and from spawner surveys in the upper mainstem and Dry Creek. Complementary data on water quality were collected by means of continuously-recording datasondes at 9 sites throughout the estuary and from grab samples at 5 additional sites. Invertebrate sampling was conducted at six sites. Details regarding the specifics of these monitoring activities are covered in individual chapters of this report.

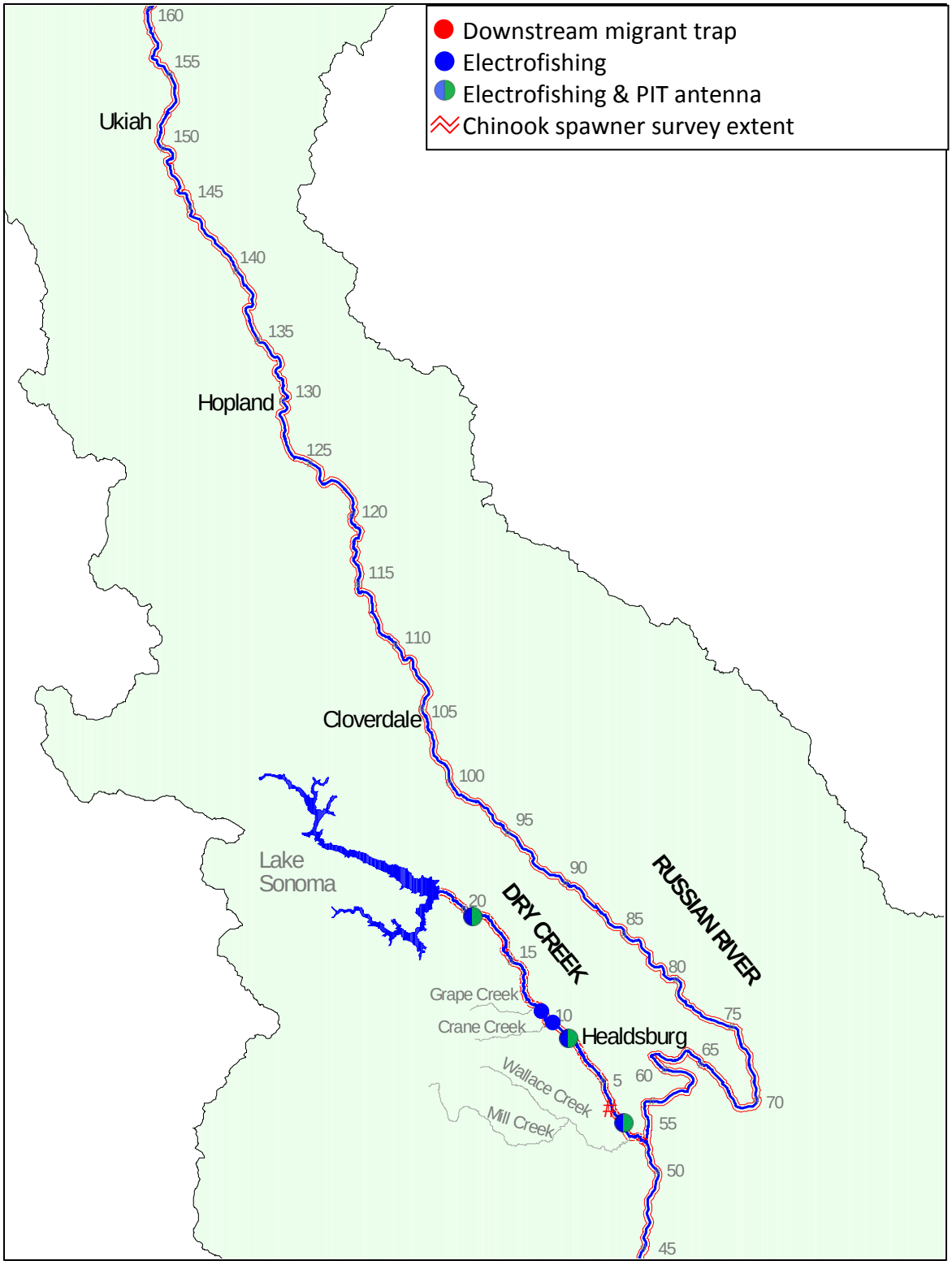


Figure 10.1a. Spatial extent of fisheries and water quality monitoring related to the Russian River Biological Opinion upstream of Dry Creek, 2010. Gray numbered dots indicate distance in kilometers from the mouth of the stream.

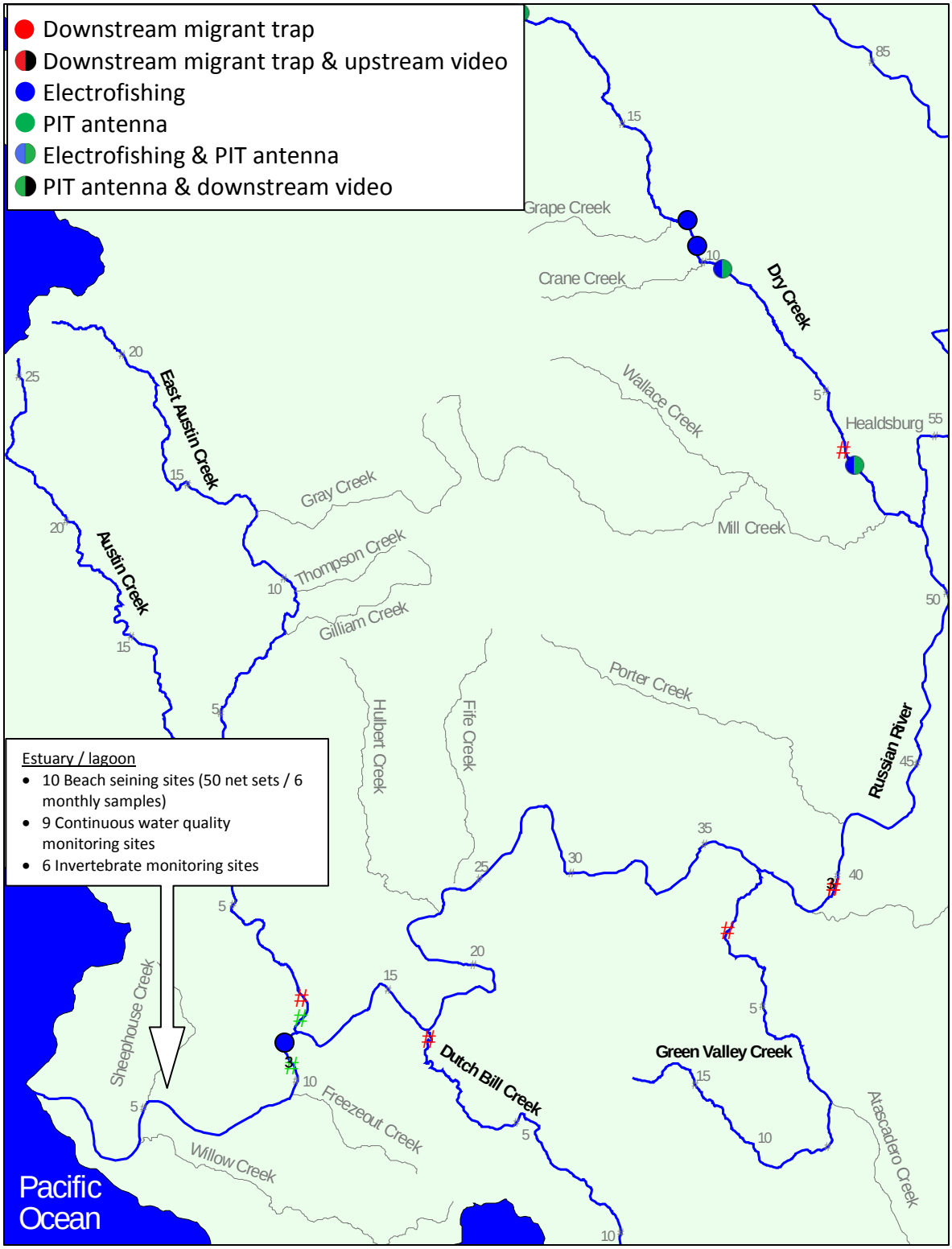


Figure 10.1b. Spatial extent of fisheries, water quality and invertebrate sampling related to the Russian River Biological Opinion downstream of Dry Creek, 2010. Gray numbered dots indicate distance in kilometers from the mouth of the stream.

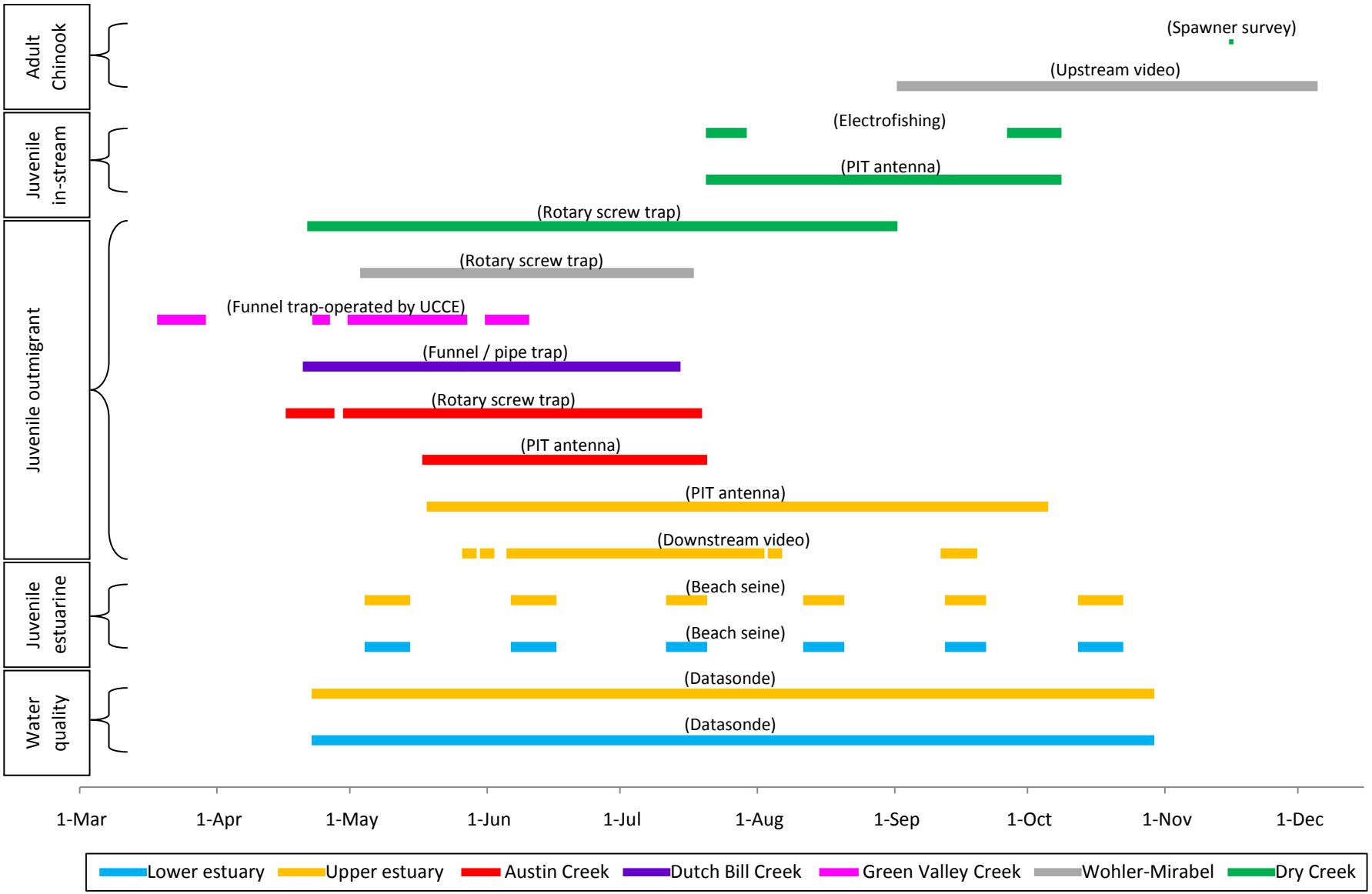


Figure 10.2. Temporal and life stage extent of sampling at fisheries and water quality monitoring sites related to the Russian River Biological Opinion, 2010.

Fish Data

Abundance

Installation of downstream migrant traps (DSMT) in 2010 was delayed because of late storms and associated high flows. Despite this delay, trap operation was fairly smooth once traps were finally installed. Capture of steelhead parr was highest in Austin Creek (4,682) and Dry Creek (2,049) and lowest in traps on Dutch Bill (58) and Green Valley Creeks (5); as in 2009, we captured relatively few steelhead smolts at downstream migrant traps in 2010. For traps that were in operation in both 2009 and 2010 (Dry Creek and Wohler-Mirabel), the number of coho smolts captured and the composition of their origin was similar between years. When compared to 2009, Chinook salmon smolt capture in 2010 was 60% higher at Wohler-Mirabel yet 77% lower at Dry Creek. The reasons for this inconsistency is likely related to a host of factors that may include sampling artifacts (e.g., trap inefficiencies due to high flows which we expect was a significant issue at Wohler-Mirabel) as well as abiotic factors operating to regulate alevin or early fry populations (e.g., high winter flows leading to redd scour which may have been an issue on Dry Creek).

In 2010, there was a 42% increase in the number of individual salmonids (all three species combined) captured during beach seining in the estuary as compared to 2009. Much of this difference can be attributed to an increase in sampling effort in 2010. Catch per unit effort (CPUE) of juvenile steelhead was somewhat higher (0.86 fish per seine haul) than the 2004-2010 average (0.74) yet CPUE for Chinook was only 40% of the 2004-2010 average of 2.14.

Based on seining catches in the estuary and trap captures at Wohler-Mirabel, there is a loose correspondence in both juvenile steelhead abundance and Chinook smolt abundance in the mainstem and the estuary particularly when abundance is high (Figure 10.3 and 10.4). Although based on fewer years of data, there also appears to be somewhat of a correspondence for juvenile steelhead and Chinook smolt abundance between Dry Creek and elsewhere. Trends between the size of the spawning cohort and their offspring are also similar (Figure 10.5 and 10.6).

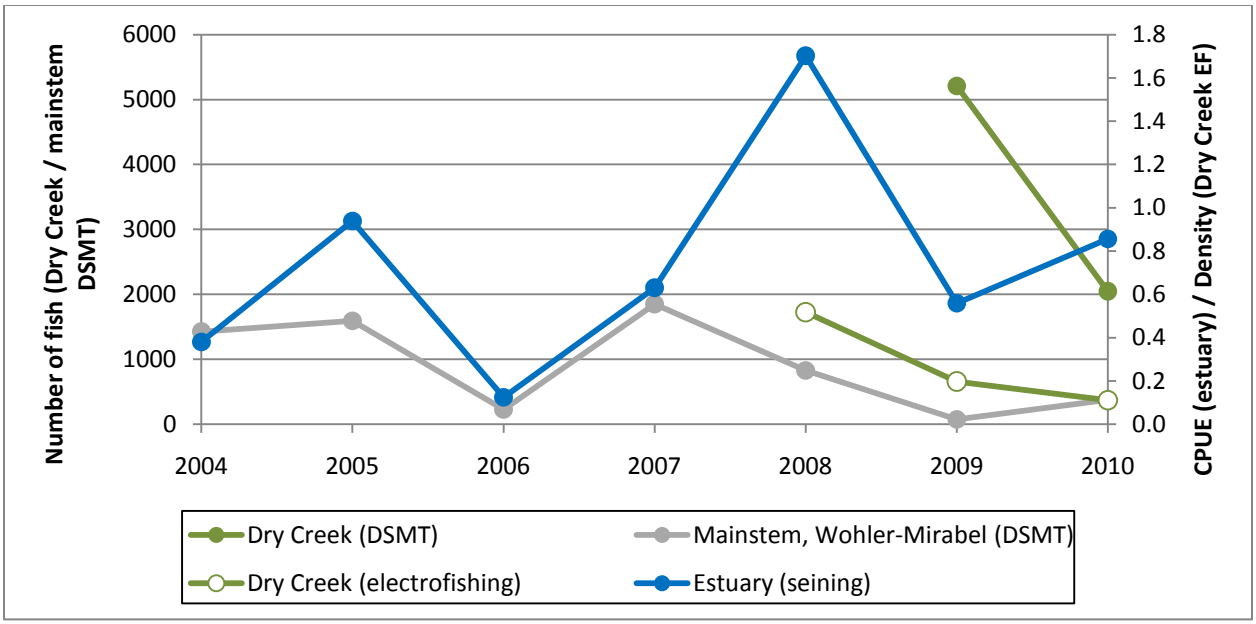


Figure 10.3. Catch per unit effort of juvenile (non-smolt) steelhead in the estuary (beach seining) and number of juvenile steelhead captured in Dry Creek (DSMT and electrofishing) and the mainstem (DSMT), 2004-2010.

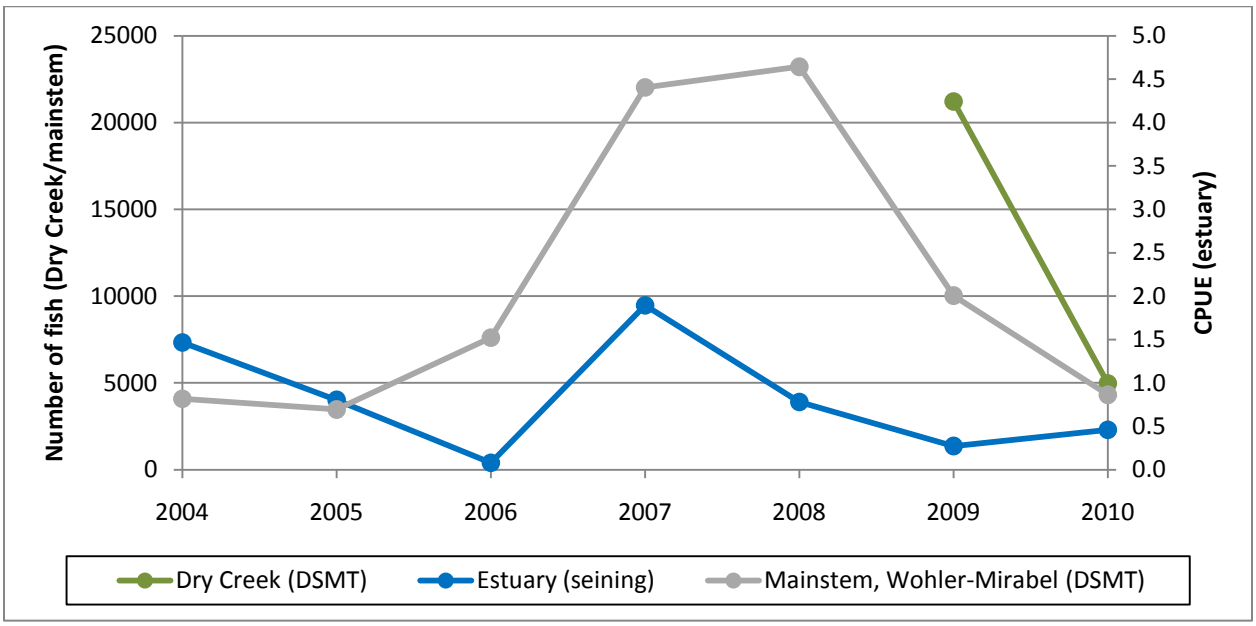


Figure 10.4. Catch per unit effort of Chinook salmon smolts in the estuary (beach seining) and number of Chinook salmon smolts captured in Dry Creek (DSMT) and the mainstem (DSMT), 2004-2010.

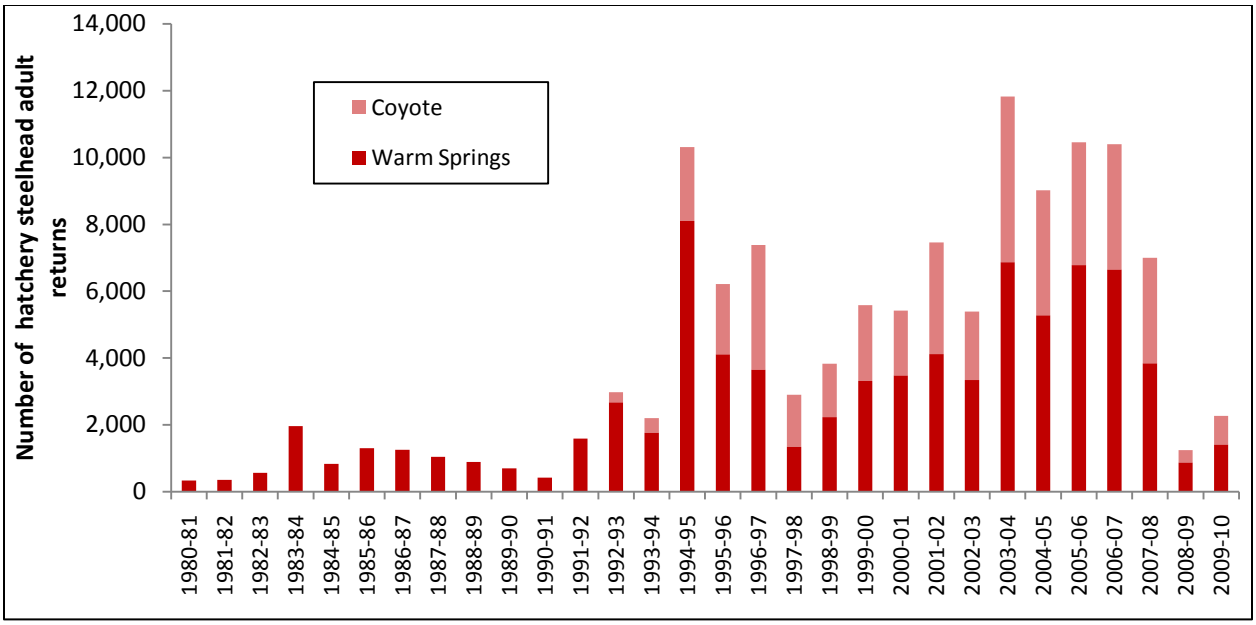


Figure 10.5. Number of adult steelhead returning to Russian River hatcheries by return year (CDFG unpublished data).

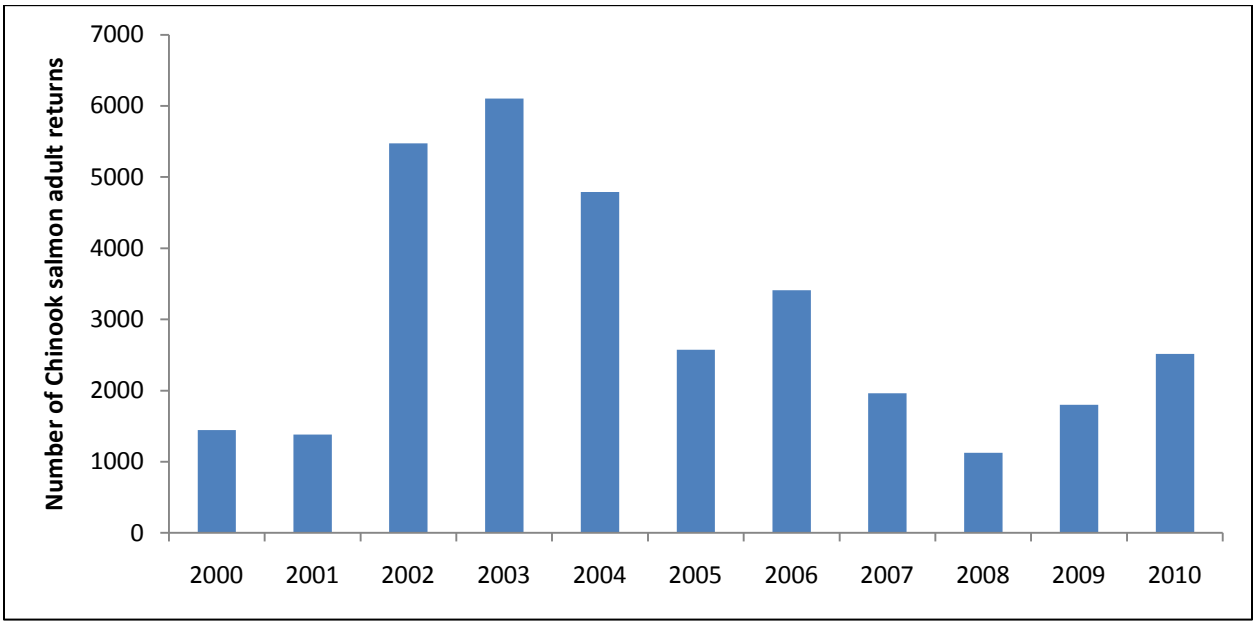


Figure 10.6. Number of adult Chinook salmon returning to Russian River by return year.

Chinook size

Similar to 2009, the run timing of Chinook smolts was later in Dry Creek as compared to Wohler-Mirabel (8 days). A consequence of this later timing was that relatively fewer Dry Creek fish would be represented in the Wohler-Mirabel catch early in the season (i.e., more individuals from mainstem habitat) as compared to later in the season. If the relative sizes of fish produced outside of Dry Creek are larger, then this should show up in larger sizes of fish captured at Wohler-Mirabel during the early part of the season. That pattern is supported by the size distributions from the two sites (Figure 10.7).

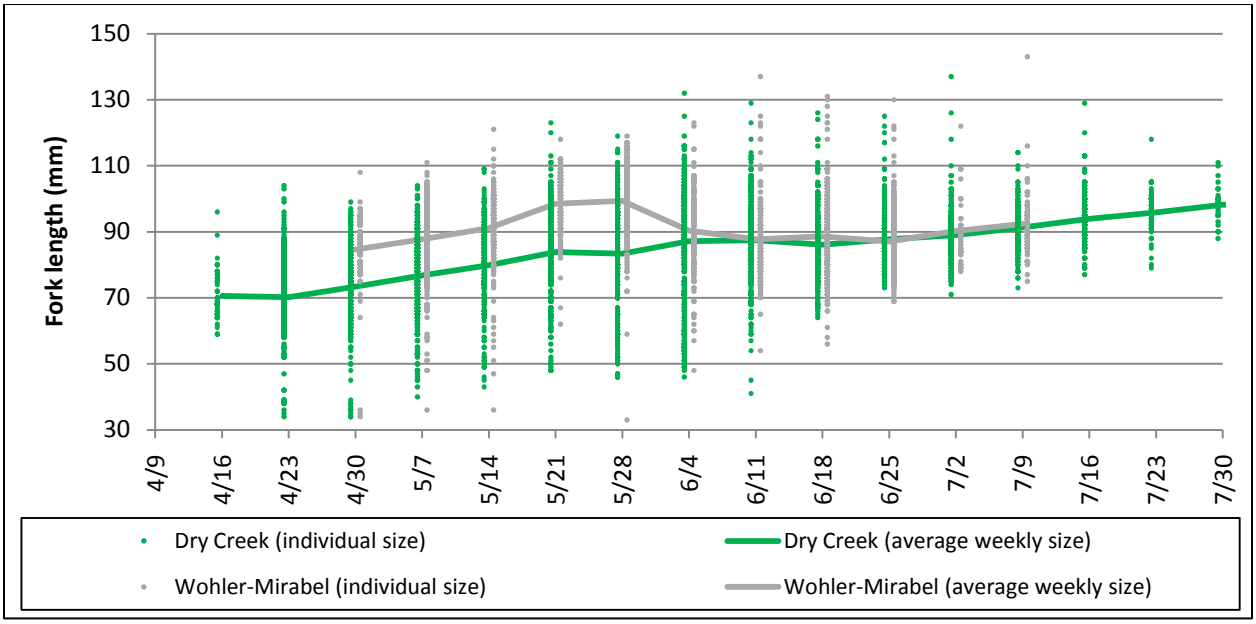


Figure 10.7. Individual and average weekly Chinook salmon smolt sizes at Dry Creek and Wohler-Mirabel, 2010.

PIT-tagged steelhead

In 2010, we PIT-tagged 2,299 individual juvenile steelhead at all sites combined (Table 10.1). We later physically gathered 1,364 detections to help inform us about growth (Table 10.2, Figure 10.8) and transition time (Table 10.3) within and among various portions of the estuary, mainstem, lower River tributaries and Dry Creek.

In 2010 we learned that the estuary afforded conditions leading to the highest growth rates of steelhead of any of the habitats we monitored. We also learned that a significant proportion of steelhead captured in lower Austin Creek in 2010 took advantage of this habitat and that their rate of movement into the estuary was rapid (<2 days). The fact that we did observe movement of a few juvenile steelhead that were tagged outside of Austin Creek into Austin Creek (Dutch Bill Creek and the estuary, Table 10.1) suggests that Austin Creek itself may serve also serve as rearing habitat for juvenile steelhead from other streams.

Table 10.1. Number of juvenile steelhead tagged in 2010 and later detected at various sites. Numbers in parentheses represent the number PIT-tagged.

Detection / tagging site			Recapture site														
			Estuary			Austin Creek		Dutch Bill Creek	Green Valley Creek	Main-stem	Dry Creek						
			Lower reach	Upper reach	Duncans Mills	Steel bridge	Gravel mine	Monte Rio Park	Lower trap site	Wohler-Mirabel	Westside Road	Lower reach		Middle reach		Upper reach	
Tributary	Site	Gear	Seining	Seining	PIT antenna	PIT antenna	DSMT	DSMT	DSMT	DSMT	DSMT	PIT antenna	Electrofishing	PIT antenna	Electrofishing	PIT antenna	Electrofishing
Estuary	Lower reach	Seining	14 (186)			1											
	Upper reach	Seining		7 (55)	2	2											
	Duncans Mills	PIT antenna			na												
Austin	Steel bridge	PIT antenna		9	41	na											
	Gravel mine	DSMT		13	53	547	114 (994)										
Dutch Bill	Monte Rio Park	DSMT				3		0 (46)									
Green Valley	Lower trap site	DSMT							0 (18)								
Mainstem	Wohler-Mirabel	DSMT								0 (96)							
Dry Creek	Westside Road	DSMT									0 (9)						
	Lower reach	PIT antenna										na	3				
		Electrofishing									1	35	43 (352)				
	Middle reach	PIT antenna										1		na	1		
		Electrofishing										3		11	55 (347)		
	Upper reach	PIT antenna														na	
		Electrofishing														16	36 (196)

Table 10.2. Mean individual growth rates (mm per day) of juvenile steelhead captured and tagged in 2010 and later recaptured in 2010. Numbers in parentheses represent sample sizes.

Detection / tagging site			Recapture site					
			Estuary		Austin Creek	Dry Creek		
			Lower reach	Upper reach	Gravel mine	Lower reach	Middle reach	Upper reach
Tributary	Site	Gear	Seining	Seining	DSMT	Electrofishing	Electrofishing	Electrofishing
Estuary	Lower reach	Seining	0.82 (14)					
	Upper reach	Seining		0.62 (6)				
Austin	Gravel mine	DSMT		1.13 (13)	na			
Dry Creek	Lower reach	Electrofishing				0.43 (41)		
	Middle reach	Electrofishing					0.42 (54)	
	Upper reach	Electrofishing						0.21 (36)

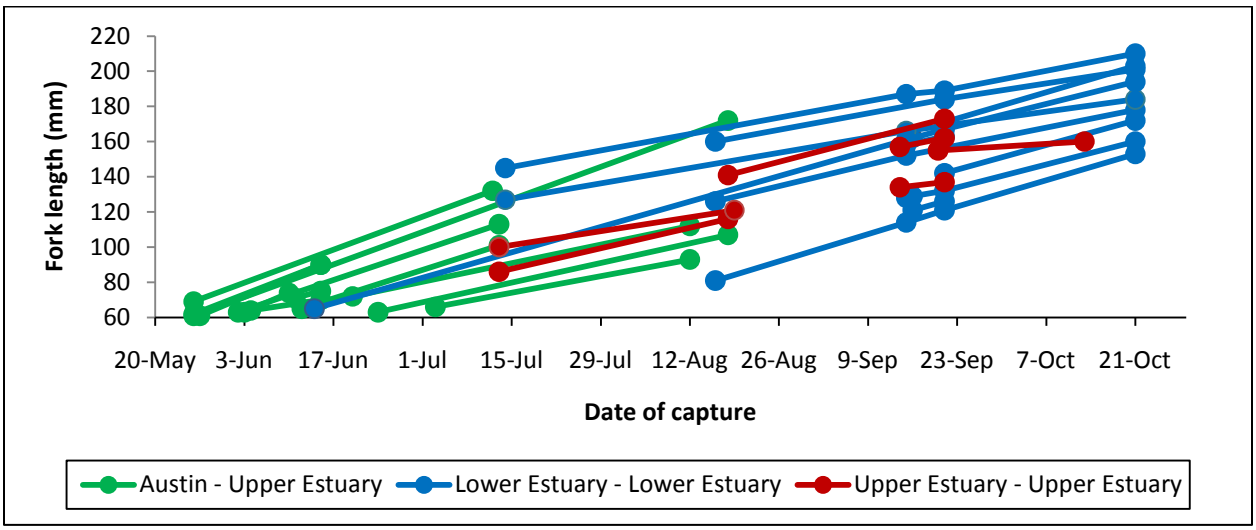


Figure 10.8. Initial sizes and recapture sizes of juvenile steelhead PIT- tagged in either Austin Creek at the downstream migrant trap or in the estuary during beach seining. Colors of lines represent capture and recapture locations.

Table 10.3. Transit time (days) of juvenile steelhead between various locations, 2010. Numbers in parentheses represent sample sizes.

Detection / tagging site			Recapture site					
			Estuary			Austin Creek		Dutch Bill Creek
			Lower reach	Upper reach	Duncans Mills	Steel bridge	Gravel mine	Monte Rio Park
Tributary	Site	Gear	Seining	Seining	PIT antenna	PIT antenna	DSMT	DSMT
Estuary	Lower reach	Seining				35 (1)		
	Upper reach	Seining			12.5 (2)	42.5 (2)		
	Duncans Mills	PIT antenna						
Austin	Steel bridge	PIT antenna		27.7 (9)	8.2 (41)			
	Gravel mine	DSMT		38.2 (13)	8.4 (53)	1.4 (547)		
Dutch Bill Creek	Monte Rio Park	DSMT				7.3 (3)		

Conclusions and Recommendations

In 2010, the Water Agency continued to refine methods and approaches for gathering the information necessary to inform the decisions as the RPA is implemented. As the Water Agency continues to implement the Russian River Biological Opinion, information on abundance, movement and growth will be key to our understanding of how various management actions outlined in the RPA translate to population benefits.

Figure 10.9 is a first attempt to illustrate prevailing estuarine water quality conditions experienced by emigrating or rearing coho, Chinook, and steelhead. Because we are only just beginning to appreciate patterns of movement, growth, and behavior of fish that rear in the estuary, these plots are most useful to interpret conditions encountered by emigrating juveniles and smolts. We used the cumulative weekly trap capture of coho at Mirabel Dam, Chinook in Dry Creek, and steelhead in Austin Creek, plotted as percentiles, to serve as metrics of lower Russian River outmigration. We plotted these cumulative percentiles against water temperature and dissolved oxygen levels recorded by data sondes in the upper (Freezeout Creek) and lower (Patty's Rock) reaches of the estuary. To provide context to these data, we

also depicted ranges of water quality suitability for salmonids based on the literature (Table 10.4).

The 50th percentile in these cumulative curves indicates that fish emigrating during the first half of the outmigration period in 2010 (May 1 to June 1) likely encountered good to fair temperature and dissolved oxygen conditions in the upper and lower estuary. However, during the later portion of the emigration period (90th percentile, June 1 to June 26) temperature conditions throughout the water column, and dissolved oxygen at depth, in the upper estuary approached stressful levels. In contrast, lower estuary temperature and dissolved oxygen were fair to good during this time.

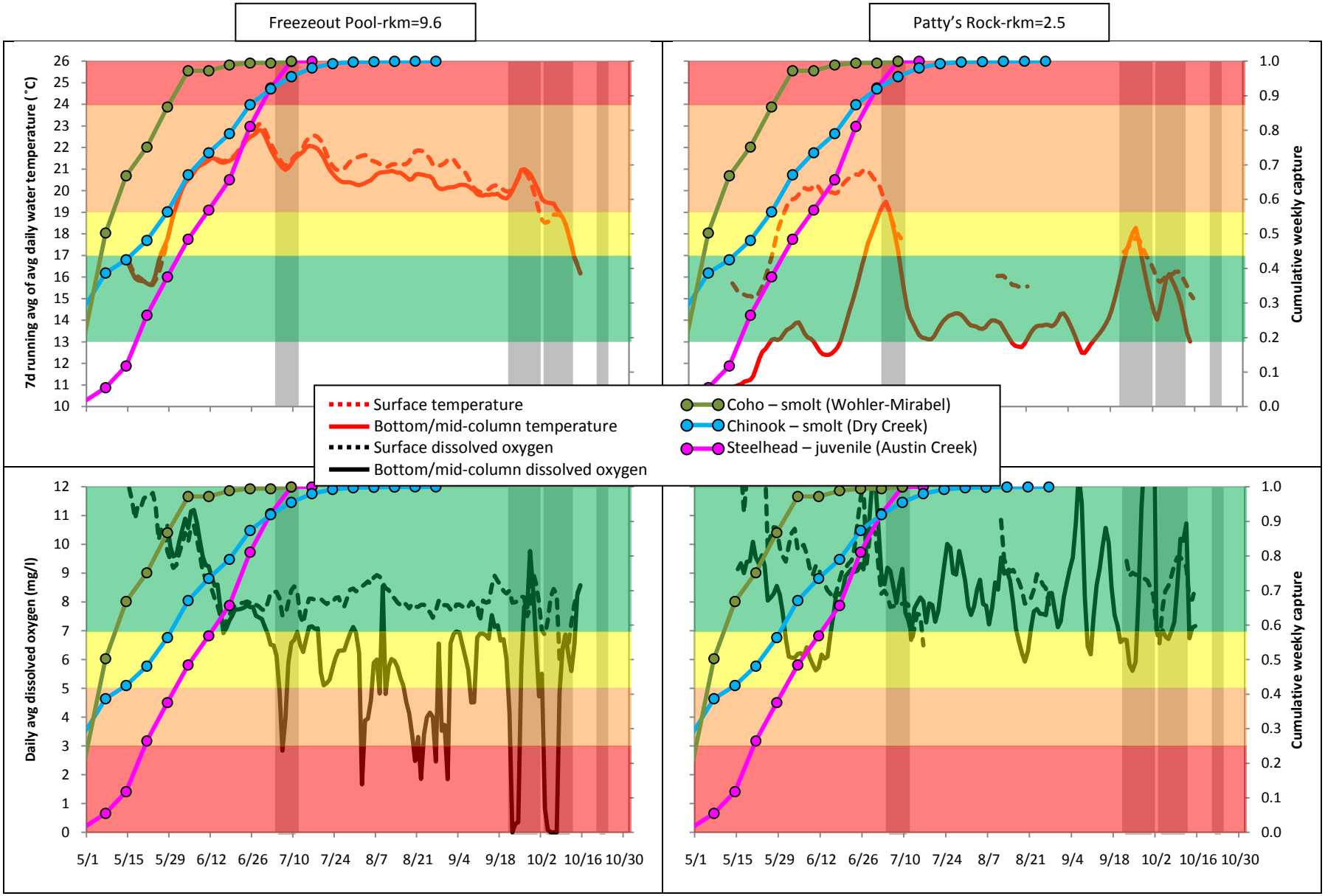


Figure 10.9. Seven day running average of daily average water temperature (upper panels) and average daily dissolved oxygen (lower panels) at Freezeout Pool (upper estuary) and Patty's Rock (lower estuary). Salmonid capture is from representative sites in the basin. Horizontal shaded areas correspond to literature-based criteria (see Table 10.4) and shaded vertical areas depict periods when the estuary was closed.

Table 10.4. Temperature and dissolved oxygen thresholds used for ranking observed estuarine water quality for rearing salmonids in 2010. Temperature thresholds are based on Sullivan et al. (2000) and NCRWQCB (2000).

Quality	Maximum weekly average temperature (˚C)	Dissolved oxygen (mg/l)
Best	13-17	7-12
Good	17-19	5-8
Poor	19-24	3-5
Worst	>24	<3

11: Appendices

All Appendices are included in the accompanying electronic media.