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NORTH COAST ALGAE AND NUTRIENTS STUDY 2010-2011

South Fork Eel River and Russian River

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Executive Summary

General problems associated with nutrient enrichment (eutrophication) and with increases in algal blooms as a result of biostimulatory conditions have been reported in the South Fork Eel and Russian River watersheds for decades. Since 2001, incidences of cyanotoxin-related dog deaths have occurred in some rivers and waterbodies in the North Coast region. Frequent observations of cyanobacteria blooms, and in some cases the presence of cyanotoxins, have been reported in the South Fork Eel River. To investigate these issues, the Regional Water Board's Surface Water Monitoring Program initiated the studies described in this report.

The North Coast Algae and Nutrients Study was conducted as an initial survey of select areas in the South Fork Eel River in 2010 and in the Russian River in 2011. The Study Areas were divided into four stream reaches, each approximately 0.2-miles long and spaced a few miles apart to track spatial gradients. Additional reaches outside of the Study Areas of each river were chosen only to provide context on biostimulatory conditions and are not otherwise presented or discussed in the same manner as the four fixed stream reaches. However, these data are presented in the Appendices. Temporal patterns within each river were gleaned from multiple visits to each stream reach during late spring, summer, and fall. This was one of the first studies conducted to examine the seasonal development of algal communities in Northern California, and one of the first implementations of the Surface Water Ambient Monitoring Program sampling protocol honed by A.E. Fetscher and colleagues in 2007-2009. It was also one of the first studies investigating biostimulatory conditions and their link to nuisance algal blooms and potentially toxin-producing cyanobacteria[1](cyanobacteria harmful algal blooms or cyanoHABs) in the North Coast.

This report presents six groups of results: (1) the spatial and temporal patterns in benthic algal biomass, as manifested by the amount of chlorophyll *a* (Chl-a) and organic matter (measured as ash-free dry mass (AFDM)) per unit area; (2) the spatial and temporal patterns in nutrient concentrations; (3) spatial and seasonal patterns in water quality characteristics (temperature, dissolved oxygen, pH, and specific conductance); (4) taxa composition of diatoms in the Study Area during summer and fall, based on cell counts; (5) biovolumes of filamentous "soft algae" including green algae and cyanobacteria in the Study Area throughout the summer and fall; and (6) presence and relative abundance of cyanobacterial genera in the Study Areas during summer and fall.

Nitrogen and phosphorus were readily available in both Study Areas throughout the spring, summer, and fall, often at concentrations exceeding the water quality benchmarks (WQB) developed by US Environmental Protection Agency (USEPA) for Aggregated Nutrient Ecoregion II (South Fork Eel River) and Aggregated Nutrient Ecoregion III (Russian River). Total nitrogen concentrations exceeded the Ecoregion II WQB of 0.12 mg/L in 10 of 30 South Fork Eel River samples and exceeded the Ecoregion III

[1] This study did not directly monitor or analyze the presence of cyanotoxins.

WQB of 0.38 mg/L in 1 of 43 mainstem Russian River samples. Total phosphorous was in exceedance of the Ecoregion II WQB of 0.01 mg/L 100% of the time (30 of 30 samples) in South Fork Eel River, and 35 of 43 samples were in exceedance of the Ecoregion III WQB of 0.02 mg/L in mainstem Russian River.

These concentrations indicate relatively moderate eutrophication, i.e., biostimulatory conditions were present, but algal growth resulted in very few exceedances of Beneficial Use Risk Categories (BURC) WQBs for Chl-a. The relationships between nutrient concentrations and algal biomass values are not always clear as seasonal trends and spatial gradients were variable in the two Study Areas.

In 2010, the South Fork Eel River followed seasonal water quality and flow conditions typical of an unmanaged stream located within a Mediterranean climate, with diminution of flow, gradual rise in specific conductance, and increasing daily amplitudes of dissolved oxygen and pH over the summer. Water temperatures peaked in July-August. The Russian River, a reservoir release dominated system, experienced relatively stable water quality and flow conditions in 2011, with little variability is these characteristics.

In both watersheds, taxonomic analysis of diatom communities showed a seasonal decrease in the relative abundance of nitrogen-heterotrophic taxa (i.e., taxa that cannot fix nitrogen from the air and need it as nitrate). This means that nitrogen-fixing taxa become more abundant, and may indicate that nitrate availability in the algal mat has diminished over the summer, giving an edge to taxa that can fix nitrogen from the air.

Filamentous benthic algal mats (mostly green algae of the Chlorophyta and Streptophyta groups) were very prominent in the Russian River, yielding total soft algae biovolumes of up to 7500 mm^3/cm^2 as compared to 70 mm^3/cm^2 in the South Fork Eel River. Soft algae biovolumes peaked in early August 2011 in the Russian River. An increase in the relative abundance of cyanobacteria (a sub-group of soft algae) was observed in early September. The presence of cyanobacterial taxa that can produce toxins (cyanotoxins) was very sporadic, with one peak of potential toxin-producing cyanobacteria (550 mm^3/cm^2) in the downstream reach (Reach 4) of the Russian River. In comparison, the relative abundance of cyanobacteria was much higher in the South Fork Eel River, and 45% of the samples – including all the samples from Reach 2 - were dominated by cyanobacteria. Of these, cyanobacteria genera capable of producing cyanotoxins were present in very low biomass: the maximum biovolume was only 7 mm^3/cm^2 in the South Fork Eel River. These observations pointed to the inherent variability in bloom dynamics and to the sporadic occurrence of blooms of potentially toxic cyanobacteria genera.

Epilogue

Publication of the results from the initial survey was postponed in favor of initiating more targeted cyanoHABs monitoring, implemented bi-weekly beginning in 2016, to identify potentially harmful cyanobacterial blooms in the Russian River and South Fork Eel River. Monitoring results were used to post health advisories as needed.

The South Fork Eel River and Russian River have become the stage for more rigorous efforts by the Regional Water Board and its partners to characterize cyanobacterial communities, determine what cyanotoxins they produce, and measure the actual concentrations of various cyanotoxins in situ. The information about cyanobacterial communities gleaned from this study provided a basis for further studies by the Regional Water Board, research institutes, academia, and others. Samples from the North Coast were used for advanced taxonomical analysis and gene-expression studies. New diagnostic tools utilizing molecular biology methods were also implemented, including identification of DNA fragments in environmental samples to detect the presence of toxin-coding genes or to quantify specific cyanobacterial genes. These studies have resulted in numerous scientific technical reports and journal articles (see compiled list in the Reference section 5.1).

List of Acronyms

AFDM	Ash-Free Dry Mass
BURC	Beneficial Use Risk Categories
CY	Calendar Year
CyanoHABs	cyanobacteria harmful algal blooms
DO	Dissolved oxygen
DOC	Dissolved Organic Carbon
HA	Hydrologic Area
HABs	Harmful Algal Blooms
HSA	Hydrologic Sub-Area
IBI	Index of Biotic Integrity
MDL	Method Detection Limit
MMI	Multi-Metric Index
MQO	Measurement Quality Objective
NCRWQCB	North Coast Regional Water Quality Control Board
NNE	Nutrient Numeric Endpoints
RL	Reporting Limit
RuR	Russian River
RWQCB	Regional Water Quality Control Board
SFBRWQCB	San Francisco Bay Regional Water Quality Control Board
SFEeL	South Fork Eel River
SOP	Standard Operating Procedures
SCCWRP	Southern California Coastal Water Research Project
SWAMP	Surface Water Ambient Monitoring Program (of the California State Water Resources Control Board)
TOC	Total Organic Carbon
TN	Total Nitrogen
TP	Total Phosphorus
USEPA	United States Environmental Protection Agency
USGS	United States Geologic Survey
WQB	Water Quality Benchmark
YSI	Yellow Springs Instruments

Glossary

Allochthonous – derived from a source external to the stream channel (e.g., riparian vegetation as a source of organic matter) as opposed to autochthonous, which indicates a source inside the stream channel (e.g., algae or macrophytes rooted in the stream)

Ash-free dry mass (AFDM) – the portion, by mass, of a dried sample that is represented by organic matter; the concentration of AFDM per stream surface area sampled is often used as a surrogate for algal biomass

Benthic algae – algae that are attached to, or have at one point been anchored to, the stream bottom, in contrast to planktonic algae which are free-floating in the water column

Biostimulatory Conditions – Conditions that enhance the growth of nuisance and/or invasive aquatic plants, often resulting in algal blooms (including harmful algal blooms; see HABs below). These conditions are usually associated with increased nutrient concentrations and are often related to decreased water flow, higher temperatures, and higher solar radiation due to loss of riparian canopy

Chlorophyll *a* – A green pigment that can capture the sun's energy. Chlorophyll allows plants (including algae) to photosynthesize, i.e., use sunlight to convert carbon dioxide molecules into organic compounds. Chlorophyll *a* is the predominant type of chlorophyll found in green plants and algae

Chlorophyta - a taxonomic group comprised of green algae. Green algae represent a heterogeneous assemblage of organisms belonging to two lineages (Chlorophyta and Streptophyta) and currently classified into 12 different classes. Green algae with filamentous and plant-like habits are common in freshwater and terrestrial environments, where they play a key ecological role

Cyanobacteria –historically referred to as "blue-green" algae, they are actually bacteria (chlorophyll-*a* containing prokaryotes) that are capable of photosynthesis and co-occur with "true" (i.e., eukaryotic) benthic algae in streams; useful as a bioindicator, and field-sampled and laboratory-processed as soft-bodied algae

Diatom – a unicellular golden-brown alga (Bacillariophyta) that possess a rigid, silicified (silica-based) cell wall in the form of a "pill box"

Eutrophication – The long-term process of nutrient accumulation in a waterbody. Excess of nutrients causes a dense growth of plant life, which could lead to oxygen depletion and death of organisms that require oxygen

Harmful Algal Blooms (HABs)– A "bloom" is rapid proliferation of algae and/or cyanobacteria. HABs refer to blooms of cyanobacterial species that can produce toxins that are harmful to humans and wildlife

Homogenize – to create a homogeneous solution or slurry. In the algal sampling protocol, it refers to the mixture of algae scraped from benthic particles with the finely chopped fragments of macroalgae. This mixture is used to dispense subsamples for taxonomic identification and biomass quantification (chlorophyll a, and AFDM)

Index of Biotic Integrity (IBI) – a quantitative assessment tool that uses information about the composition of one or more assemblages of organisms to make inferences about condition, or ecological health, of the environments they occupy (*e.g.*, algae or benthic macroinvertebrates)

Nitrogen-Fixing Taxa - microorganisms that have the ability to convert molecular nitrogen (N2) from the atmosphere to reduced nitrogen (e.g., ammonia (NH3) or amino groups (-NH2)), which is the form needed for life. Nitrogen fixers are common among diatoms, cyanobacteria, and soil bacteria such as the Rhizobium taxa that are attached to legume roots

Nitrogen Heterotrophs - all living things that cannot fix atmospheric nitrogen and require nitrogen that is already in a compound with hydrogen, oxygen, and/or carbon

Reach – delineated linear segment of a stream or river where monitoring and sampling occurs

Reach-wide benthos (RWB) – method for biotic assemblage sample collection that does not target a specific substrate type, but rather systematically selects sampling locations across the reach, allowing for any of a number of substrate types to be represented in the resulting composite sample

Riparian – an area of land and vegetation adjacent to a stream that has a direct effect on the stream by providing shade and habitat for wildlife, contributing allochthonous organic matter, modulating water levels via evaporative transpiration, etc.

Soft algae – non-diatom algal taxa; for the purposes of document, cyanobacteria are included in this assemblage

Substrate – Solid surface to which organisms can attach; in a streambed it includes both inorganic (e.g., pebbles) and organic particles (e.g. plants)

Taxonomy Metrics – various end-points of interest that can be calculated from taxonomic identification and enumeration results. For example, the percent of motile diatoms is calculated from the number of individuals (counts) belonging to motile diatom species, as a percent of total diatoms count for that sample

Wetted width – the width of the channel containing water (the active channel), defined as the distance between the sides of the channel at the point where substrates are no longer surrounded by surface water

Water Quality Benchmark - is a catch-all term to include objectives, guidelines, limits, targets, standards, and other types of values for concentrations of constituents that should not be exceeded in a given water body

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1 Introduction

The North Coast Regional Water Board's (Regional Water Board) Surface Water Ambient Monitoring Program (SWAMP) assesses waterbodies within the North Coast Region of California to support adaptive management decisions related to water quality protection. The North Coast Algae and Nutrients Study of 2010-2011 was one of the first applications of the SWAMP algae sampling protocol (Fetscher et al 2009) to algal community research in Northern California. It was also one of the first studies in the North Coast to link biostimulatory conditions to algal blooms, nuisance algae, and potentially toxic cyanobacteria.

This report documents the results of two short-term special studies:

- The South Fork Eel River (SFEel) **Algae and Nutrient Study**, conducted during Calendar Year (CY) (2010), and

- The Russian River (RuR) **Algae and Nutrient Study** CY (2011).

The watersheds selected for these studies were prioritized based on a number of factors, including known or suspected nuisance algae and cyanobacteria blooms, adequacy of existing chemical, physical, and biological data, and the potential for water quality to degrade or improve.

1.1 The problem of biostimulatory conditions

Plant nutrients – predominantly nitrogen and phosphorus - are essential to the health and integrity of a waterbody. Nutrients promote algal growth, which is essential to a viable stream ecosystem: algae are the primary producers in the aquatic food chain. Algae also provide important habitat for invertebrates and other aquatic life within a waterbody, and they are a source of dissolved oxygen necessary for survival of aquatic organisms.

Algal productivity and density are influenced by factors that include nutrient concentrations, water flow, temperature, stream channel configuration, riparian condition, and the aquatic grazing community. Algal communities can be maintained at stable, healthy levels through a balance of these factors. However, "biostimulatory conditions", as manifested by disturbances to some of these factors (particularly excess nutrients and loss of riparian canopy), can result in enhanced growth of nuisance algae and/or invasive aquatic plants. Excess nutrients and solar radiation often lead to algal blooms, including harmful algal blooms (HABs) that produce toxins. When algal and aquatic plant biomass is excessive, the production of oxygen during the day and oxygen consumption (respiration) during the night (when photosynthesis is not occurring), can create amplified dissolved oxygen concentration fluctuations that destabilize the aquatic ecosystem. Thus, excessive algal growth can lead to depressed oxygen conditions in overnight or pre-dawn hours, which can be stressful or even lethal to aquatic life. Enhanced photosynthetic activity during the day can also alter the pH of a waterbody resulting in elevated pH levels. In addition, nuisance algal blooms can affect the aesthetics of the river, leading to limitations on recreational usage, which can impact the local economy. Finally, it can lead to a change in the algal community potentially favoring the growth of toxin-producing cyanobacteria that may be harmful or even lethal to animals or humans.

1.2 Rationale and Objectives of the Algae and Nutrients Study

General problems associated with nutrient enrichment (eutrophication) and with increases in algal blooms as a result of biostimulatory conditions have been reported in the South Fork Eel and Russian River watersheds for decades. Since 2001, incidences of cyanotoxin-related dog deaths have occurred in the rivers and waterbodies in the North Coast region. Frequent reports of cyanobacteria blooms, and in some cases the presence of cyanotoxins, have been reported in the South Fork Eel River. To investigate these issues, the Regional Water Board's SWAMP program initiated the studies described in this report.

The monitoring effort was designed to answer the following questions:

- What is the spatial and seasonal variability in nutrient concentrations and benthic algal biomass within the South Fork Eel and Russian Rivers study reaches?
- Were biostimulatory conditions manifested in the South Fork Eel and Russian Rivers study reaches during the study period?
- How did nutrient concentrations in the study's samples compare to the USEPA Aggregated Ecoregions Nutrient guidance?
- Were cyanobacteria genera that are capable of producing cyanotoxins present in the study reaches in 2010-2011?
- What was the spatial and seasonal variability in the benthic algal communities within the South Fork Eel and Russian Rivers study reaches in 2010-2011?

1.3 Scope of the Report

This report provides a data summary for the Algae and Nutrients Study monitoring conducted during 2010 in the South Fork Eel River and 2011 in the Russian River. Data collected were reviewed to identify spatial and/or temporal variability and compared with published water quality benchmarks.

The authors of this report hope that all the basic information a reader will find essential to understanding the report has been provided. However, this report leans heavily on rationale, discussions, and details contained in three previously released documents, and the reader is advised to have these documents accessible:

- Summary Report for the North Coast Region (RWQCB-1) for years 2000-2006 (NCRWQCB 2008).
- SWAMP Quality Management Plan (Puckett 2002) and SWAMP Quality Assurance Program Plan (2008) with their appendices and Standard Operating Procedures (SOPs)
- SWAMP SOPs for algae and macroinvertebrate bioassessment (Ode *et al.* 2007, 2010 and 2016; Fetscher *et al*. 2009).

Chapter 2 (Methods) of this report provides background information on the watersheds sampled and the sampling locations. It also describes the study design, the logistics of field operations, the laboratory methodology, and the data processing procedures. Given the limited dataset for this study, Chapter 3 (Results) highlights those results that provide answers to the study questions, show a clear trend, or indicate a clear difference between reaches. The remaining data are presented in the appendix for the reader's reference. Results are arranged by watershed for each group of indicators collected at the study reaches (Section 3.1 for SFEel and 3.2 for RuR); these are followed by a comparison between the two watersheds studied (Section 3.3). Chapter 4 (Discussion, Conclusions, and Recommendations) provides a discussion of select results and reiterates the lessons learned. Chapter 5 (References) provides the references for the articles cited in this report and presents a compiled list of reports and Journal articles contributed to and authored by Regional Water Board staff, which present the results of work staff have conducted since 2011 to further our knowledge on biostimulatory conditions, harmful algal blooms, and cyanotoxins. The body of this report (Chapters 1 through 5) is followed by a set of appendices that contain the entire set of monitoring results and are an integral part of the reporting effort. [Note: For the sake of readability and brevity, this report shows only a few figures and tables (those that tell a story, show a clear trend, or indicate a clear difference), while all data are provided as appendices.]

This report has been in preparation for a number of years, but information gleaned from its data has been used to inform multiple studies since 2011. The new, subsequent studies will be mentioned in the following chapters if relevant, and a complete list of these scientific technical reports and journal articles is provided at the end of the report in section 5.1.

2 Methods

2.1 Watershed and site descriptions

2.1.1 Watershed and site selection criteria

The watersheds selected for the algae and nutrients study, South Fork Eel River in 2010 and Russian River in 2011, represented two ecosystems impacted by natural and suspected anthropogenic eutrophication. Study Areas of approximately 20-mile stretches were chosen within the lower one third of each watershed, based on their flow regime and history of nuisance algal growth. Four stream reaches were selected for monitoring within each Study Area and were spaced a few miles apart to represent a spatially meaningful horizontal gradient[2]. Each Reach was 0.2 miles long and had sufficient variability to accommodate all desired monitoring activities; actual sampling and deployment locations were selected based on their wadeability, accessibility, and presence of safe deployment niches for monitoring equipment.

Sampling reaches within South Fork Eel River Study Area were selected at fixed intervals. Sampling reaches within the Russian River Study Area were selected based upon

[2] Reach order is from upstream stations to downstream stations, as the stream flows.

instream conditions, focusing on free-flowing sections of the river and avoiding impoundments created by the installation of summer recreational dams.

Data were also collected from locations outside of the Study Area: Reach 0 in the South Fork Eel River and in Dry Creek a tributary to the Russian River. These reaches were chosen only to provide biostimulatory conditions context and not presented or discussed the same way as the fixed sampling reaches. However, these data are presented in the Appendices.

2.1.2 South Fork Eel River Watershed Overview

The South Fork Eel River is located in northern Mendocino and southern Humboldt Counties and comprises 688 square miles, with elevation that ranges from 100 to 4,500 feet. The South Fork Eel River flows northward for nearly 100 river miles from the headwaters in the Laytonville area in Mendocino County, along US Highway 101, through Humboldt Redwoods State Park in Humboldt County, and finally joining the mainstem Eel River near the town of Weott, approximately 40 river miles from the Pacific Ocean.

The South Fork Eel River watershed lies within a region dominated by a Mediterranean climate, which is characterized by hot, dry summers and cool wet winters. During the dry season, generally May through September, the most northern and westerly portions of the South Fork Eel River basin are strongly influenced by the coastal marine layer and defined by morning fog and overcast conditions, whereas the more inland portions of the basin are typically hot and dry. The annual average rainfall as measured at Miranda is 47 inches. Approximately 93% of the annual rainfall occurs between October 1 and April 30.

The principal land use in the basin is commercial timber production (44% of the basin area) and family-owned grazing, timber, and agricultural (including marijuana/or cannabis) operations (15% of the basin). Public lands account for 23% of the basin area while dispersed rural development accounts for the remaining 18% of the basin. The total South Fork Eel River basin resident population estimated from the 2010 Census was 8,984 people.

The South Fork Eel River is a free-flowing river with no impoundments. The unregulated flows reflect the seasonality of the precipitation record with higher runoff flows in the winter and low base flows in the summer months.

Historical land management practices, including timber harvesting, road building, and rural development, in combination with major flood events in 1955 and 1964, have exacerbated naturally high erosion rates in the South Fork Eel River resulting in considerable sediment loading over time. Sedimentation has increased stream widths, decreased stream depths, and caused the loss of riparian vegetation. This in turn has had the effect of increasing solar radiation and elevated water temperatures.

2.1.3 Russian River Watershed Overview

The Russian River spans two counties, Mendocino County in its northern reaches and Sonoma County to the south and comprises 1,485 square miles, with elevation that ranges from sea level to 4,300 feet. The Russian River flows southward for nearly 110 river miles from its headwaters north of Ukiah in Mendocino County, along US Highway 101, through several alluvial valleys before turning west for the last 30 miles and entering the Pacific Ocean at Jenner in Sonoma County.

The Russian River watershed lies within a region dominated by a Mediterranean climate, which is characterized by hot, dry summers and cool wet winters. During the dry season, generally May through September, the most southern and westerly portions of the Russian River basin are strongly influenced by the coastal marine layer and defined by morning fog and overcast conditions, whereas the more inland portions of the basin are typically hot and dry. The 28-year annual average rainfall is 30 inches. Approximately 95% of the annual rainfall occurs between October 1 and April 30.

Land use in the upper Russian River watershed supports multiple thriving land uses, which produce a variety of anthropogenic influences, stemming both from urban and rural living. It is quite rural with considerable agriculture, timber and open space. As such, it provides a vibrant tourist trade, with wine tasting, restaurants, and outdoor activities, especially during the summer months. Overall, approximately 90 mi^2 (6% of the watershed) has been developed for residential, commercial, and industrial use. Agriculture, including wine-producing vineyards, has been a significant activity in the Russian River watershed since the mid-1800s, and is still the predominant land use in the watershed. Substantial areas of undeveloped lands that historically were not in agricultural production have been converted to vineyards in recent years with currently more than 60,000 acres devoted to vineyards. Public lands account for 8% of the basin area while urban areas account for 10% of the basin. The total Russian River basin resident population estimated from the 2010 Census was 340,000 people.

The Russian River is a highly regulated river with two large dam impoundments and several seasonal summer dams. The impoundments attenuate the natural flows of the river by lessening the high flows of winter and increasing the low flows of summer. Except for large storm events, the flows in the Russian River are dominated by releases from Lake Mendocino and Lake Sonoma.

2.1.4 Years 2010-2011 sampling stations

As mentioned above, the Study Areas were selected in response to known or suspected nuisance algae and HABs. For example, a number of documented or suspected dog deaths in the lower South Fork Eel River due to toxin-producing cyanobacteria prompted our investigation to focus on the area located between the towns of Redway and Myers Flat. In the Russian River our investigation focused on the lower gradient reaches located between the towns of Healdsburg and Monte Rio where extensive algal blooms have been reported.

Table 2.1-1 shows the latitude and longitude coordinates of the sites monitored in each watershed during the study. The designated beneficial uses for each of the watershed segments, as identified in the North Coast Regional Water Board's Basin Plan (Basin Plan), are shown in **Table 2.1-2**. Both Study Areas (South Fork Eel River and Russian River) support a myriad of existing beneficial uses.

Table 2.1-1: Sampling stations for the North Coast Algae and Nutrient Study

Reach Name	Station Name/Location	Station	Latitude	Longitude	Elevation (ft)
South Fork Eel River (SFEel) 2010					
REACH 0	SF Eel River at Redway	111SF2765	40.12689	-123.83057	269
(Redway)	Sonde Reach 0	111SF2683	40.13237	-123.81932	260
REACH 1	SF Eel River above Sylvandale	111SF2538	40.14781	-123.80190	254
(Sylvandale)	Sonde Reach 1	111SF2423	40.16140	-123.79155	238
REACH 2	SF Eel River below Phillipsville	111SF1944	40.21684	-123.79095	203
(Phillipsville)	Sonde Reach 2	111SF1819	40.21943	-123.80717	200
REACH 3	SF Eel River below Miranda	111SF1569	40.24307	-123.83101	211
(Miranda)	Sonde Reach 3	111SF1353	40.25962	-123.84370	193
REACH 4	SF Eel River above Myers Flat	111SF1016	40.26682	-123.86703	161
(Myers Flat)	Sonde Reach 4	111SF0875	40.26899	-123.87619	164
Russian River (RuR) 2011					
REACH 1	RuR at Healdsburg Memorial Beach	114RR2940	38.60357	-122.85993	72
(Healdsburg)	RuR below Healdsburg Memorial	114RR2899	38.59716	-122.85786	68
	Sonde Reach 1	114RR2861	38.59080	-122.85844	60
REACH 2	RuR above Syar Pond	114RR2769	38.57671	-122.85724	54
(Syar)	RuR at Syar Pond	114RR2678	38.56326	-122.85302	51
	Sonde Reach 2	114RR2599	38.55171	-122.85824	49
REACH 3	RuR at Odd Fellows Crossing	114RR1644	38.50329	-122.96154	22
(Korbel)	RuR near Korbel	114RR1599	38.50504	-122.96825	21
	Sonde Reach 3	114RR1531	38.51578	-122.97141	16
Reach 4A*	RuR at Johnson's Beach	114RR1325	38.49938	-122.99900	17
(Johnson's)	RuR below Johnson's Beach	114RR1310	38.49946	-123.00160	15
Reach 4*	RuR at Vacation Beach	114RR1159	38.48329	-123.01070	9
(Vacation)	RuR below Vacation Beach/Sonde	114RR1041	38.47718	-122.98987	7
Dry Creek	Dry Creek above RuR confuence	114DC0037	38.58642	-122.86024	61
	Dry Creek Sonde	114DC0037	38.58642	-122.86024	61

Note: Elevation values were derived from USGS The National Topo Map. All coordinates use WGS84.
* Summer dam installations and removal occurred at Johnsons Beach and Vacation Beach. Monitoring sites changed as the flow changed. See Appendices for exact monitoring dates for each station.

Table 2.1-2: Beneficial Uses for the North Coast Algae and Nutrient Study Reaches

Unit	Study Station included	Area Name	AGR	AQUA	COLD	COMM	EST	FRSH	GWR	IND	MIGR	MUN	NAV	POW	PRO	RARE	REC1	REC2	SHELL	SPWN	WILD	WARM
111.31	SF1944, SF1819, SF1569, SF1353, SF1016, SF0875	Weott Hydrologic Subarea	E	P	E	E		E	E	E	E	E	E	P	P	E	E	E		E	E	E
111.32	SF2765, SF2683, SF2538, SF2423	Benbow Hydrologic Subarea	E	P	E	E		E	E	E	E	E	E	P	P	E	E	E		E	E	E
114.11	RR2940, RR2899, RR2861, RR2769, RR2678, RR2599, RR1644, RR1599, RR1531, RR1325, RR1310, RR1159, RR1041	Guerneville Hydrologic Subarea	E	P	E	E	E	E	E	E	E	E	E	P	P	E	E	E	P	E	E	E
114.24	DC0037	Warm Springs Hydrologic	E	E	E	E		E	E	E	E	E	E	E	P	E	E	E		E	E	E

E = Existing; P = Potential

Beneficial use codes:

AGR Agricultural Supply
AQUA Aquaculture
COLD Cold Freshwater Habitat
COMM Commercial and Sport Fishing
EST Estuarine Habitat
FRSH Freshwater Replenishment
GWR Groundwater Recharge
IND Industrial Service Supply
MIGR Migration of Aquatic Organisms
MUN Municipal and Domestic Supply
NAV Navigation
POW Hydropower Generation
PRO Industrial Process Supply
RARE Rare, Threatened, or Endangered Species
REC-1 Water Contact Recreation
REC-2 Non-Contact Water Recreation
SHELL Shellfish Harvesting
SPWN Spawning, Reproduction, and/or Early Development
WARM Warm Freshwater Habitat
WILD Wildlife Habitat

Figure 2.1-1 is a map detailing the four reaches sampled within the SF Eel River study area, and Reach 0 above the Study Area. Each of the various monitoring activities were conducted at an appropriate location, selected to accommodate the special requirements of that activity. For example, water samples were collected in well-mixed areas, bioassessments were conducted in wadeable sections, and Yellow Springs Instruments (YSI) manufactured Multiparameter Water Quality Sondes (sondes) were deployed in protected sites.

Figure 2.1-1: Study Area, monitoring stations, and algae sampling reaches in the South Fork Eel River in 2010

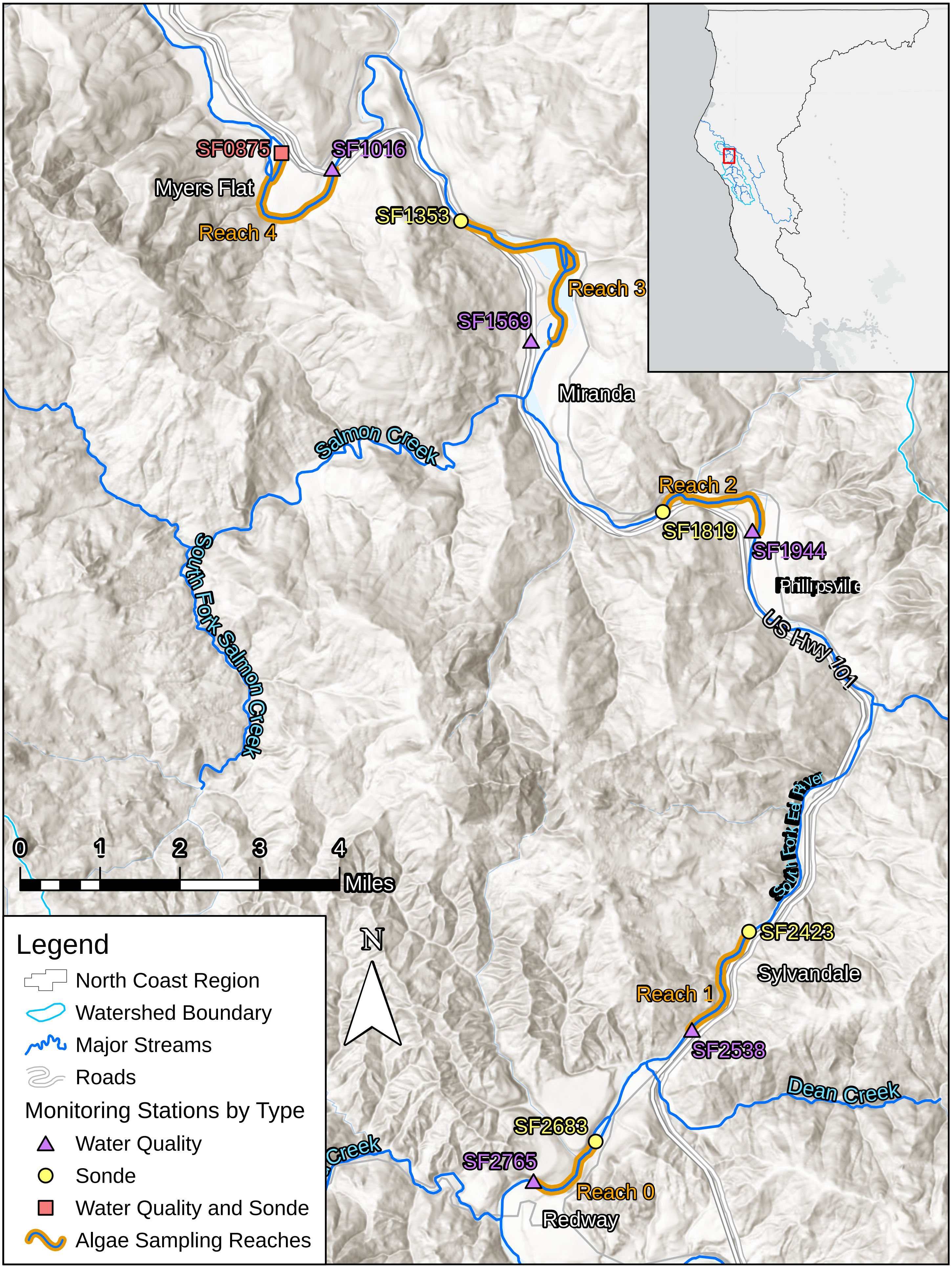

Figure 2.1-2 is a map detailing similar information for the Russian River Study Area. Where wadeable areas could not be found in the selected reaches of the river, bioassessment sampling was conducted from a kayak.

Figure 2.1-2: Study Area, monitoring stations, and algae sampling reaches in the Russian River in 2011

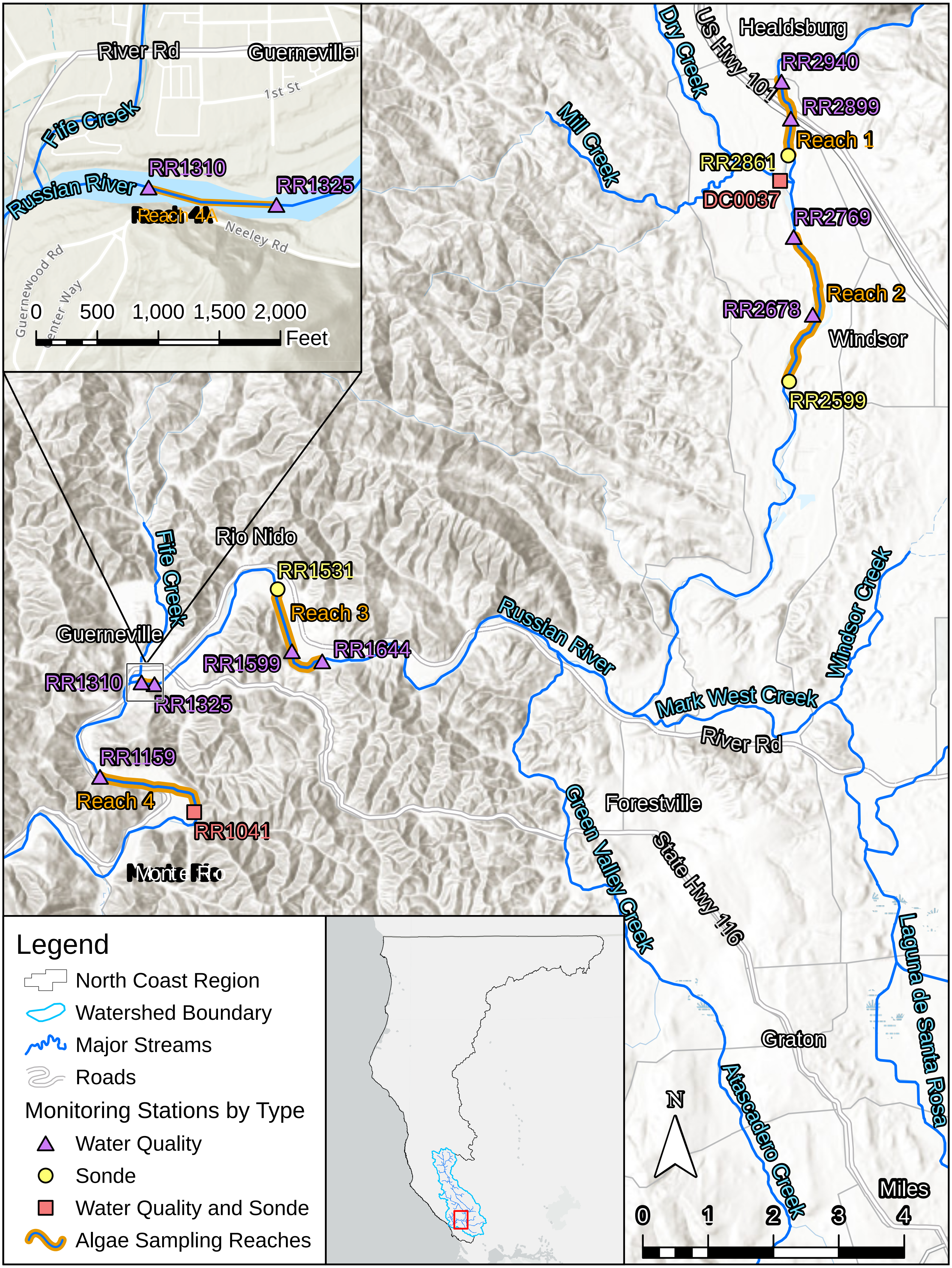

Figure 2.1-3 is a smaller scale map of the Russian River watershed showing the locations of Lake Mendocino and Lake Sonoma, two dammed reservoirs that release water into the Russian River. Lake Sonoma drains the north-west portions of the Russian River watershed, whereas much of Lake Mendocino water is imported from the Eel River watershed to augment water supply for agriculture, recreation, and drinking water supply in the Russian River basin. Summer releases from the reservoirs provide for consistent stream flows in the Russian River.

Figure 2.1-3: Russian River watershed showing Lake Mendocino and Lake Sonoma

2.2 Sampling design and rationale

2.2.1 Spatial sampling design

Study Areas were chosen using a targeted sampling design principle. based on flow regime and history of algal blooms. Sampling reaches within each Study Area were selected systematically (where possible) to examine horizontal gradients along the river, with consecutive sampling reaches spaced a few miles apart from each other. Within the four designated sampling reaches in each river, the locations for each monitoring activity were selected targeting spots suitable for benthic algae and water sample collection and for safe deployment of sondes. Thus, some reaches had separate Stations for different activities (Table 2.1.1 above).

2.2.2 Temporal sampling design

Each annual study consisted of a number of visits per site during the sampling period (June-October) of that year, to track the changes occurring during the entire growth (and summer recreation) season. Sondes (collecting time series data of dissolved oxygen, pH, specific conductance, and temperature) were deployed for the entire sampling periods, with several maintenance intervals. Water samples for nutrient analyses as well as algal samples were collected 5-6 times during the spring, summer, and fall.

2.2.3 Inventories of monitoring activities

Tables 2.2-1a and 2.2-1b show a summary of monitoring activities performed in years 2010-2011. The information is elaborated on in Appendix A.

The South Fork Eel Study Area was monitored between June and October 2010 for a total of 70 site visits (Appendix Table A-1). Beyond visiting the four study reaches, as mentioned previously, staff also visited a station upstream of the Study Area to document boundary conditions (Reach 0). Total station visits, samples and deployments include the Reach 0 station.

Table 2.2-1a: South Fork Eel River summary of 2010 monitoring activities included in this report.

Characteristic group	Medium	Activity Category	Field Activity type	Laboratory work	Season & Timing (Note 1)	Total # of Stations	Total # of Station Visits or Samples or deployments (Note 2)
Local conditions (Note a)	All	Observation	Categorical Observations	None	All	5	70
"Vital signs" (Note b)	Water	Measured	Discrete Field Measurements	None	All	5	62
Benthic algae assemblages	Biota	Collected	Biota Sample	Diatoms and Soft Algae Taxonomy	Spring, summer, fall	4	20
Benthic algae biomass	Biota	Collected	Biota Sample	Analyses	Spring, summer, fall	4	20
Physical habitat attributes	All	Observation	Categorical Observations, Numeric-range estimates,	None	Spring, summer, fall	5	62
Conventional WQ characteristics (including salts & nutrients)	Water	Collected	Sample (abiotic media)	Analyses	All	5	30
Sonde probes suite (Note c)	Water	Measured	Time-series Field Measurements	Calibrations and accuracy checks	Spring, summer, fall	5	33

Note 1 Station visits occurred any time of day (not directed to a specific time). Trip scheduling was directed to non-rainy weather, i.e., base flow conditions.
Note 2 Activities done at specific stations are shown in Appendix Table A-1.
Note a Local conditions include estimated flow, estimated wetted channel width, weather, Station appearance & odors, water color, and special notable features.
Note b The “vital signs” are: temperature, pH, dissolved oxygen, and specific conductance; these were measured during sample collection to support lab data.
Note c The YSI Sonde probe suite included temperature, pH, dissolved oxygen, and specific conductance, measured every 15 min. (Appendix E).

The Russian River Study Area was monitored between June and October 2011 for a to-tal of 83 site visits (Appendix Table A-2). Beyond visiting the four study reaches, as mentioned previously, staff also visited a station on Dry Creek, a major tributary, just above its confluence with the Russian River. Total station visits, samples and deploy-ments include the Dry Creek station.

Table 2.2-1b: Russian River summary of 2011 monitoring activities included in this report.

Characteristic group	Medium	Activity Category	Field Activity type	Laboratory work	Season & Timing (Note 1)	Total # of Stations	Total # of Station Visits or Samples or deployments (Note 2)
Local conditions (Note a)	All	Observation	Categorical Observations	None	All	14	83
"Vital signs" (Note b)	Water	Measured	Discrete Field Measurements	None	All	14	83
Benthic algae assemblages	Biota	Collected	Biota Sample	Diatoms and Soft Algae Taxonomy	Spring, summer, fall	6	23
Benthic algae biomass	Biota	Collected	Biota Sample	Analyses	Spring, summer, fall	6	23
Conventional WQ characteristics (including salts & nutrients)	Water	Collected	Sample (abiotic media)	Analyses	All	10	43
Sonde probes suite (Note c)	Water	Measured	Time-series Field Measurements	Calibrations and accuracy checks	Spring, summer, fall	5	45

Note 1 Station visits occurred any time of day (not directed to a specific time). Trip scheduling was directed to non-rainy weather, i.e., base flow conditions.
Note 2 Activities done at specific stations are shown in Appendix Table A-2.
Note a Local conditions include estimated flow, estimated wetted channel width, weather, Station appearance & odors, water color, and presence of special features
Note b The “vital signs” are: temperature, pH, dissolved oxygen, and specific conductance; these were measured during sample collection to support lab data.
Note c The YSI 6600 Sonde probe suite included temperature, pH, dissolved oxygen, and specific conductance, measured every 15 min. (Appendix E).

2.3 Field Operations

All field operations were conducted by Regional Water Board staff (staff) following SWAMP and USEPA SOPs, with minor variations as needed described in the sections below.

2.3.1 Field Measurements and Water Sampling for Chemical Analyses

Water grab samples for the analysis of nutrients (Appendix B) and other conventional water quality characteristics (Appendix C) were collected per the SWAMP protocols (MPSL 2007). At the time of sampling, staff also recorded field observations (e.g., weather, flow conditions, etc.), physical habitat characteristics, and collected instantaneous field measurements of dissolved oxygen, pH, specific conductance, and temperature to support lab data. The results of field observations and measurements conducted in each visit are provided in Appendix D.

2.3.2 Algal Bioassessment and Physical Habitat assessments

The spatial sampling frame used for bioassessments followed the SOP developed for SWAMP (Fetscher *et al* 2009) with fixed reach length of approximately 1000 ft. (~300 m) and the distance between transects of approximately 100 ft. (~30 m). In the non-wadeable reaches of the Russian River, staff followed the USEPA-developed National Rivers and Streams Assessment Field Operations (USEPA 2007).

For each reach, algal samples were collected from the eleven transects, then composited and homogenized, and each of these composite samples yielded two test-tubes of preserved algae for taxonomic analysis (soft algae and diatoms) (Appendix F) as well as two glass-fiber filters for analysis of benthic algal biomass indicators chlorophyll *a* (Chl-a) and organic matter (measured as ash-free dry mass (AFDM)) (Appendix B). The crew also conducted several physical habitat observations and estimates at each transect, as conditions allowed (see Appendix G).

2.3.3 Time-Series (continuous) monitoring

Time-Series (Continuous) field measurements were a major component of the monitoring effort. These data were collected utilizing Yellow Springs Instruments (YSI) manufactured model 6600/6920 Multiparameter Water Quality Sondes (sondes). The sondes were deployed at five (5) sites in both the South Fork Eel River and Russian River Study Areas throughout the sampling season, from mid-June to early October. The sondes were programmed to measure and log dissolved oxygen, pH, specific conductance, and temperature at 15-minute intervals. Sites were visited at two to four-week intervals to maintain and recalibrate the sondes, and to retrieve the logged data.

Detailed deployment information is provided in Appendix E. Staff conducted pre-deployment calibrations and post-deployment accuracy checks in the laboratory, as well as accuracy checks and calibrations during maintenance events in the field.

2.4 Laboratory analyses

Samples of water and benthic algae were sent to the appropriate laboratories for processing, analyzing, sorting, and counting, using a variety of methods. **Table 2.4-1** below shows the groups of analytes quantified by analytical methods. A brief description, plus additional information on selected laboratory activities, is provided below.

Table 2.4-1: Laboratory analyses performed with water and benthic algae samples in 2010-2011

Group	Analyte w Fraction & Unit	Year	Method	Preparation	MDLs Min	MDLs Max	RLs Min	RLs Max
Nutrients								
	Ammonia as N; Total; mg/L	2011	QC 10107061G	FieldAcidified	0.01	0.04	0.02	0.08
	Ammonia as N; Dissolved; mg/L	2010	QC 10107061G	LabFiltered, LabAcidified	0.01	0.01	0.02	0.02
	Nitrate + Nitrite as N mg/L	2011	QC 10107041B	FieldAcidified	0.005	0.005	0.01	0.01
	Nitrate as N mg/L	2011	QC 10107041B	FieldAcidified	0.005	0.005	0.01	0.01
	Nitrate as N; Dissolved; mg/L	2010	QC 10107041B	LabFiltered, LabAcidified	0.005	0.005	0.01	0.01
	Nitrite as N; Dissolved; mg/L	both	QC 10107041B	FieldFiltered	0.002	0.0023	0.005	0.005
	Nitrogen, Total; Total; mg/L	2010	QC 10107044B	LabAcidified	0.02	0.02	0.05	0.05
	Nitrogen, Total; Total; mg/L	2011	QC 10107044B	FieldAcidified	0.0208	0.02	0.05	0.05
	OrthoPhosphate as P; Dissolved; mg/L	both	QC 10115011M	FieldFiltered	0.0013	0.002	0.005	0.005
	Phosphorus as P; Total; mg/L	2010	QC 10115012B	LabAcidified	0.005	0.005	0.01	0.01
	Phosphorus as P; Total; mg/L	2011	QC 10115012B	FieldAcidified	0.0042	0.01	0.01	0.02

Group	Analyte w Fraction & Unit	Year	Method	Preparation	MDLs Min	MDLs Max	RLs Min	RLs Max
Other Conventional Characteristics								
	Alkalinity as CaCO3; Dissolved; mg/L	both	QC 10303311A	LabFiltered	2.5	2.5	10	10
	Hardness as CaCO3; Total; mg/L	2011	QC 10301311B	FieldAcidified	2.22	3	10	10
	Hardness as CaCO3; Dissolved; mg/L	2010	QC 10301311B	LabFiltered, LabAcidified	3	6	10	20
	Chloride; Dissolved; mg/L	both	EPA 300.0	LabFiltered	0.1	1	0.25	2.5
	Total Dissolved Solids; Dissolved; mg/L	both	SM 2540 C	None	10	10	10	10
	Silica as SiO2; Dissolved; mg/L	both	QC 10114271A	LabFiltered	0.37	1	2	2
	Sulfate; Dissolved; mg/L	both	EPA 300.0	LabFiltered	0.25	2.5	0.4	5
	Dissolved Organic Carbon; Dissolved; mg/L	both	EPA 415.1M	FieldFiltered, FieldAcidified	0.5	0.5	1	1
	Total Organic Carbon; Total; mg/L	both	EPA 415.1M	FieldAcidified	0.5	0.5	1	1
Benthic algal biomass indicators								
	AFDM_Algae; benthic (Particulate); g/m2	both	WRS 73A.3	FieldFiltered, FieldFrozen	1.42	4.2	4.27	12.61
	Chlorophyll *a* ; benthic (Particulate); mg/m2	both	SM 10200 H-2b	FieldFiltered, FieldFrozen	0.07	17.91	0.07	61.05
	Pheophytin *a* ; benthic (Particulate); mg/m2	both	SM 10200 H-2b	FieldFiltered, FieldFrozen	0.07	16.19	0.07	55.19

MDL - minimum detection limit; RL - reporting limit;
All analyses were performed by the Department of Fish and Game Water Pollution Control Laboratory (DFG-WPCL)

2.4.1 Algae taxonomy

Four subsamples were derived from each algal composite sample. Two subsamples were analyzed for algal biomass indicators (Section 2.4.2) and two were collected for laboratory taxonomic identification of diatoms and soft algae. Diatom sub-samples were shipped to University of Colorado Boulder (UCOB) Museum of Natural History, where 300 organisms (600 valve count) from each sample were identified to the species level. The soft algal sub-samples were sent to California State University at San Marcos (CSUSM) for taxonomic identification and qualitative analysis of algal taxon richness and quantity in terms of biovolumes. Additionally, the lab at CSUSM performed taxonomic identification on a separately collected qualitative reach-wide benthos (RWB) sample to identify as many of the species observed in each study reach.

2.4.2 Algal biomass indicators

The two subsamples for the analyses of benthic chlorophyll *a* (Chl- a) and ash-free dry mass (AFDM) were filtered, in the field, onto pre-ashed (incinerated by the lab before sampling) glass-fiber filters. The loaded filters were delivered on ice to the Department of Fish and Game Water Pollution Control Laboratory (DFG-WPCL) lab. The lab determined the concentration of Chl-a by extracting the photosynthetic pigments from the filter directly and measuring the absorbance of the extract at various wavelengths. AFDM concentration was determined gravimetrically, by weighing each filter before and after ignition at >500 C which burned all the organic matter (i.e., the dry mass that is not inorganic ash).

2.4.3 Chemical analyses

Nutrients and other conventional constituents were also analyzed at the DFG-WPCL laboratory. Table 2.4-1 shows the methods used and the actual ranges of detection limits and reporting limits achieved for each analyte in water or benthic suspensions.

2.5 Data processing and interpretation

After the data verification and validation process was completed by SWAMP, the monitoring results generated in the Algae and Nutrients Study were processed by this report's team in a number of ways:

- **endpoint derivation** for individual samples (e.g., algal metrics);
- computation of **summary statistics** such as median and 25 and 75 percentiles for data sets made of multiple measurements (e.g., time series (continuous) temperature measurements);
- generation of preliminary plots to indicate relationships or trends; and
- comparisons of constituent concentrations or conditions to **water quality benchmarks**, either individually or in compilations (e.g., weekly minimum)

Outputs of these processing methods were used for creation of result presentation items in this report's tables and figures. It must be noted that this small-scale pilot study provided a very small dataset with intense variability (due to natural variations plus the variability in habitats and sampling methods). Thus, the data were not robust enough for any hypothesis testing or for derivation of advanced explanatory correlations.

2.5.1 Summary statistics and graphs for time-series field measurement (continuous monitoring) episodes

Data from the entire monitoring period (June to October) was compiled and organized in 2-week datasets (Appendix E). The minimum and maximum values within each data set were easily identified by an Excel function, and so were the median, the 25th percentile, and the 75th percentile values used to construct a box-plot presentation for each data set. This type of 'box and whisker' plots is widely used to explore the distribution of independent data points (e.g., Helsel and Hirsch 2005), but it has often been used for presentation of the general tendencies of continuous monitoring data as well.

2.5.2 Comparison of monitoring results to water quality benchmarks

The phrase 'water quality benchmark' (WQB) is a catch-all term to include objectives, guidelines, limits, targets, standards, and other types of values for concentrations of constituents that should not be exceeded in a given water body. There may be a profound difference between each sub-set of benchmarks, for example, objectives are used as regulatory tools, while guidelines are used for evaluation but are not legally binding; "thresholds" may refer to healthy conditions while "targets" are values we are trying to achieve (Sutula 2018).

The word 'exceedance' means that the concentration of a particular constituent exceeded the benchmark (and this was not 'good'). However, dissolved oxygen values are 'good' if they are above the benchmark, and 'good' pH values are within a defined range (usually 6.5 to 8.5), above and below which the conditions are considered 'not good', i.e., an 'exceedance'.

Table 2.5-1 shows the water quality benchmarks used in this report. The benchmarks were selected from a variety of sources, such as the Basin Plan for protection of aquatic life, the USEPA criteria, and a peer reviewed literature article. A comparison of the data in relation to these benchmarks is shown in Appendix B and E. Appendix B presents the nitrogen, phosphorus, and benthic Chl-a data results, with values exceeding these benchmarks shown in bold text. Appendix E provides figures summarizing the temperature, DO, specific conductivity, and pH data.

Table 2.5-1: Water quality benchmarks for protection of aquatic life

Characteristic	Description of Benchmark	Numeric Limit	Units	Reference
Oxygen, dissolved[3]	Daily Instantaneous Minimum Water Quality Objective, COLD[4]	6.0	mg/L	NCRWQCB (2018) Basin Plan 3.3.5
pH	Water Quality Objective Range	6.5 to 8.5	S.U.	NCRWQCB (2018) Basin Plan Table 3-1
Chlorophyll *a* (benthic)	BURC I Presumptive unimpaired COLD	<100	mg chl-a/m^2	TetraTech 2006 *(Note 1)*
	BURC II Potentially impaired COLD	100-150	mg chl-a/m^2	
	BURC III Presumptive impaired COLD	>150	mg chl-a/m^2	

Note 1: BURC = Beneficial Use Risk Categories
Beneficial Use Risk Category I. Presumptive unimpaired (use is supported)
Beneficial Use Risk Category II. Potentially impaired (may require an impairment assessment)
Beneficial Use Risk Category III. Presumptive impaired (use is not supported or highly threatened)

Aggregated Ecoregion Reference Conditions*

Characteristic	Applicability	25th Percentile	Units	Reference
Nitrogen, total as N	South Fork Eel River	0.12	mg/L	EPA Nutrient Ecoregion II, 2000
Phosphorus, total as P		0.01	mg/L	
Nitrogen, total as N	Russian River	0.38	mg/L	EPA Nutrient Ecoregion III, 2000
Phosphorus, total as P		0.02	mg/L	

*Based on 25th Percentile Only

3 NCRWQCB (2018) Basin Plan also includes a WARM objective but for this report we used the COLD objective to determine compliance as it is a more stringent threshold.

4 NCRWQCB (2018) Basin Plan also includes a 7-day moving average DO threshold for COLD and WARM which are not discussed in this report as we are using the daily minimum to determine compliance.

2.5.2.1 Water quality benchmarks for biostimulatory conditions and for nutrients

Biostimulatory conditions in aquatic ecosystems are manifested by proliferation of algae and water plants, resulting in high concentrations of Chl-a and AFDM. We used the benthic Chl-a benchmarks, and the Beneficial Use Risk Categories (BURCs), that have been developed for California based on protection of specific beneficial uses (Creager *et al* 2006).

Nutrient benchmarks are developed and honed for specific environments as manifested by ecologically categorized Ecoregions; please see the designation history of Nutrient Ecoregions below. We used the total N and total P benchmarks that have been developed for two of the 14 Aggregated Nutrient Ecoregions (EPA 2000a,b), "II" (Eel River) and "III" (Russian River). As shown in Table 2.5-1 and in Appendix B, the values for South Fork Eel River are much lower than for Russian River. The suitability of these values has been widely challenged (Ice and Blinkly 2003, Sutula et al 2018). It is still controversial and there are a number of task forces and expert panels studying the issues (Sutula et al 2018 and others), but at this time there are no new recommendations to replace the benchmarks used in our report.

Background: Ecoregion designation history

The Aggregated Nutrients Ecoregion Map was developed to simplify the regulatory application of nutrient benchmarks by combining all Omernik-Level-III ecoregions that are similar enough in respect to the impact of nutrients (EPA 2002). For example, Omernik Level III Ecoregion 1 and 78 are both in the same nutrient aggregate. There are 14 Aggregated Nutrient Ecoregions; these were also given Roman numerals, which is easily confused with Omernik Levels of breakdown. The South Fork Eel River Study Area is in Aggregated Nutrients Ecoregion "II" (Western Forested Mountains), and the Russian River Study Area straddles the boundary between Aggregated Nutrients Ecoregion "II" and Aggregated Nutrients Ecoregion "III" (Xeric West).

2.6 Data quality

Regional Water Board staff followed all appropriate SOPs to assure the generation of data of known and documented quality. The data reported in Section 3 and in the Appendices are SWAMP compliant. This means the following:

a) Sample container, preservation, and holding time specifications of all measurement systems have been applied and were achieved as specified;
b) All the quality checks required by SWAMP were performed at the required frequency;
c) All measurement system batches/runs included their internal quality checks and diagnostic checks (e.g., electrode mV value), and had functioned within their performance/acceptance criteria; and
d) All SWAMP measurement quality objectives (MQOs) were met.

As in any data collection effort, some trip batches, laboratory batches, or individual results did not meet all the conditions stated above, and the comprehensive list of these occurrences is available with Regional Water Board staff. However, these data can still be usable if the flaw or omission was not considered detrimental, and they were flagged as “estimated”. Data verification and validation procedures followed the SWAMP Quality Management Plan (Puckett 2002), the SWAMP Quality Assurance Program Plan (SWAMP 2008), and the SWAMP Quality Assurance Project Plan for bioassessments (SCCWRP 2009).

3 Results

This chapter presents the results obtained at the sites selected for the Algae and Nutrient Study of 2010-2011 as performed by Regional Water Board staff. Year 2010 activities were conducted in a defined Study Area within the South Fork Eel River, and 2011 activities were conducted in a defined Study Area of the Russian River. The Algae and Nutrient study focused on sites that were visited multiple times over spring, summer, and fall, to document seasonal variability. The study results presented in this chapter are organized for each year/watershed by subject-matter, with separate sections for various biological characteristics, physical-habitat conditions, and water quality.

For the sake of brevity and to avoid the uninformative repetition of tables and figures, this Results section highlights only results that provide clear answers to the study questions and that show clear trends or differences between reaches. However, the entire dataset is provided in the appendices to this report.

The appendices are organized by subject matter, in the same order as the subjects are presented in the following subsections. This order is as follows: (1) Benthic biomass indicators and (2) nutrients in water (Appendix B), (3) conventional water quality characteristics (Appendix C), observations and field measurements (Appendix D), continuous field measurements (Appendix E), (4, 5, 6) benthic algae taxonomy (Appendix F), and substrate observations (Appendix G). The appendices also contain an inventory of station visits, samples, and field activities (Appendix A).

Section 3.1 is dedicated to the South Fork Eel River Study Area, Section 3.2 provides findings from the Russian River Study Area, and Section 3.3 shows additional relationships between indicators, as well as comparison between the two watersheds.

3.1 Spatial and seasonal trends in the South Fork Eel River Study Area

The Study Area was monitored between June and October 2010 in a total of 70 site-vis-its (Appendix Table A-1). Beyond visiting the four study reaches, the field crew also visited a site upstream of the Study Area (Reach 0) to demonstrate the boundary conditions entering the first sample reach (Figure 2.1-1 in the Methods section). Data for Reach 0 are only discussed briefly in this report in the context of biostimulatory conditions (Figure 3.1-4b) and are not otherwise presented or discussed as this reach lies outside of the Study Area. However, these data are presented in the Appendices.

3.1.1 Benthic algae biomass (Chl-a and AFDM) in SFEel

Figure 3.1-a shows concentrations of benthic Chl-a and **Figure 3.1-b** shows concentrations of AFDM in the SFEel Study Area over the summer and fall of 2010 study period. These 3-D plots demonstrate both spatial and temporal trends, and reveal concentration gradients in both dimensions: the temporal (seasonal) trend shows a buildup of algae over the summer, which peaks in the fall, and the spatial pattern indicate that benthic biomass cover was generally higher in the upstream portion of the Study Area (Reaches 1 and 2).

Chl-a concentration in Figure 3.1-a exceeded the BURC thresholds on 2 of 20 occasions (see Appendix Table B-1), when benthic biomass of primary producers peaked in fall. Most of the benthic Chl-a samples were below the BURC I threshold (<100 mg chl-a/m^2) indicating presumably unimpaired conditions. Only 2 samples exceeded this benchmark; these were collected in Reach 2 in late-September (within the BURC II category of 100-150 mg chl-a/m^2) and in Reach 1 in mid-September (exceeding BURC III; >150 mg chl-a/m^2).

Concentrations of AFDM in Figure 3.1-1b shows spatial and temporal patterns which are very similar to Chl-a: Concentrations were higher upstream and in the fall.

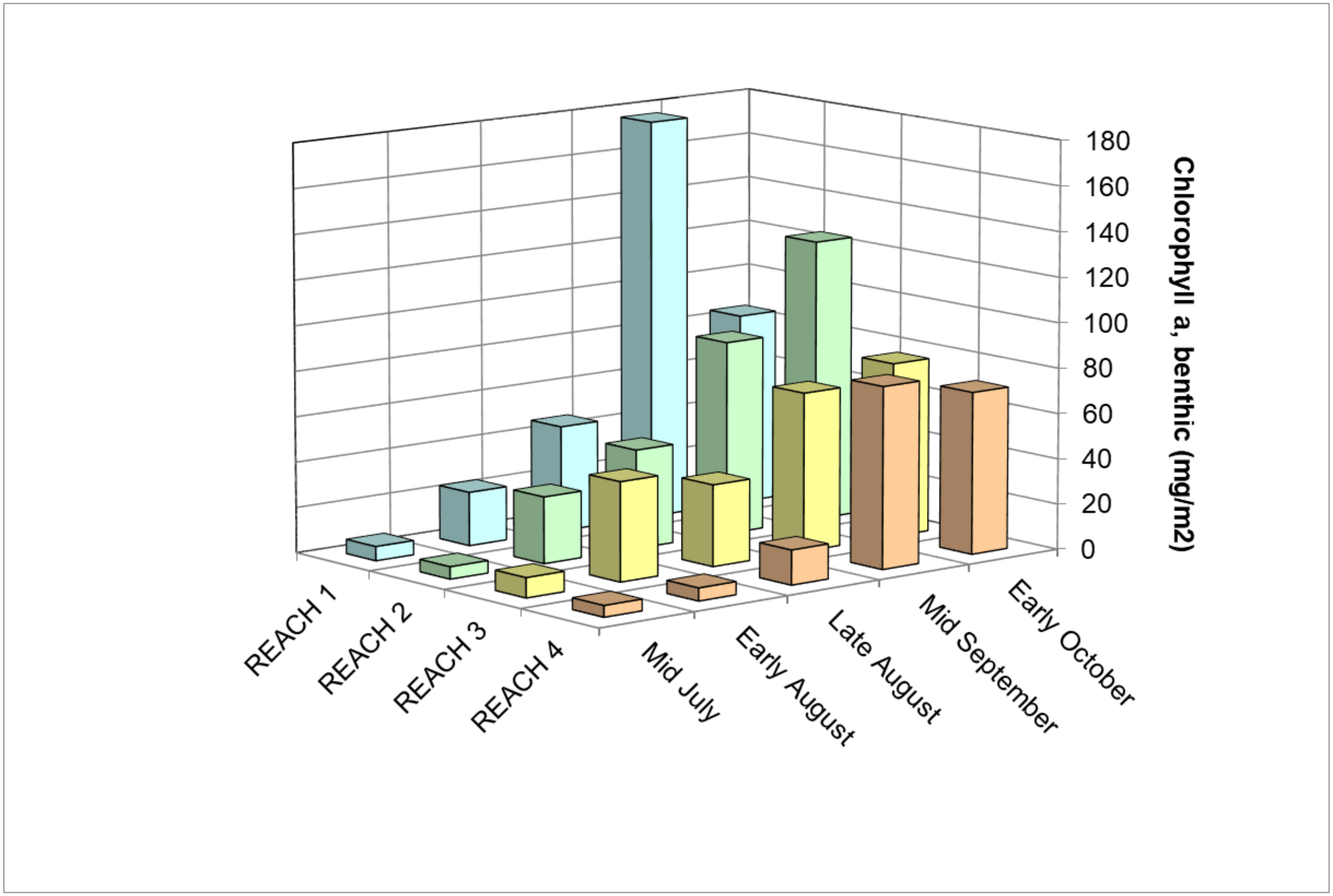

Figure 3.1-1a: Concentrations of benthic biomass indicators in the SFEel Study Area in 2010: Chlorophyll a

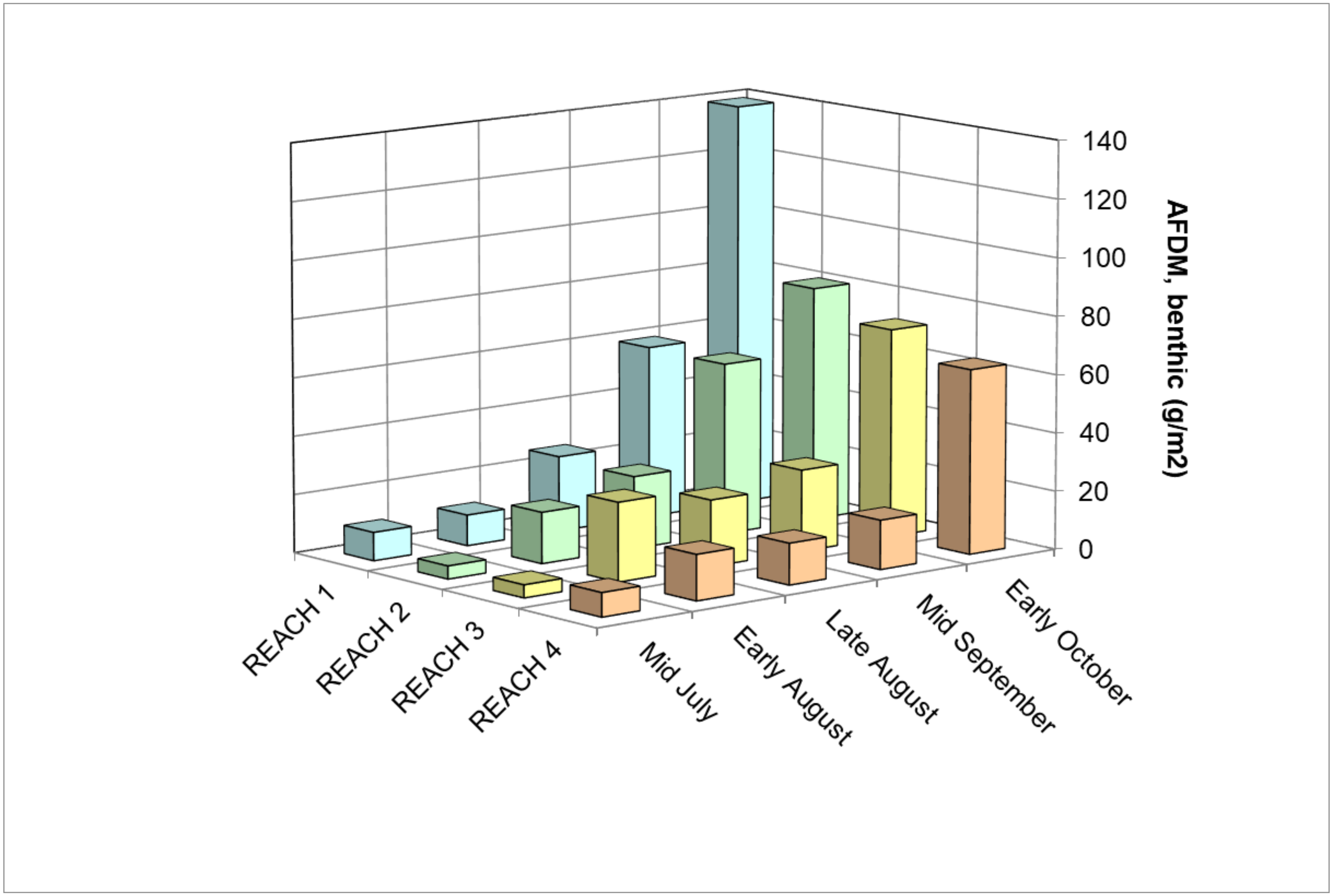

Figure 3.1-1b: Concentrations of benthic biomass indicators in the SFEel Study Area in 2010: Ash-Free Dry Mass (AFDM)

3.1.2 Nutrients in SFEel

Figure 3.1-2a shows the concentrations of nitrogen and **Figure 3.1-2b** shows the concentrations of phosphorus in the SFEel Study Area over the summer and fall of 2010. Nutrients were detected throughout the study period, at concentrations that were generally low and stable (without major variations), ranging from 0.024 to 0.265 mg/L for total nitrogen, and 0.014 to 0.034 mg/L for total phosphorus[5]. There was no spatial gradient – nutrient concentrations did not change much along the Study Area. However, there were different seasonal patterns for the two nutrients: total nitrogen concentrations peaked in September and October, while total phosphorus levels peaked in early August and decreased later in the season.

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[5] Each sample was tested for total phosphorous and for dissolved orthophosphate using two different analytical methods; each method has its inherent measurement error and in some cases the results for dissolved orthophosphate were higher than the results for total phosphorus (see Appendix B). In these cases, the resulting maximum value of phosphorus was reported in the figures.

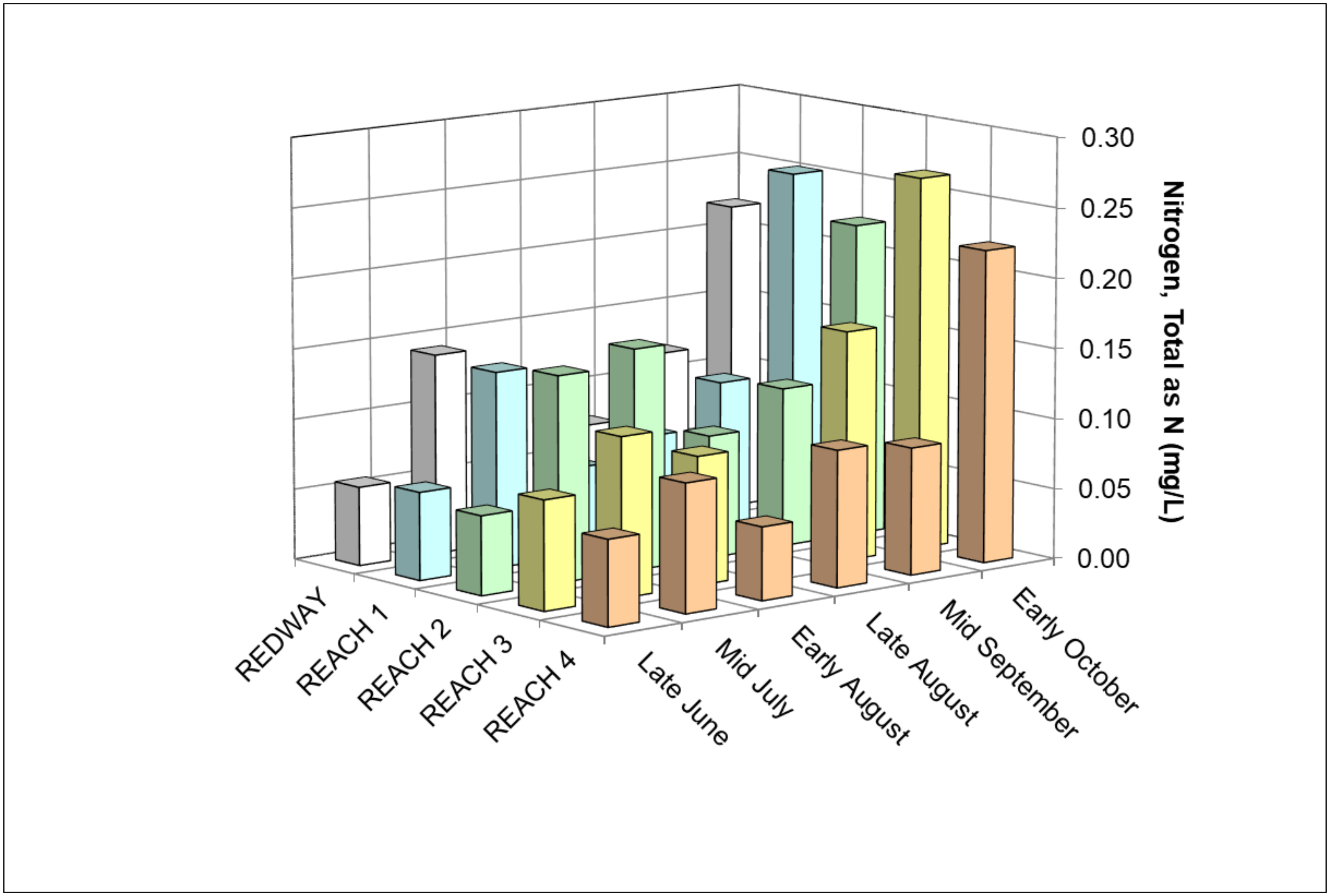


Figure 3.1-2a: Concentrations of Total Nitrogen in water in the SFEel Study Area in 2010

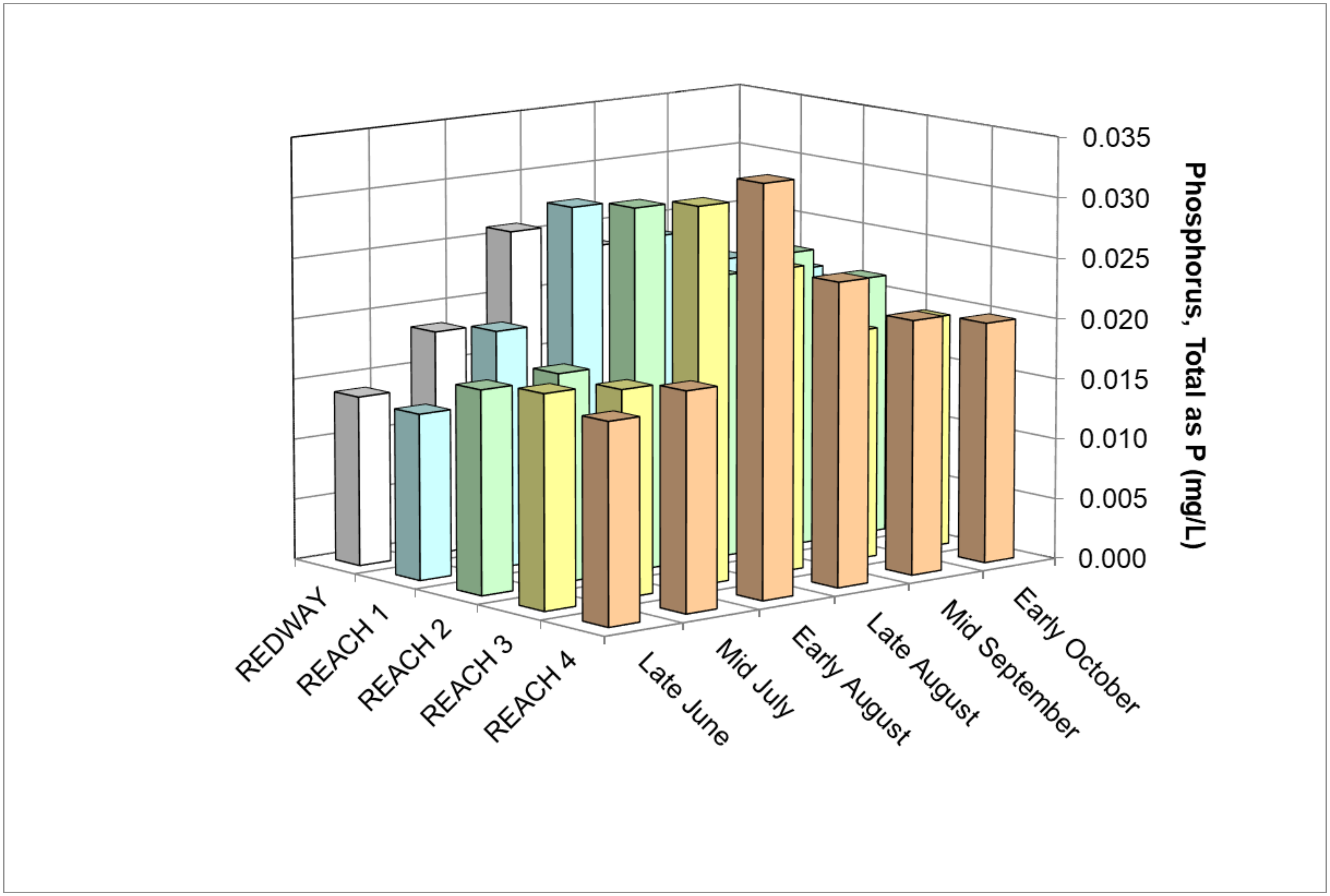


Figure 3.1-2b: Concentrations of Total Phosphorus in water in the SFEel Study Area in 2010 (Bars show the maximum measured concentration of P for each sample)

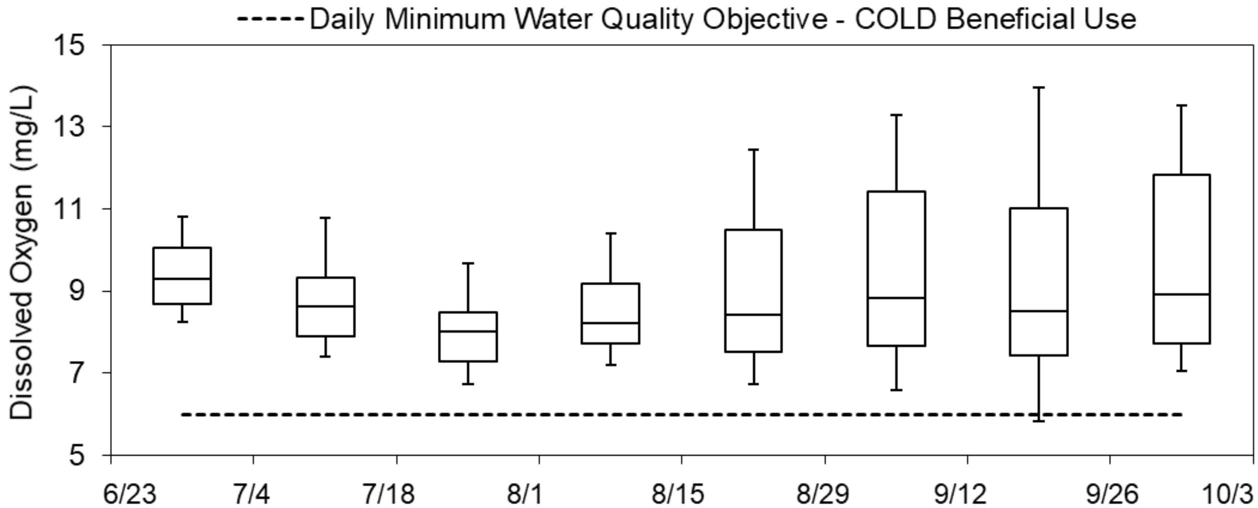
Appendix B tables show the entire biomass and nutrients data sets, with bold text denoting those samples that exceed the water quality benchmarks for Aggregated Nutrient Ecoregion II (Table2.5-1), which includes the Eel River. The total nitrogen water quality benchmark (0.12 mg/L) was exceeded in 10 of 30 samples, and total phosphorous or orthophosphate (whichever was higher) exceeded the benchmark of 0.01 mg/L 100% of the time (30 of 30 samples) (see Appendix B). This total phosphorus water quality benchmark (EPA 2000a) for phosphorus is extremely low and is often exceeded under the natural background conditions found in totally pristine environments.

3.1.3 Time series (continuous) field measurements in SFEel

Sondes were deployed in June 2010 at 5 locations, logging dissolved oxygen, pH, specific conductance, and temperature measurements at 15-minute intervals throughout the season (till early October 2010). Field crews visited the sites every 2-4 weeks to maintain and calibrate the sensors. Deployment inventory, data quality of time series field measurement, and bi-weekly box plots for each reach are documented in Appendix E.

Figure 3.1-3 presents descriptive statistics derived from time-series field measurements collected throughout the season. Data were processed in batches representing 14-day periods, and are presented as quantile plots (also known as box-and-whisker plots); each plot shows the median, minimum, maximum, and 25 and 75 percentiles. The plots are arranged in panels for the four water quality characteristics monitored in the SFEel in 2010. The data for Reach 1 are presented below as a snapshot of the larger data set. All other plots are shown in Appendix E.

Stream temperatures (bottom panel) rose through the summer, peaking in July and August before declining in September. Dissolved oxygen concentrations mirrored the temperature pattern: higher temperatures were associated with lower dissolved oxygen concentrations (this is expected, because the solubility of oxygen in water declines as the temperature rises). The site was well oxygenated during the entire season, with very few excursions below the 6 mg/L benchmark. pH values followed the dissolved oxygen pattern (again, this is expected because photosynthetic activity raises the pH while producing oxygen). Percentile values indicate that many pH data points exceeded the pH 8.5 benchmark. Specific conductance values rose through the summer and fall and then declined during rain events, as is typical of groundwater dominated waterbodies. Specific conductance values in SFEel were consistently below 280 micro Siemen, reflecting salt concentrations that are generally not problematic to aquatic life (Appendix E).



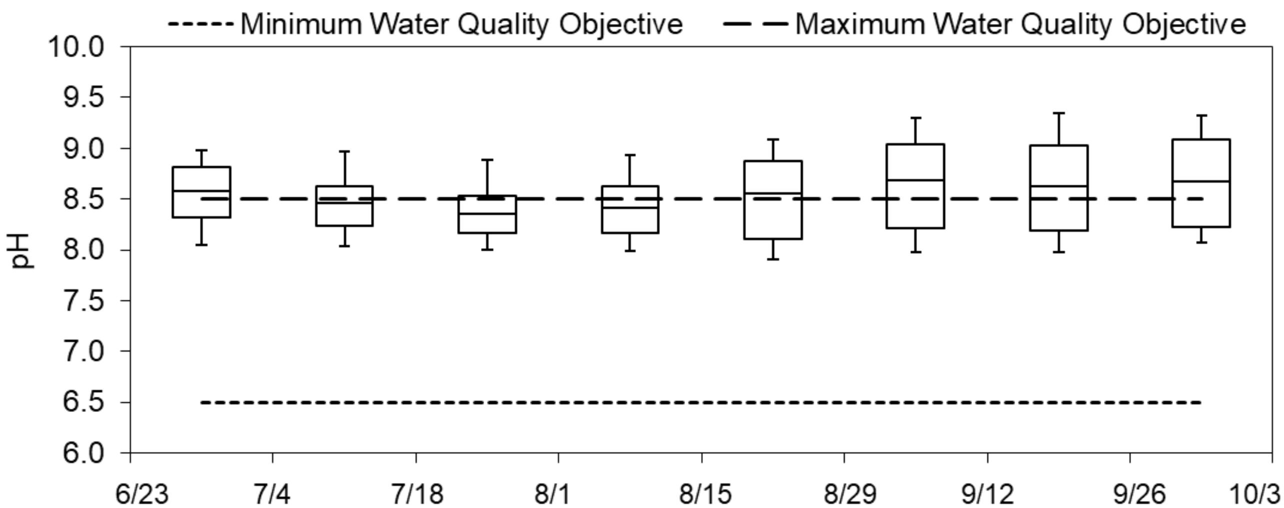
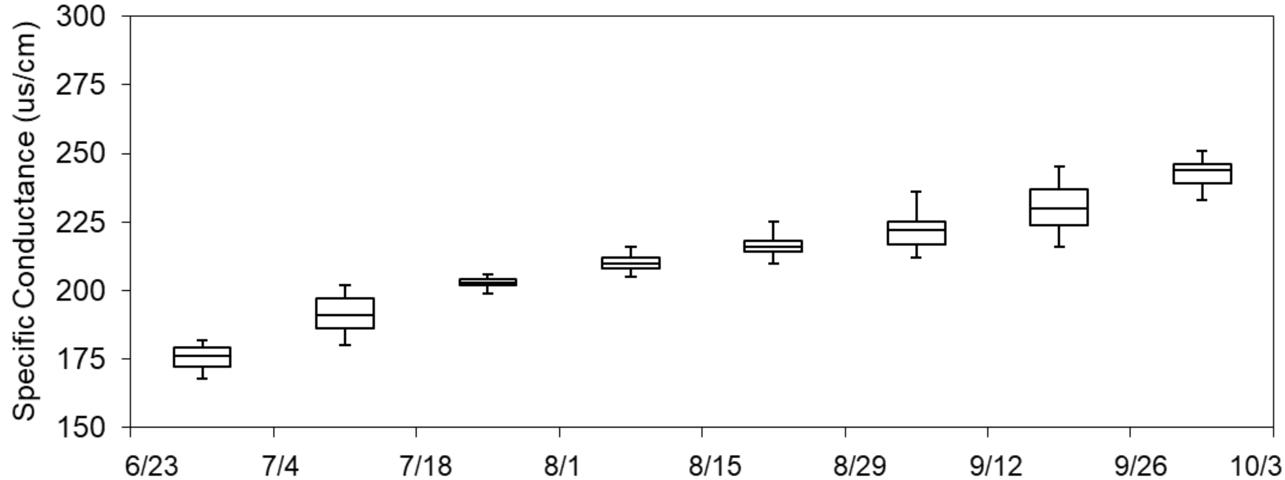


Figure 3.1-3: Time-series field measurements of selected water quality characteris-tics in Reach 1 in SFEel in 2010

The box plots provide a hint about data distribution of the original time-series measurements as aggregated for each 14-day time period, while the plots of original measurements inform about the diurnal cycle and the “daily amplitude of change”, i.e., the daily maximum minus the daily minimum.



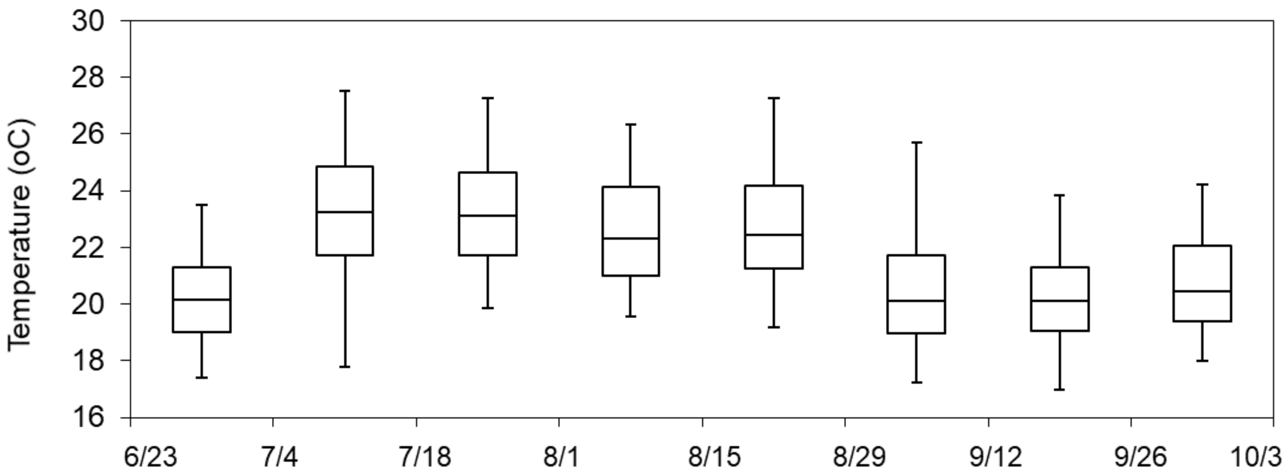


Figure 3.1-3 cont. Time-series field measurements of selected water quality characteristics in Reach 1 in SFEel in 2010

Figure 3.1-4a shows an example of the diurnal cycle for DO, pH, and temperature values in Reach 1 during a few days in September 2010. The three characteristics vary in a common pattern every day, driven by solar radiation: a gradual rise after sunrise, peak in the mid-afternoon, and a decline to a minimum several hours after sunset or just before dawn. On some days the diurnal amplitude of change is higher than on other days.

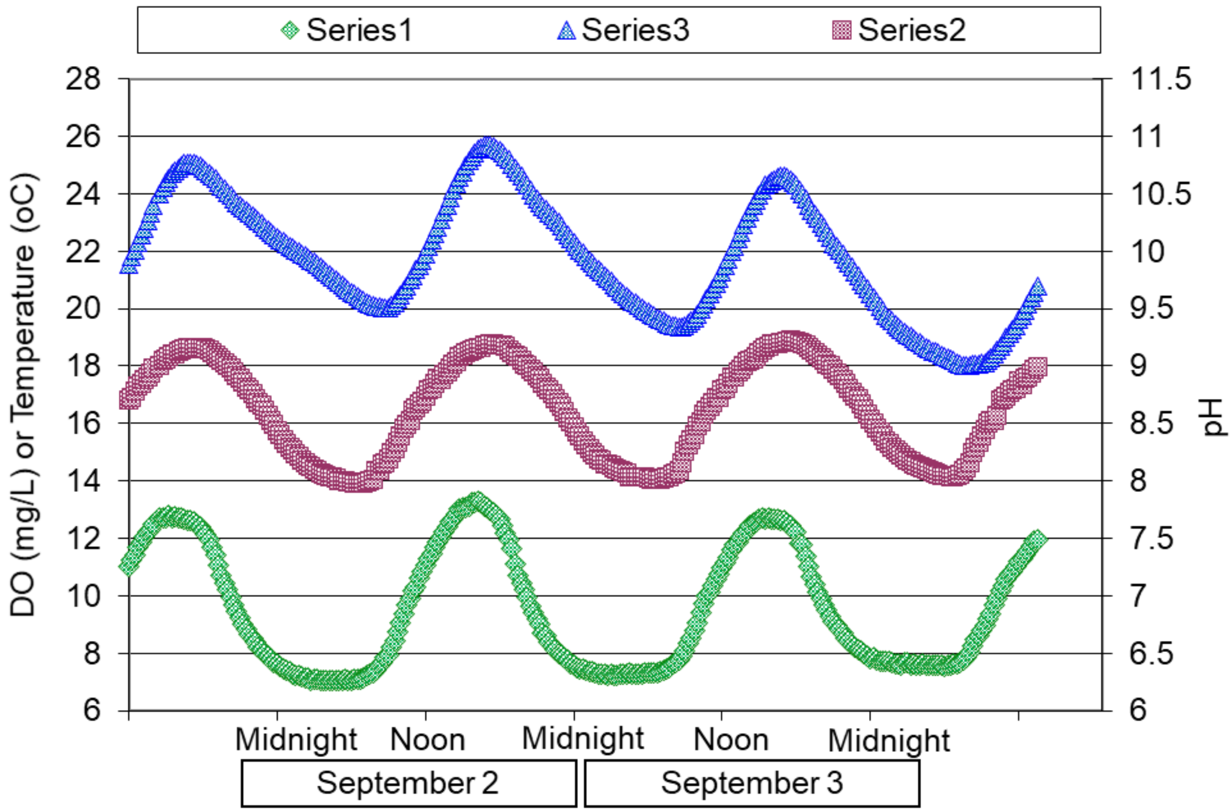


Figure 3.1-4a: Diurnal Patterns in dissolved oxygen, pH, and Temperature in Reach 1 in SFEel during three days in September 2010

Molecular oxygen is the product of photosynthesis, and pH values rise during photosynthesis when carbonic acid is removed and proton-pumps on the chloroplast membranes sequester H+ ions (acidity), leaving the water more basic. Thus, photosynthetic activities contribute to larger diurnal amplitudes in both pH and dissolved oxygen. In other words, high amplitude indicates high biomass of algae, i.e., an algal bloom. Excessive algal biomass indicates the presence of biostimulatory conditions in a given aquatic ecosystem.

Figure 3.1-4b shows the daily amplitude of pH values and **Figure 3.1-4c** shows the daily amplitude of dissolved oxygen values for the entire season as recorded at the two top SFEel Reaches (1 and 2) and in Reach 0 which is above the Study Area. The elevated daily amplitude of both dissolved oxygen and pH values between study initiation and July 12 in Reach 0 and Reach 1 are indicative of an early season algal bloom. In early August, after a short period of reduced photosynthetic activity, a steady increase was observed in Reach 1 and Reach 2 (but not in reach 0); this activity increased throughout the study period in parallel to the increase in biomass (Figure 3.1-1 above). Downstream reaches 3 and 4 did not experience similar blooms in early summer; however photosynthetic activity in these reaches increased over the summer and into the fall, as gleaned from the gradual increases in the distribution of DO and pH values in the box plots (Appendix E).

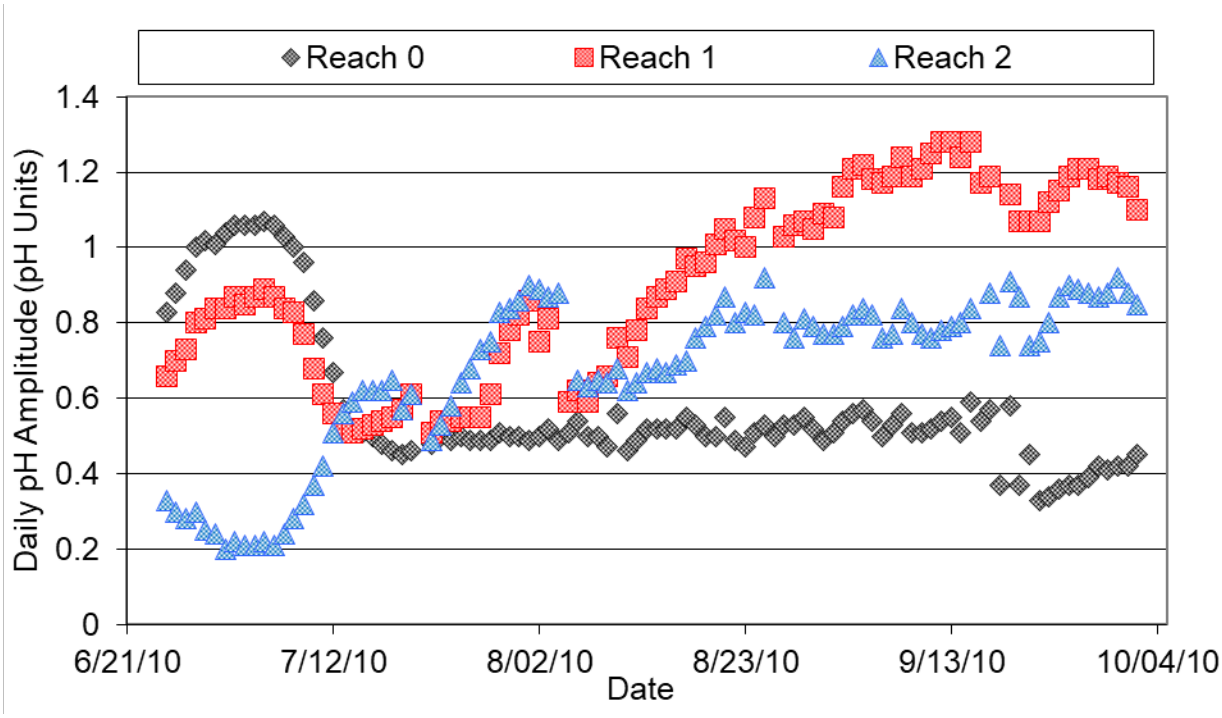


Figure 3.1-4b: Daily amplitude of pH values change (daily max minus daily min) at three SFEel reaches during the 2010 study season

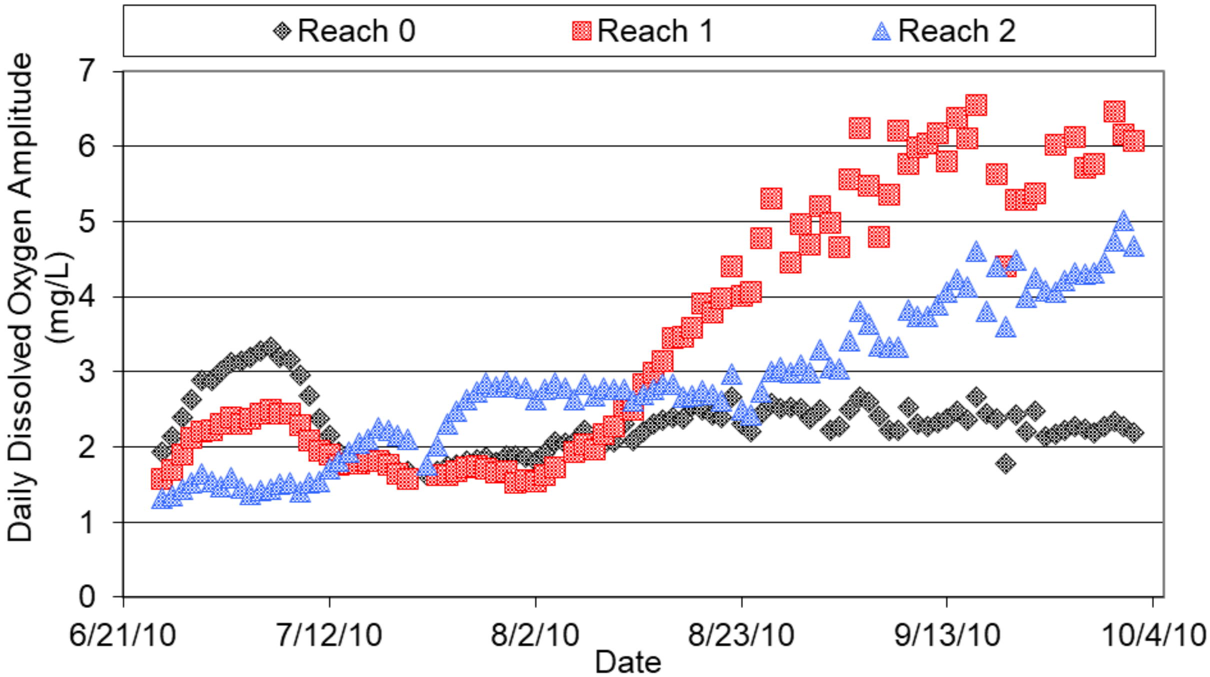


Figure 3.1-4c: Daily amplitude of dissolved oxygen values change (daily max minus daily min) at three SFEel reaches during the 2010 study season

3.1.4 Algae taxonomy and stream condition indicators

3.1.4.1 Background: benthic algae taxonomy

Communities of benthic algae (algae attached to objects) and aquatic macrophytes (water plants) have been used as integrative indicators of stream health for over two decades. Monitoring of benthic algae in freshwater streams was introduced to SWAMP in the late 2000s, along with development of protocols for sampling benthic diatoms and attached filamentous algae off a variety of substrates (Fetscher et al 2009). Benthic algae samples were used to derive (a) taxonomy information (i.e., species composition and biovolumes), (b) photosynthetic potential (Chl-a), and (c) organic matter content (AFDM).

The presence of biostimulatory conditions, and the resulting excess algal growth was also documented by visual and tactile estimates of the presence and thickness of algal layers that covered streambed substrate particles. For example, results obtained during SFEel sampling events in 2010 show a gradual proliferation of attached filamentous algae over the summer and fall (Appendix G).

Taxonomic data were used to calculate an array of algal metrics; these have been suggested by EPA and honed by Southern California Coastal Water Research Project (SCCWRP) and are now accessible via the SWAMP Reporting Module.

Recent analysis of over 500 randomly-selected sites in California, performed in conjunction with development and testing of an algal Index of Biological Integrity (IBI) for Southern California, indicated that the IBI values underestimated the disturbances (i.e., problems) associated with algal growth (Fetscher et al 2013). One of the major caveats in interpretation of this dataset was that each site was represented by a single sample, taken during the Index Period (May-August). In other words, the samples did not reflect the maximum growth potential for the season.

Sampling during the entire growing season was conducted in 2008 and 2009 in three perennial Reference Sites by SWAMP crews in the San Francisco Bay Region Water Quality Control Board (RB2). That study found incremental growth over the summer and fall, peaking in October (SFBRWQCB 2012). However, the information collected was limited to one minimally disturbed reference reach in each watershed. This sampling approach, which spanned the entire growing season, was implemented in our study reaches in 2010 and 2011, often in “disturbed” locations that have been impacted by various land-use practices.

3.1.4.2 Algal Taxonomy in SFEel

The question of spatial and seasonal variability in benthic algal growth in 2010 was addressed by the use of a rigorous sampling regime. The four study reaches were visited five times between early July and early October, yielding 20 composite benthic algae samples. Taxonomic data from these samples was used to calculate an array of algal Taxonomic Metrics (see glossary), including the metrics found useful (i.e., responsive, relevant, and informative) in previous studies (Fetscher et al 2013 and SFBRWQCB 2012). Selected algal metrics for all SFEel 2010 visits are shown in Appendix F, separated into diatom community metrics and soft algae (cyanobacteria and green algae, mostly filamentous) metrics.

Figure 3.1-5a presents the spatial and temporal variations in selected diatom community metrics gleaned from benthic samples collected in SFEel in 2010. This figure shows the proportion of the diatom *Achnanthes minutissima* (i.e., the number of *A. minutissima* cells as a fraction of the total diatom cells). A. minutissima is more prevalent upstream and in mid-summer conditions in the Eel River Study Area. This diatom species, one of the first colonizers after scouring events, is usually associated with low nutrients and salinity levels (Medley et al 1998, Ponadera et al 2007).

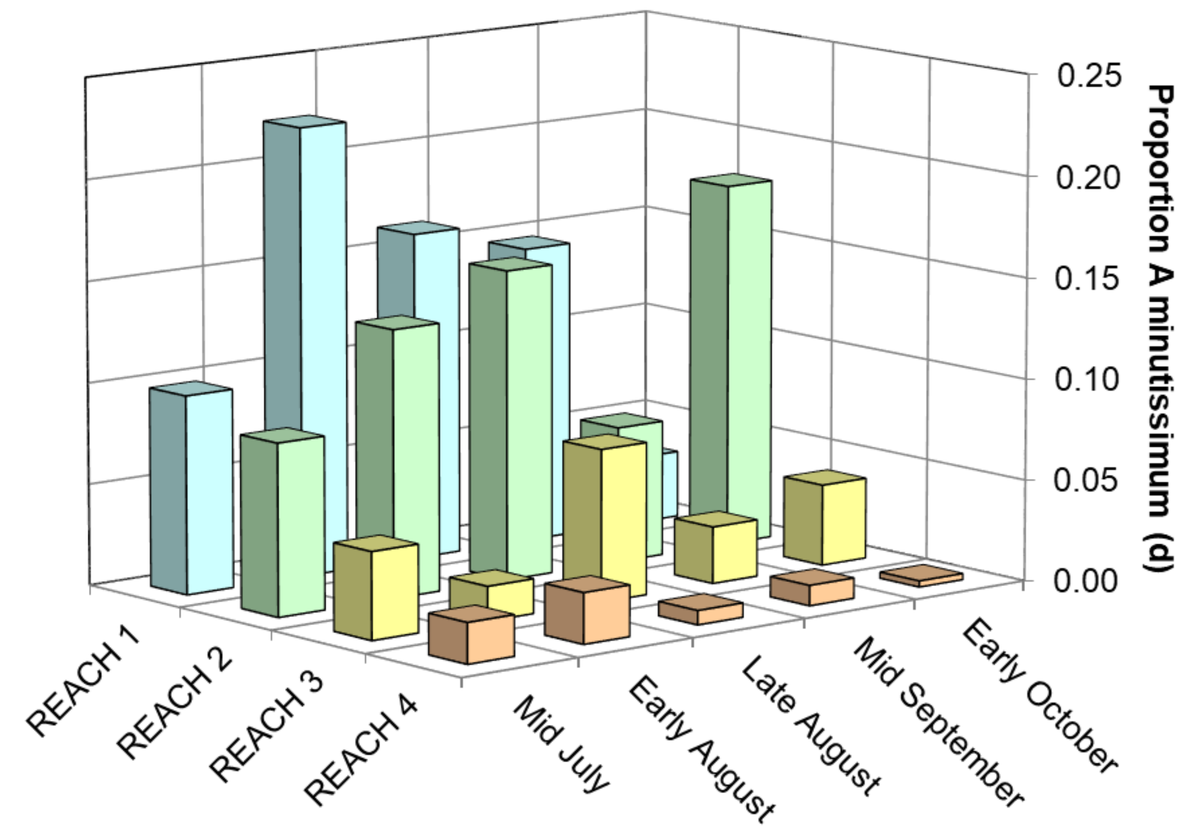


Figure 3.1-5a: Spatial and temporal variations in selected diatom community metrics gleaned from benthic sam-ples collected in SFEel in 2010: proportion of the diatom *Achnanthes minutissima*

Some diatom taxa have the ability to fix atmospheric, molecular nitrogen (N2) when nitrate (NO3) concentrations are limiting their growth. Organisms that are unable to do this are called nitrogen-heterotrophs, meaning they need N already fixed (e.g., as nitrate). **Figure 3.1-5b** shows the proportion of nitrogen-heterotrophic diatom taxa. These taxa are more prevalent upstream and in early summer.

The proportion of nitrogen-heterotrophic counts ranges between 0.02 and 0.35, possibly indicating that nitrogen fixers abound in the SFEel diatom communities, particularly in fall and downstream samples

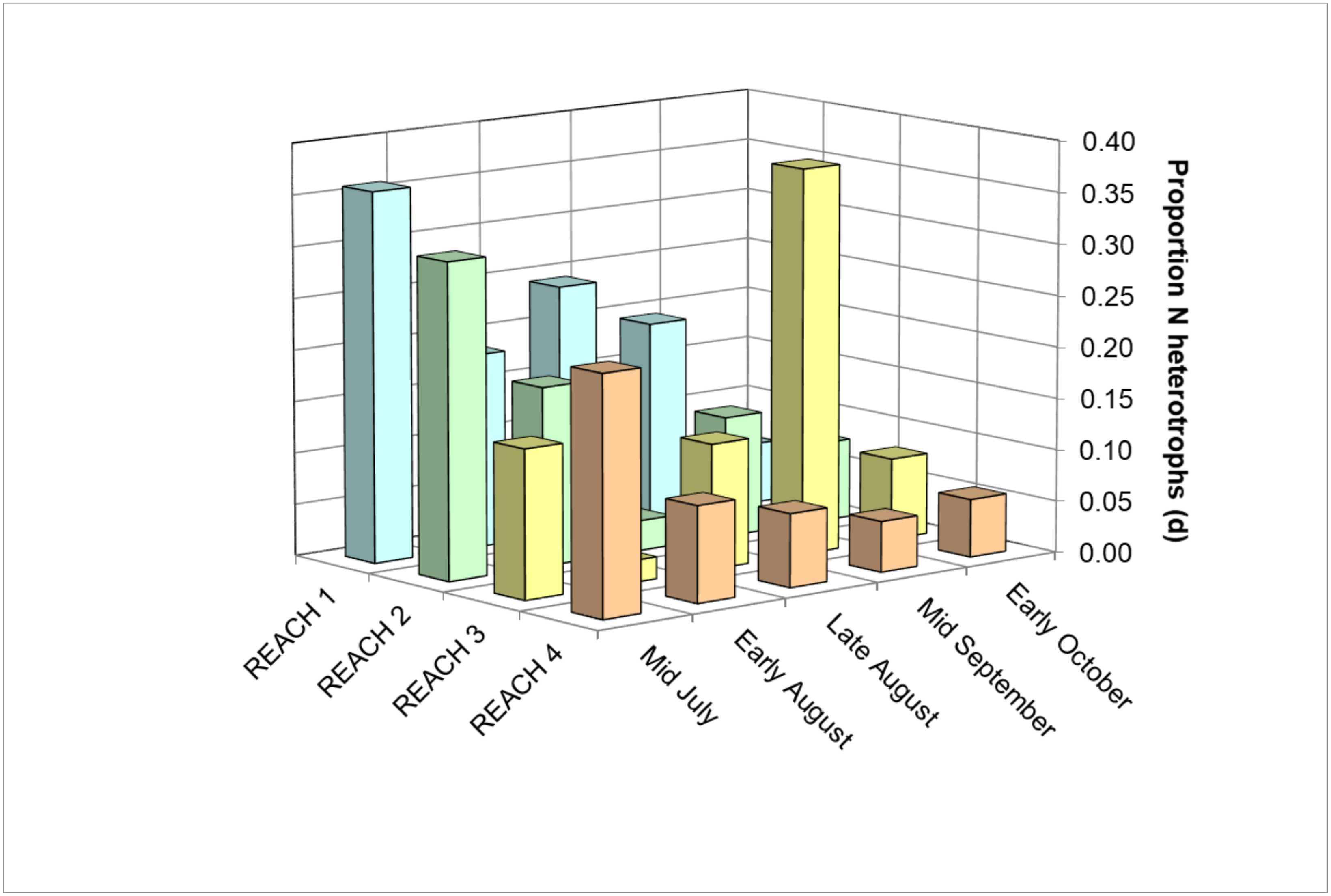


Figure 3.1-5b: Spatial and temporal variations in selected diatom community metrics gleaned from benthic sam-ples collected in SFEel in 2010: proportion of diatom taxa that cannot use molecular nitrogen (non-N-fixers)

Filamentous algae – both green algae and cyanobacteria species – are estimated by the volume of filament pieces, not by counting individual cells in each filament. **Figure 3.1-6** shows a stack-bar plot for the total biovolumes of soft algae-groups, which include green algae and cyanobacteria. Each bar represents one of the SFEel 2010 samples. The percentage of total cyanobacterial biovolume (red bar) is shown in labels above each bar. *Please note that the reach order in this plot, from left to right, is from down-stream to upstream.*

The plot shows that green algae (green bar), mostly Chlorophyta and Streptophyta, dominate in Reach 1 and Reach 3, while 9 samples (of 20) are dominated by cyanobacteria (red bar). The seasonal bloom dynamics differed from reach to reach, but the peak growth was observed in the fall. Cyanobacteria bloom biovolumes were considerably lower than green algae bloom biovolumes. In other words, in the presence of abundant green algae – which proliferate when both nitrogen and phosphorus are readily available - cyanobacteria usually comprise a small fraction of the biomass.

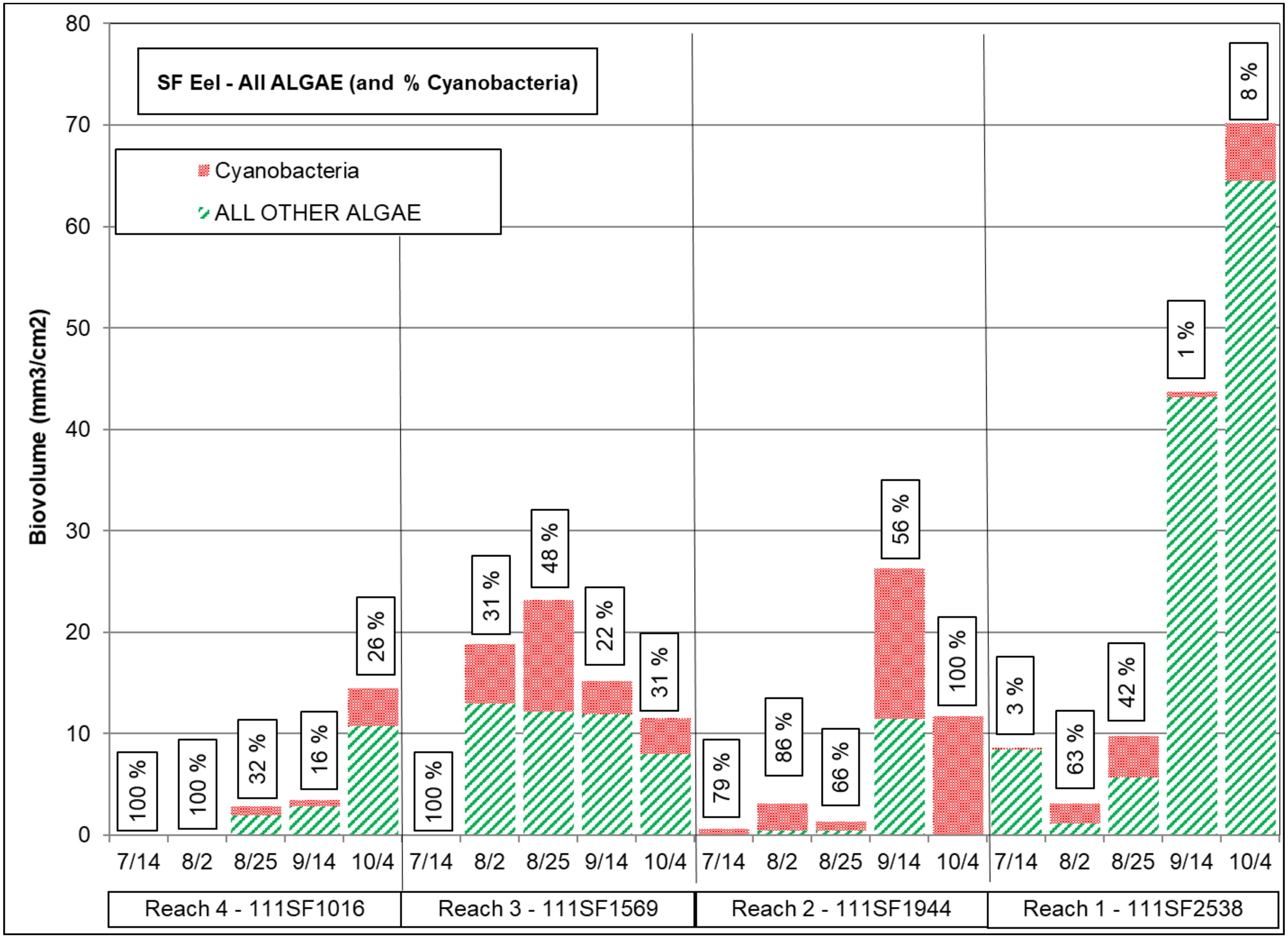


Figure 3.1-6: Biovolumes of algal taxa from various groups of soft algae collected in SFEel in 2010

3.1.5 Taxonomic composition of cyanobacteria in SFEel in 2010

Figure 3.1-7 shows the breakdown of cyanobacterial taxa into three categories based on their suspected potential to produce cyanotoxins. There was a high percentage of taxa that are known to produce cyanotoxins, particularly in Reach 3. However, the maximum biovolume of cyanotoxin producing genera was only about 7 mm^3/cm^2. These data only indicate potential; actual production and/or release of cyanotoxins were not tested in this study. Subsequent studies in the Eel River watershed have provided rigorous monitoring of the water column and the benthic cyanobacterial mats, focusing on multiple aspects of cyanobacterial toxic effects, including presence of toxin producing species, presence of cyanotoxins in the water, presence of DNA of toxin producing species, and presence of specific genes coding for cyanotoxins (Bouma-Gregson and Higgins 2015; Fetscher *et al* 2015; Anderson *et al* 2018; Howard and Fadness 2019; Kelly *et al* 2019; Conklin *et al* 2020; and other ongoing studies). Potentially

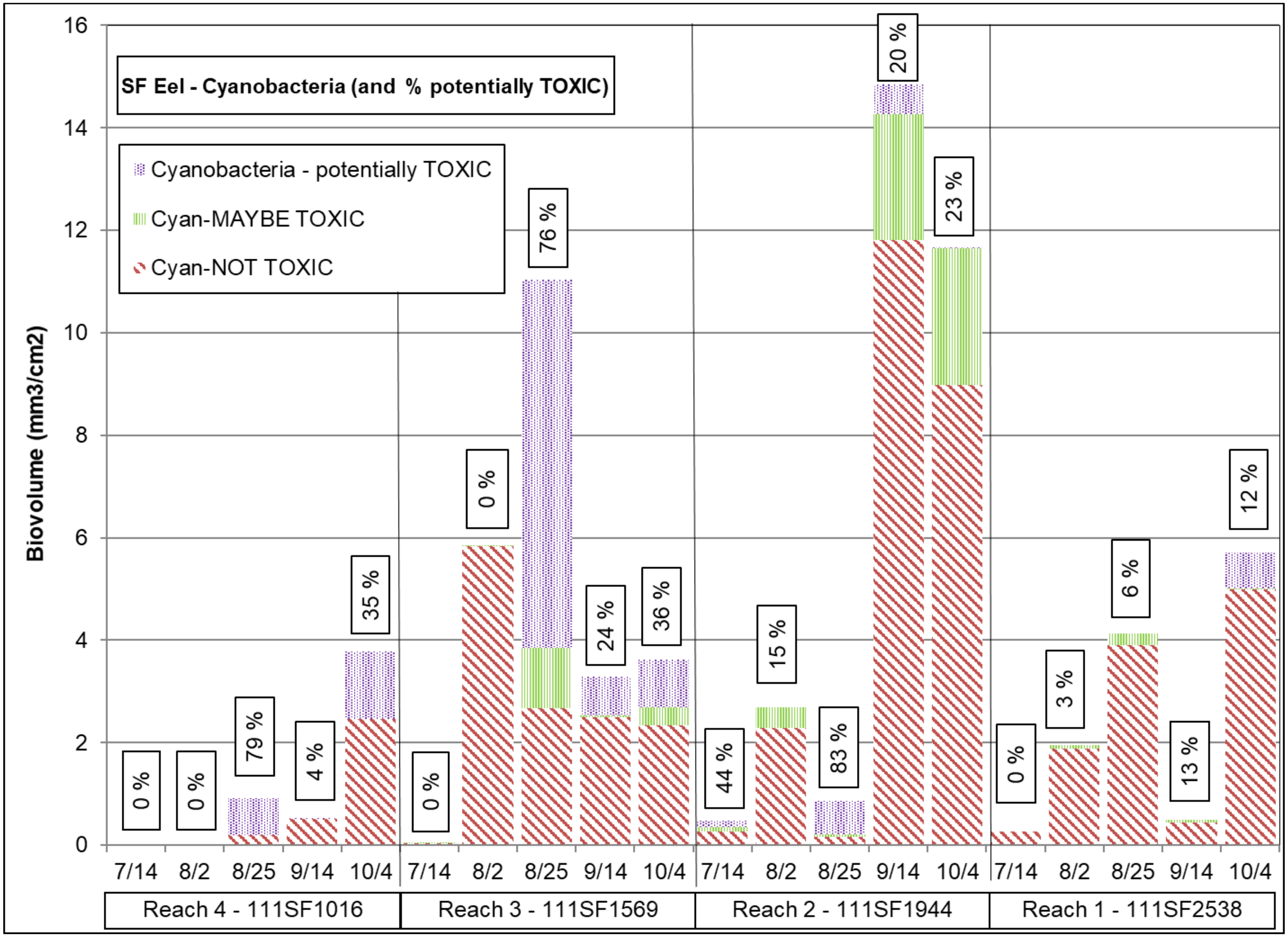


Figure 3.1-7: Biovolumes of cyanobacterial taxa groups collected in SFEel in 2010, categorized by ability to pro-duce cyanotoxins

3.2 Spatial and seasonal trends in the Russian River Study Area

The Study Area was monitored between June and October 2011 in a total of 83 site-vis-its (Appendix Table A-2). Beyond visiting the four study reaches, the field crew also visited Dry Creek (tributary to the Russian River) located outside of the Study Area. Data for Dry Creek are not specifically discussed in this report; however, these data are presented in the Appendices.

3.2.1 Benthic algae biomass (AFDM and Chl-a) in RuR

Figure 3.2-1a shows concentrations of benthic Chl-a and **Figure 3.2-1b** shows concentrations of benthic AFDM in the RuR Study Area over the summer and fall of 2011 study period. These 3-D plots demonstrate both spatial and temporal trends, and reveal concentration gradients in both dimensions. Chl-a concentration in Figure 3.2-1a shows concentrations of benthic exceeded the BURC thresholds on 7 of 23 occasions (see Appendix Table B-1b), when benthic biomass of primary producers peaked in mid- and late summer. Some Chl-a concentration gradients can be seen in both temporal and spatial dimensions. The temporal view shows increasing Chl-a over the summer and die-off in the fall, while spatial gradients indicate that Chl-a is generally higher in the upstream reach during mid-summer. Benthic Chl-a values from all reaches in early June were below the BURC I threshold (<100 mg chl-a/m^2) indicating presumably unimpaired conditions. Results from Reach 2 in mid-October and Reach 4 in Early September and mid-October were within the BURC II range (100-150 mg chl-a/m^2) indicating potentially impaired conditions during this time. Samples collected in Reach 1 in early August, early September, and mid-October exceeded the BURC III threshold (>150 mg chl-a/m^2), reflecting presumably impaired conditions during this time. AFDM concentrations Figure 3.2-1b, on the other hand, show variable and inconsistent patterns of temporal and spatial gradients.

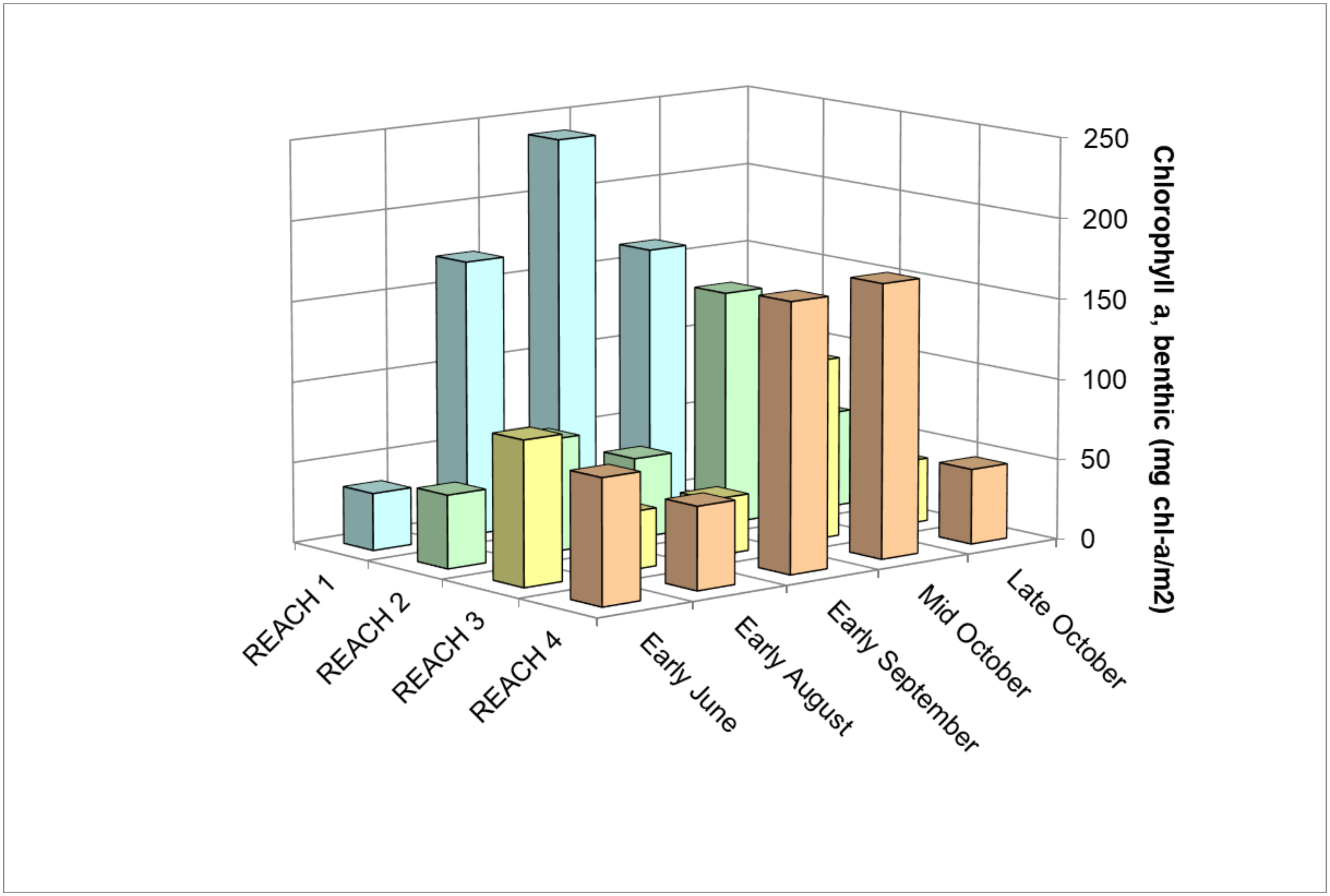


Figure 3.2-1a: Concentrations of benthic biomass indicators in the RuR Study Area in 2011: Chlorophyll a

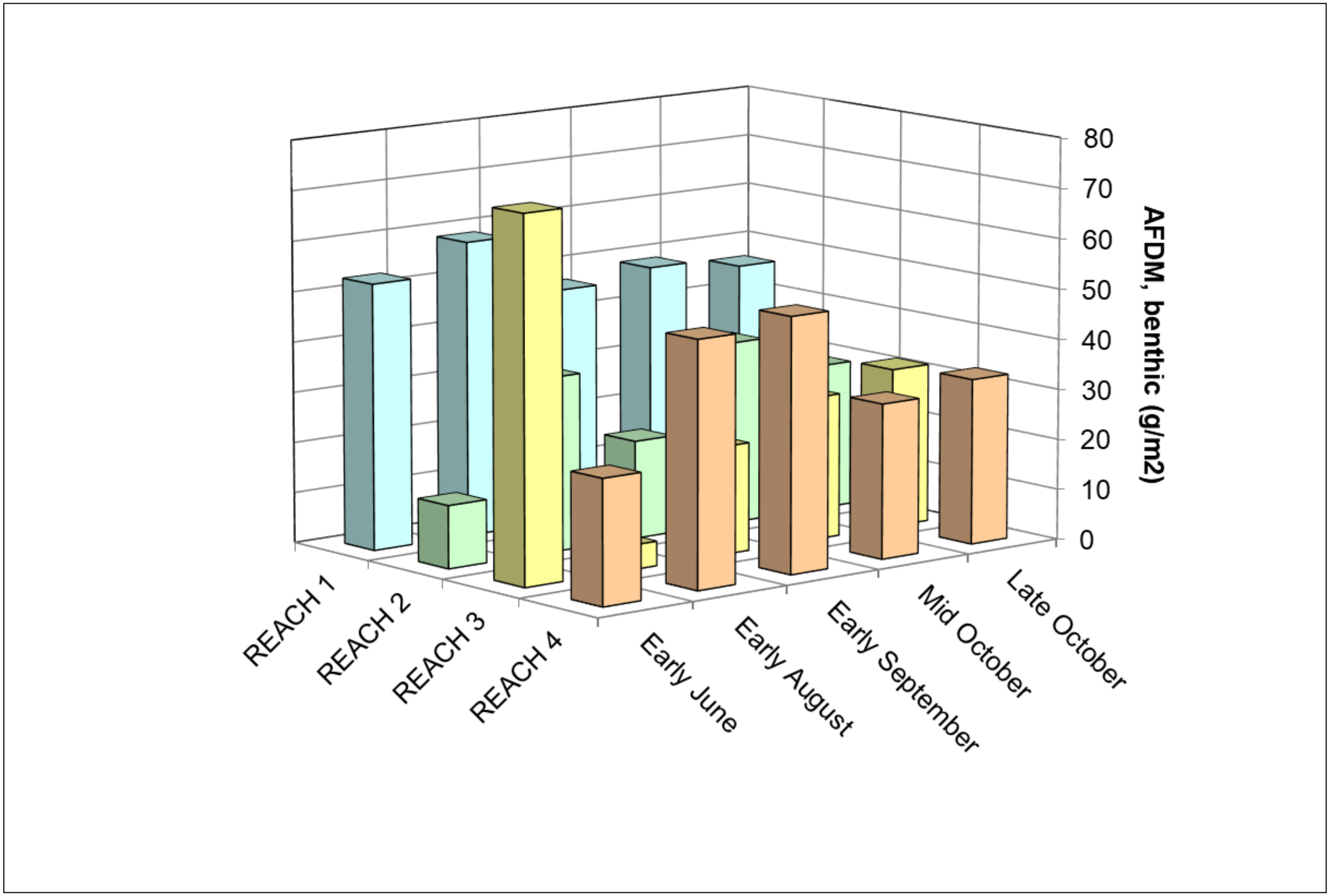


Figure 3.2-1b: Concentrations of benthic biomass indicators in the RuR Study Area in 2011: Ash-Free Dry Mass (AFDM)

3.2.2 Nutrients in RuR

Figure 3.2-2a shows the concentrations of nitrogen and **Figure 3.2-2b** shows phosphorus concentrations in the RuR Study Area. Nutrient concentrations were generally low, ranging from 0.1 to 0.4 mg/L for total nitrogen and 0.02 to 0.064 mg/L for phosphorus. Higher TN concentrations were observed in early summer (June), followed by a clear mid-summer dip (comprised mostly of organic N), and an increase in the fall with release of some inorganic N. (Appendix B). Phosphorus concentrations had a smaller mid-summer dip and peak in the fall. All Reaches had a common seasonal pattern in nitrogen concentration, without any visible spatial gradients. However, some minor (and inconsistent) spatial gradients were observed in the phosphorus concentrations.

Appendix B tables shows the entire nutrients dataset, with bold text used to highlight exceedances of USEPA's water quality benchmarks for the Aggregated Nutrient Ecoregion III (Table 2.5-1). The total nitrogen water quality benchmark (0.38 mg/L) was only exceeded in 1 of 43 samples. Total phosphorous (or orthophosphate, whichever was the maximum for a given sample) exceeded the benchmark of 0.02 mg/L in 35 out of 43 samples.

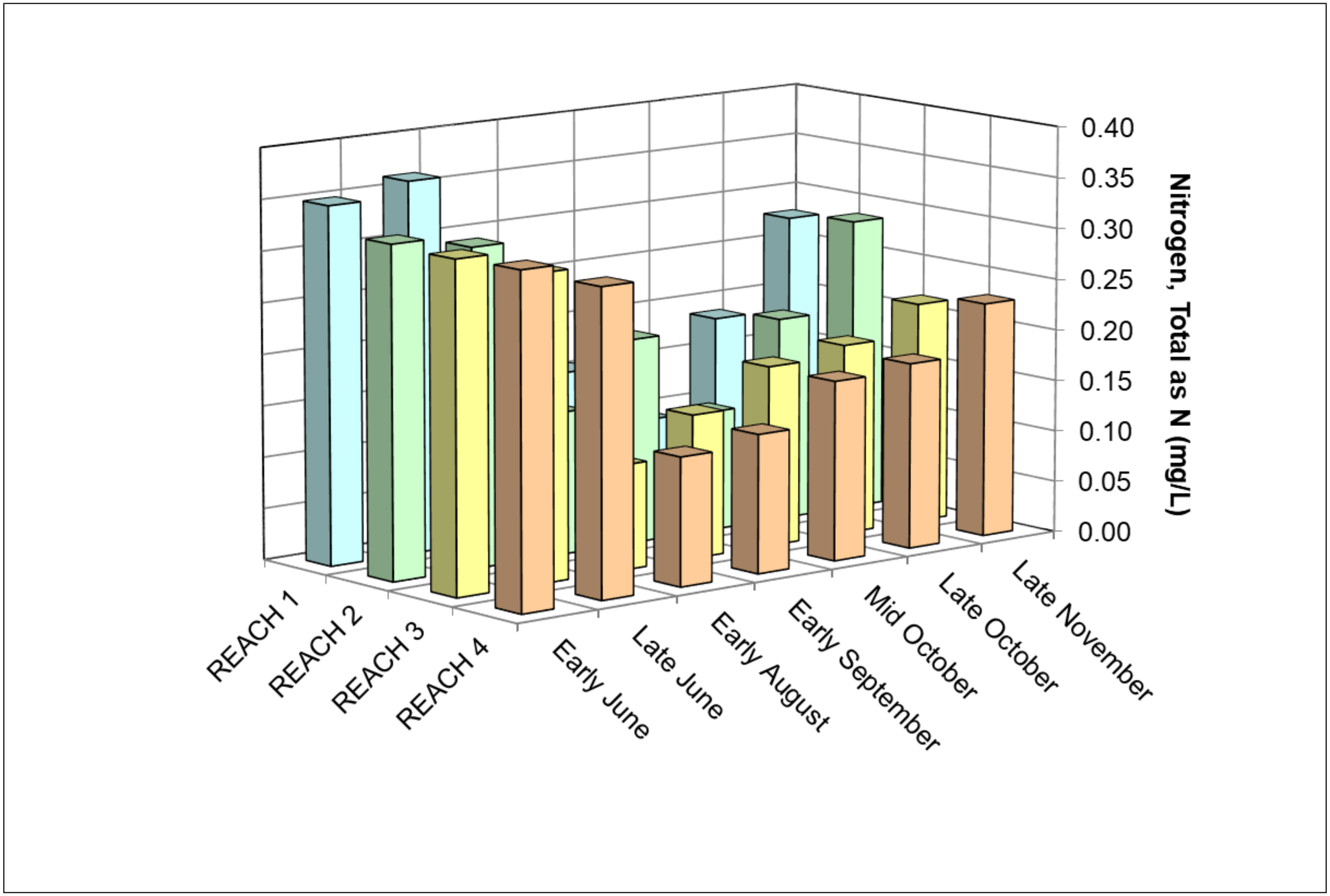


Figure 3.2-2a: Concentrations of Total Nitrogen in water in the RuR Study Area in 2011

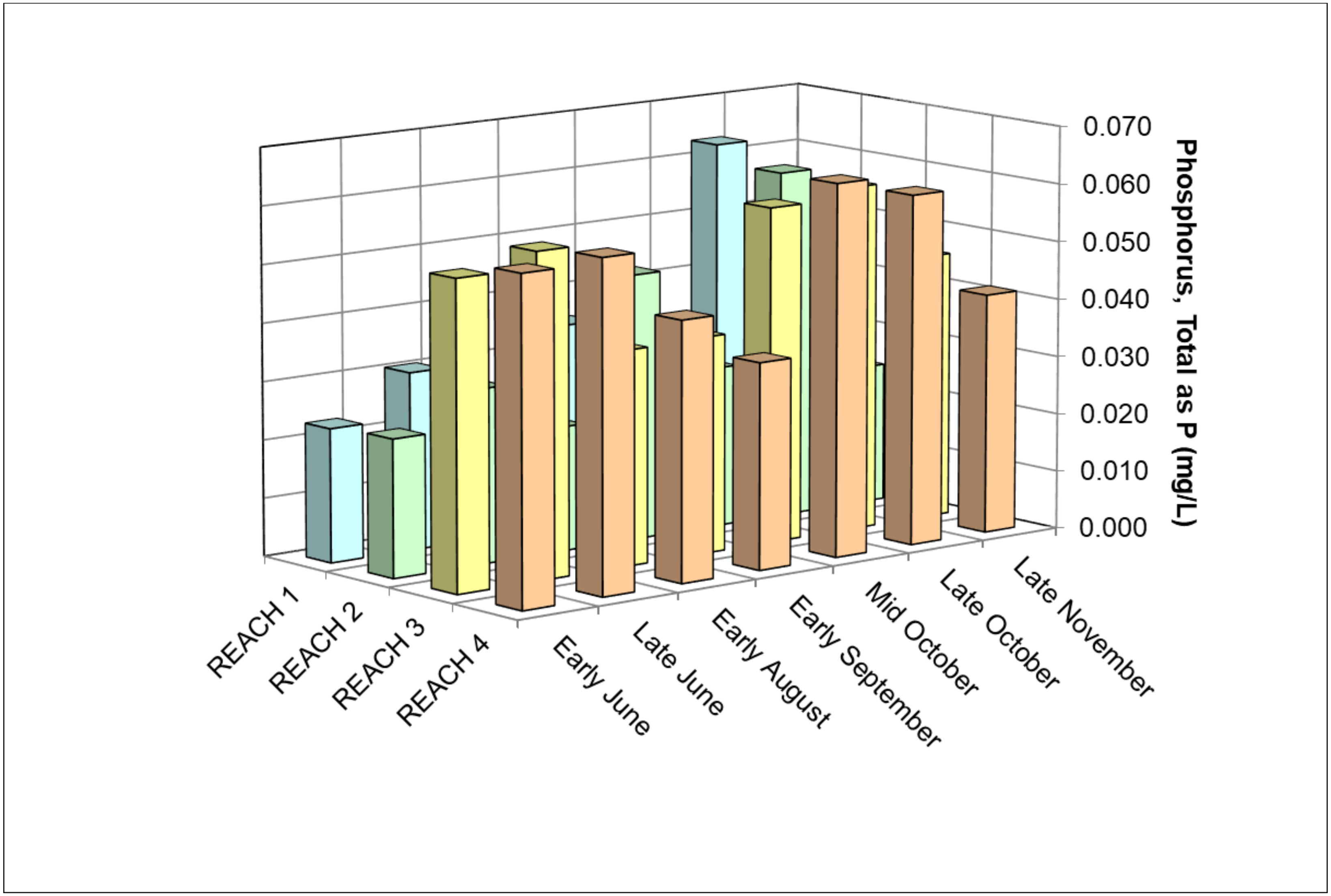


Figure 3.2-2b: Concentrations of Total Phosphorus in water in the RuR Study Area in 2011 (Bars show the maxi-mum measured concentration of P for each sample)

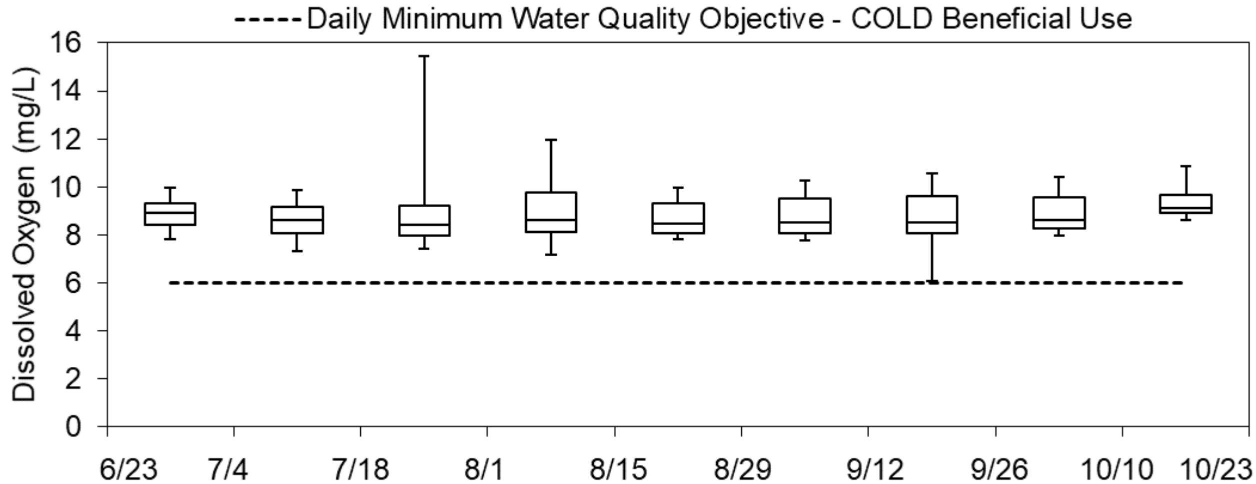
3.2.3 Time series (continuous) field measurements in RuR

Sondes were deployed in June at 5 locations (four Russian River mainstem and one in Dry Creek tributary), logging dissolved oxygen, pH, specific conductance, and temperature measurements at 15-minute intervals throughout the season (till early October). Staff visited the sites every 2-4 weeks to maintain and calibrate the sensors as well as download the logged data from each deployment period. Deployment inventory, data quality of time series field measurement, and bi-weekly box plots for each reach are documented in Appendix E.

The time-series data from all deployment periods for each station were compiled and then processed in 14-day batches; these are shown as quantile plots (also known as box-and-whisker plots). **Figure 3.2-3** presents descriptive statistics derived from measurements obtained for each 14-day period, each plot showing the median, minimum, maximum, and 25 and 75 percentiles. The plots are arranged in panels for the four water quality characteristics monitored in Reach 2 in RuR in 2011. The plots prepared for the other RuR reaches are not shown below (they are provided in Appendix E and present similar seasonal trends and exceedance patterns)

Temperature values (bottom panel) peaked June-July and declined slowly into fall, while the dissolved oxygen seasonal pattern was essentially flat with a few outlying peaks. The site was well oxygenated during the entire season, with very few excursions below the 6 mg/L benchmark. pH values also showed very little seasonal variability. Percentile values indicate that very few pH data points exceeded the pH 8.5 benchmark. Specific conductance values declined somewhat through the summer and fall, probably demonstrating the dominance of surface water inputs from the two drinking water reservoirs and the limited influence of groundwater. Specific conductance values were all below 350 micro Siemen, indicating salt concentrations that are not considered harmful to life.

The diurnal changes in water quality were very moderate in RuR throughout the season: in contrast to the natural temperature fluctuation, the values of dissolved oxygen and pH generally showed little spread between the 25^{th} and 75^{th} percentiles (meaning small daily amplitudes).



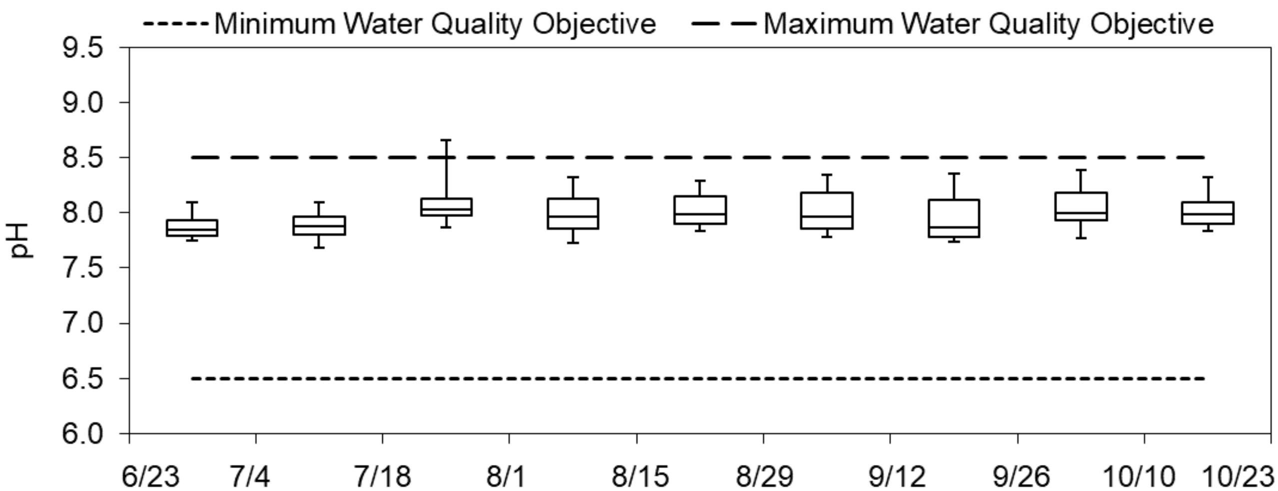
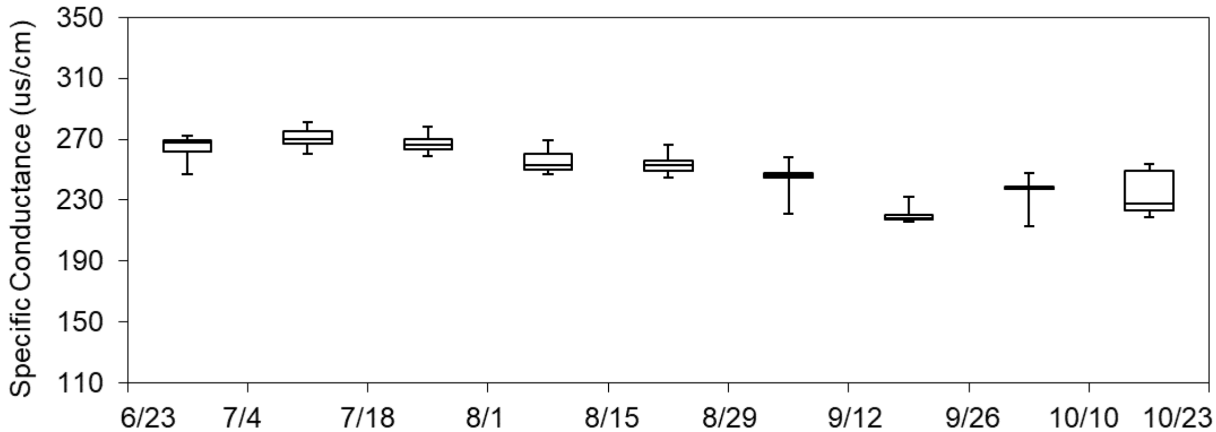


Figure 3.2-3: Time-series field measurements of four water quality characteristics in Reach 2 RuR in 2011

The box plots provide a hint about data distribution of the original time-series measurements as aggregated for each 14-day time period, while the plots of original measurements inform about the diurnal cycle and the “daily amplitude of change”, i.e., the daily maximum minus the daily minimum.



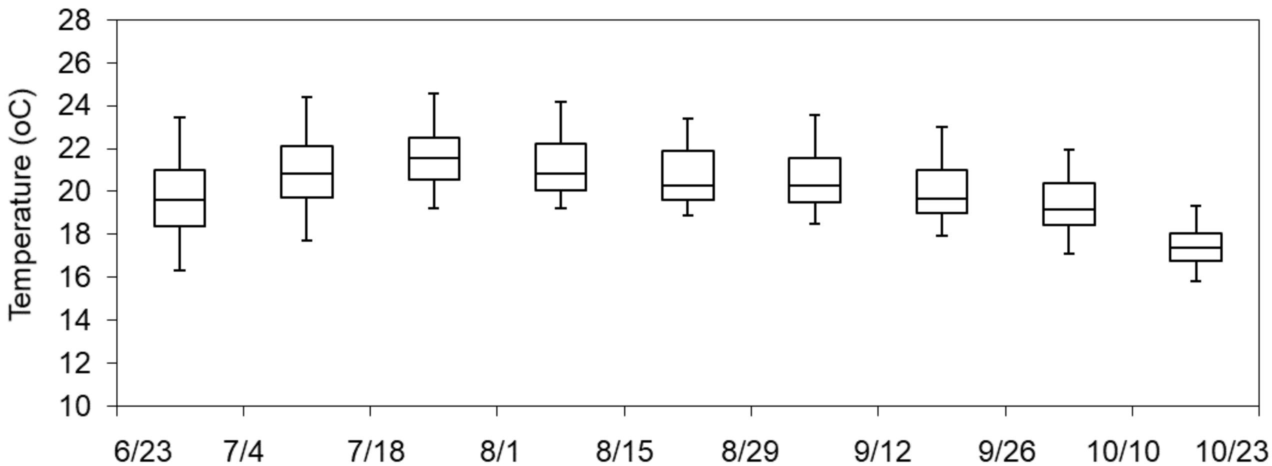


Figure 3.2-3 cont. Time-series field measurements of four water quality characteristics in Reach 2 RuR in 2011

Figure 3.2-4a shows an example of the diurnal cycle for DO, pH, and temperature values in Reach 1 during a few days in September 2011. The three characteristics vary in a common pattern every day, driven by solar radiation: a gradual rise after sunrise, peak in the mid-afternoon, and a decline to a minimum several hours after sunset or just before dawn. On some days the diurnal amplitude of change is higher than on other days.

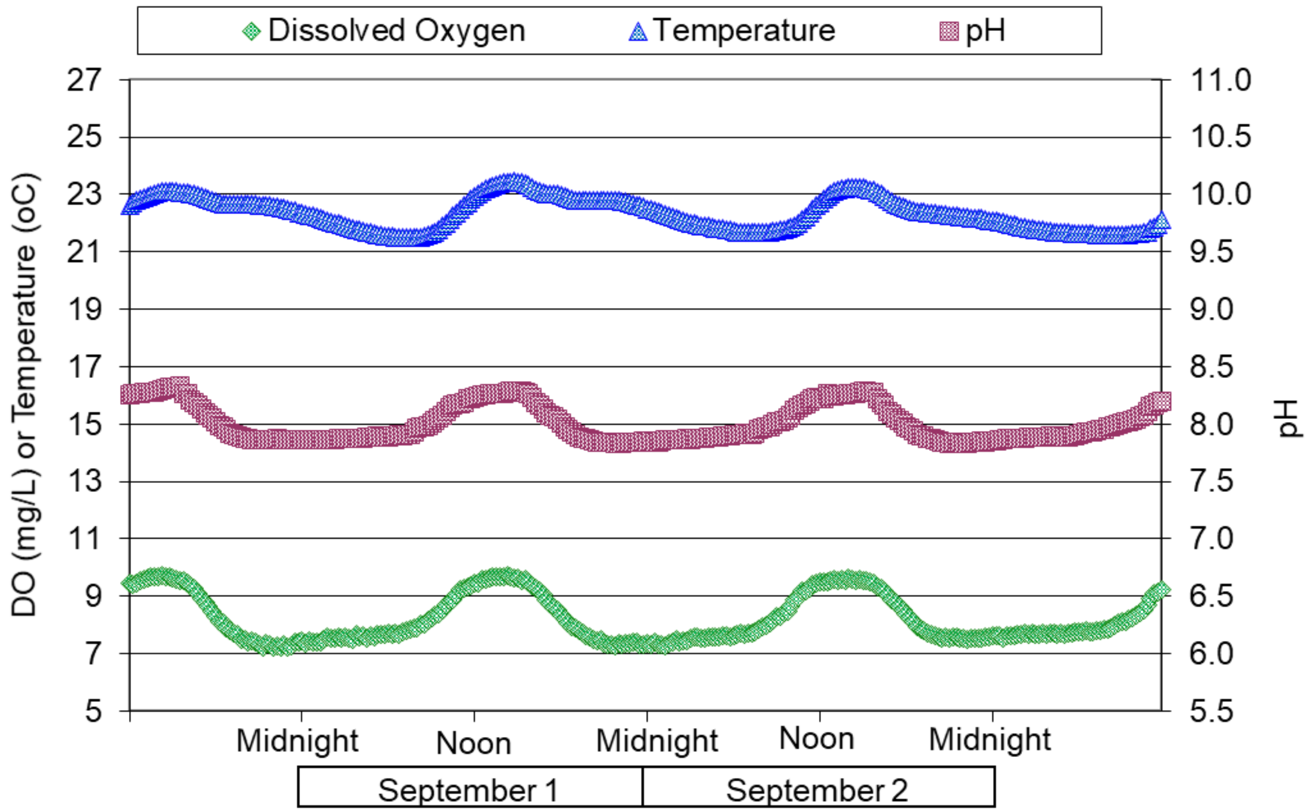


Figure 3.2-4a: Diurnal Patterns in dissolved oxygen, pH, and Temperature in Reach 1 in Russian River during three days in September 2011

Figure 3.2-4b shows the daily amplitude of pH values and **Figure 3.2-4c** shows the daily amplitude of dissolved oxygen values for the entire season as recorded at the two top Russian Reaches (1 and 2) and in Dry Creek. The elevated daily amplitude of both dissolved oxygen and pH values between July 1 and July 21 in Reach 2 is indicative of an algal bloom. An increase in daily dissolved oxygen amplitude was recorded in Reach 1 in late October though no associated increase in the daily pH amplitude was observed.

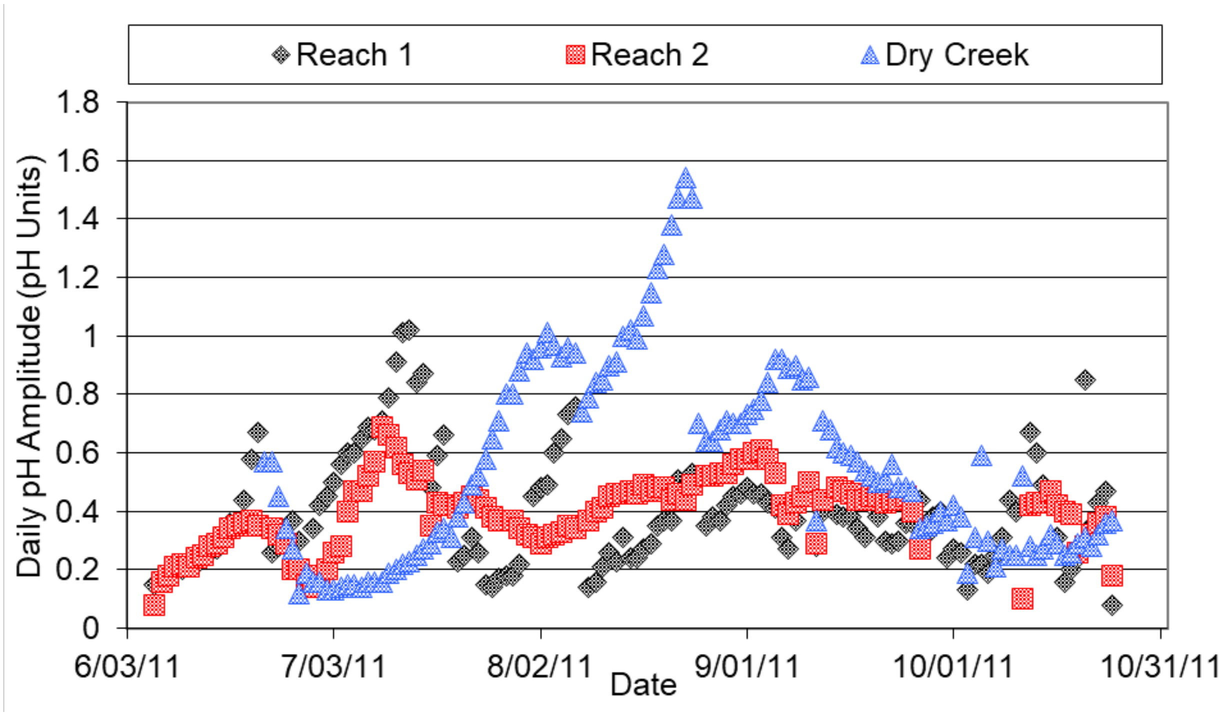


Figure 3.2-4b: Daily amplitude of pH values (daily max minus daily min) at two Russian River reaches and Dry Creek during the 2011 study season

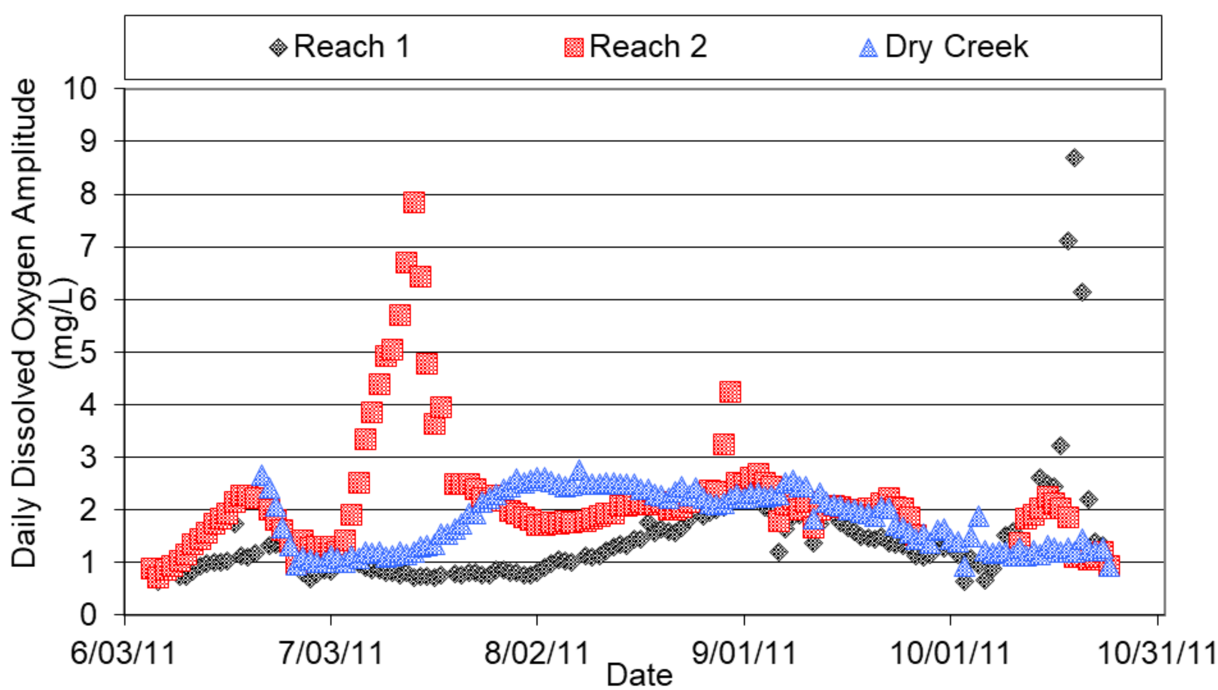


Figure 3.2-4c: Daily amplitude of dissolved oxygen values (daily max minus daily min) at two Russian River reaches and Dry Creek during the 2011 study season

Figure 3.2-4d shows that increased diurnal dissolved oxygen amplitude is a due to a decrease in dissolved oxygen concentrations suggesting that the increasing dissolved oxygen amplitude was not related to an algal bloom but to some other unknown environmental or anthropogenic factor that may have occurred upstream of Reach 1 during that time period. Downstream reaches 3 and 4 did not experience similar blooms in early summer; however photosynthetic activity in these reaches increased over the summer and into the fall, as gleaned from the gradual increases in the distribution of DO and pH values in the box plots (Appendix E).

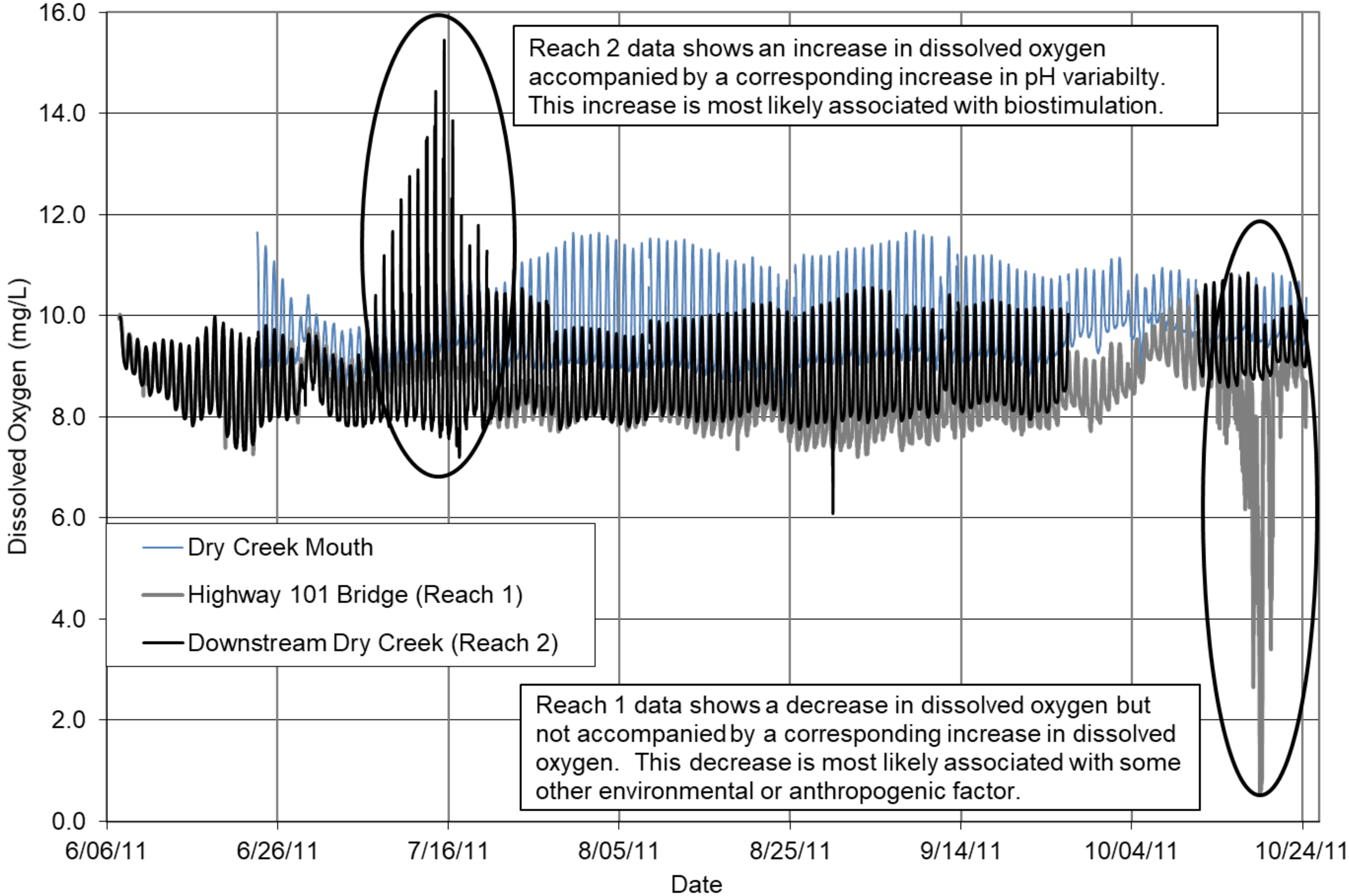


Figure 3.2-4d: Seasonal dissolved oxygen values at two Russian River reaches and Dry Creek during the 2011 study season

3.2.4 Algae taxonomy in RuR

Benthic algae communities have been studied in California streams for over a decade and proved very useful as integrative indicators of stream conditions (see background summary in Section 3.1.4 above). To study the seasonal and spatial variations, four study reaches in RuR were visited six times between early June and late October. Taxonomic data from these samples was used to calculate an array of algal metrics, shown in Appendix F, separated into diatom community metrics and soft algae (cyanobacteria and green algae, mostly filamentous) metrics.

Figure 3.2-5a presents the spatial and temporal variations in two diatom community metrics gleaned from benthic samples collected in RuR in 2011. This figure shows the proportion of the diatom *Achnanthes minutissima* (i.e., the number of *A. minutissima* cells as a fraction of the total diatom cells). This diatom species, one of the first colonizers after scouring events, is usually associated with low nutrients and salinity levels (Medley et al 1998, Ponadera et al 2007). *A. minutissima* is more prevalent upstream and in early summer in the RuR Study Area.

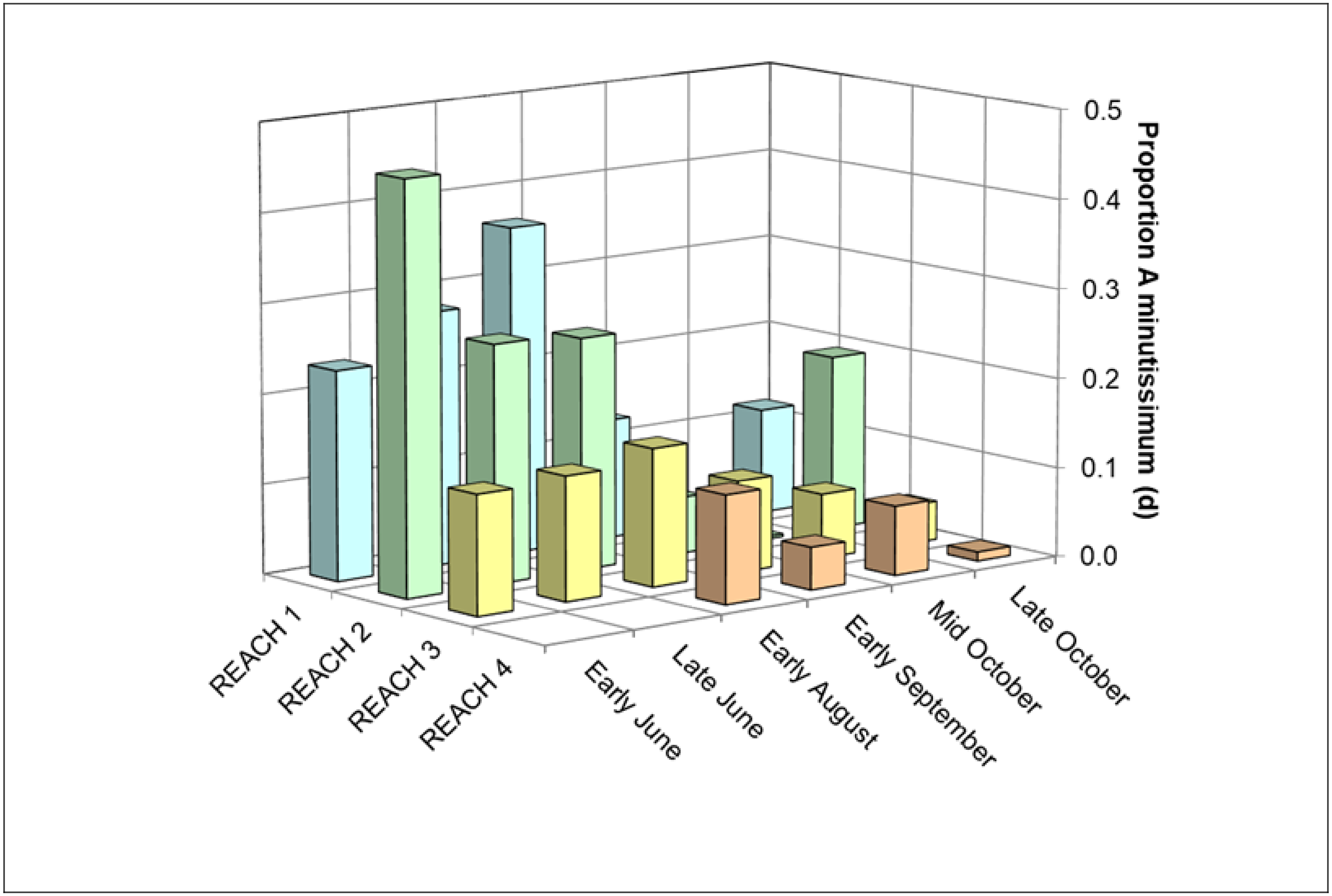


Figure 3.2-5a: Spatial and temporal variations in selected diatom community metrics gleaned from benthic sam-ples collected in RuR in 2011: proportion of the diatom *Achnanthes minutissima*

Figure 3.2-5b shows the proportion of nitrogen-heterotrophic diatom taxa (i.e., taxa that cannot fix molecular nitrogen and require nitrate for growth). These taxa are more prevalent in the three downstream reaches from early summer to early fall. The high proportion of nitrogen-heterotrophic counts were in Reach 3 in June where more than 50% of diatom cells require fixed nitrogen for growth, coincides with availability of fixed nitrogen including nitrate (Appendix B and Figure 3.2-2). The proportion of nitrogen-heterotrophs declines into late summer, in parallel to the decline in total nitrogen concentrations, indicating that nitrogen fixers take over.

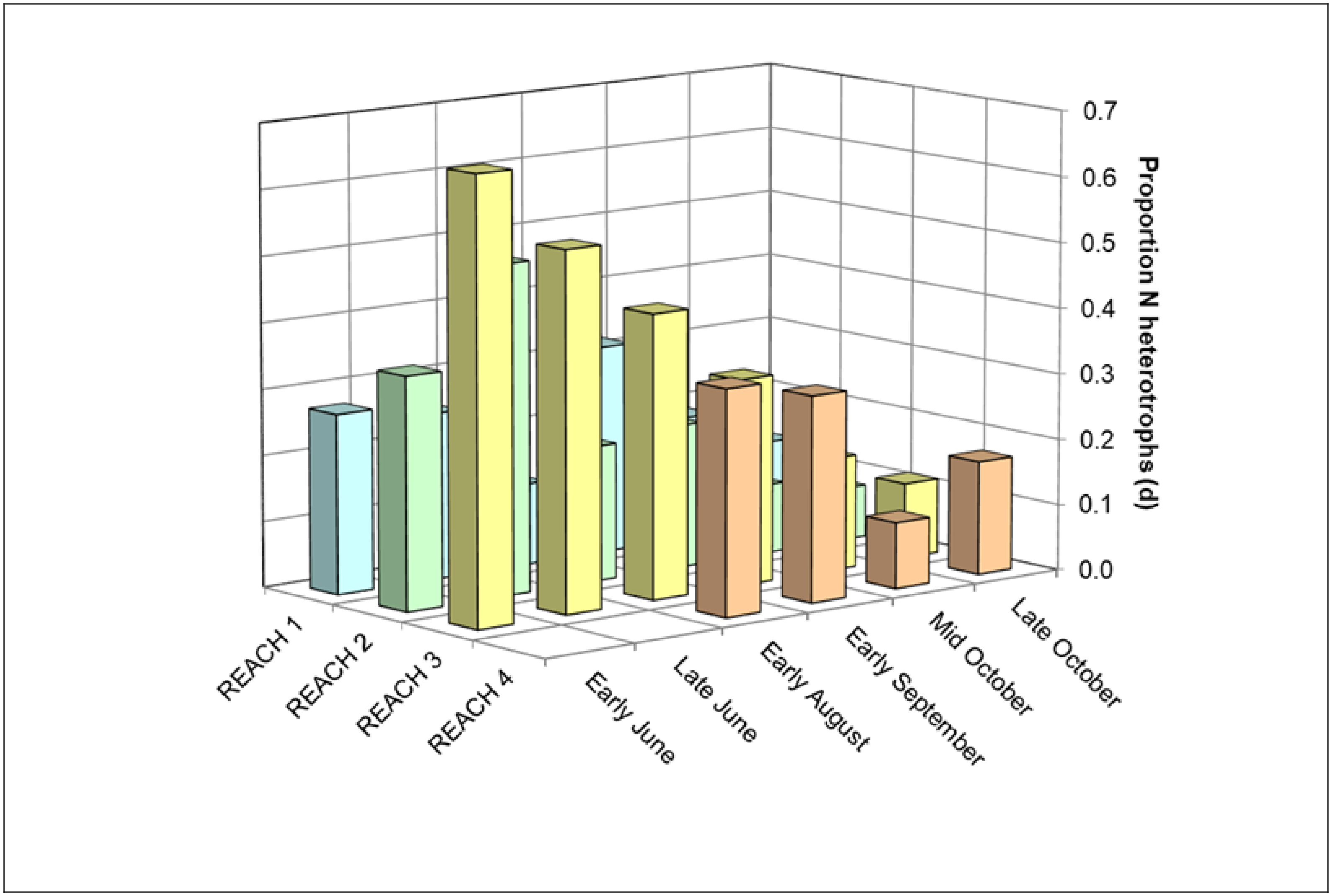


Figure 3.2-5b: Spatial and temporal variations in selected diatom community metrics gleaned from benthic sam-ples collected in RuR in 2011: proportion of diatom taxa that cannot use molecular nitrogen (non-N-fixers)

As mentioned above (Section 3.1-4), filamentous algae – both green algae and cyanobacteria species – are estimated by the volume of filament pieces, not by counting individual cells in each filament. **Figure 3.2-6** shows a stack-bar plot for the total biovolumes of soft algae-groups, which include green algae and cyanobacteria. Each bar represents one of the RuR 2011 samples. The percentage of total cyanobacterial biovolume (red bar) is shown in labels above each bar. *Please note that the reach order in this plot, from left to right, is from downstream to upstream.*

The plot shows that green algae (green bar), mostly Chlorophyta and Streptophyta, dominate in all reaches and sometimes obtain very high density (note that the maximal biovolume values in RuR are about 100 times higher than in SFEel). The seasonal bloom dynamics was similar in all four reaches, with low levels in early June which rise and peak early August. All reaches, except 2, had their second highest biovolumes in September. Green algae dominated the benthic community in all samples, and cyanobacteria biovolumes were negligible or considerably lower than green algae biovolumes. In other words, in the presence of abundant green algae – which proliferate when both nitrogen and phosphorus are readily available - cyanobacteria usually comprise a small fraction of the biomass.

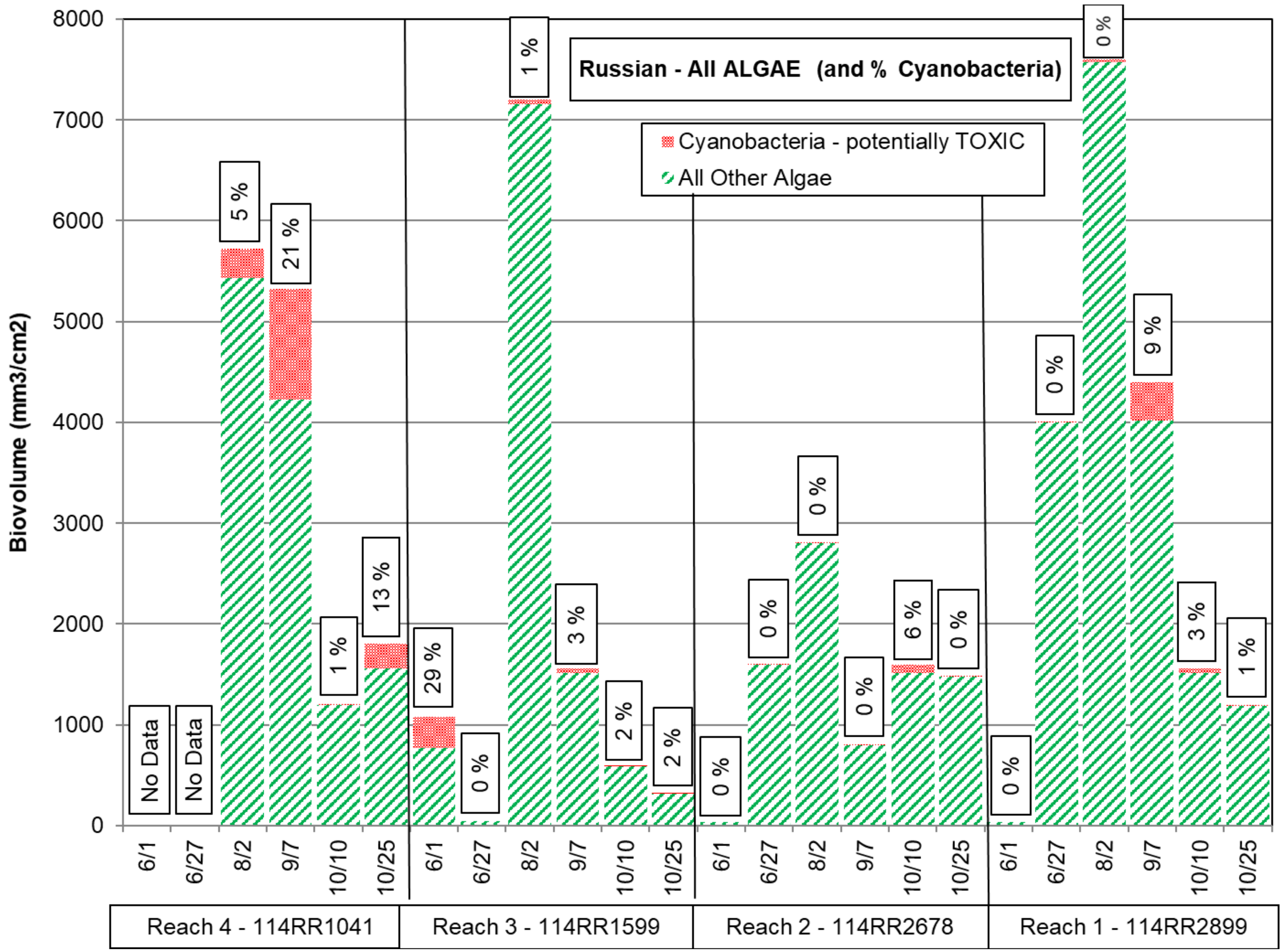


Figure 3.2-6: Biovolumes of algal taxa from various groups of soft algae collected in RuR in 2011

3.2.5 Taxonomic composition of cyanobacteria in RuR in 2011

Figure 3.2-7 shows the breakdown of cyanobacterial taxa into four categories based on their potential to produce cyanotoxins. The presence of taxa that can produce toxins was very sporadic in RuR in 2011. The highest percent of taxa that are known to produce cyanotoxins were found in Reaches 3 and 4, with one peak of toxic cyanobacteria (550 mm^3/cm^2) in Reach 4 in mid-summer. These data only indicate potential toxin; actual production and/or release of cyanotoxins were not tested in this study. The limited information about cyanobacterial communities gleaned from this pilot study was utilized in subsequent seasonal monitoring activities conducted by the North Coast Waterboard in recreational areas along the RuR. Since 2016, targeted monitoring has been conducted to identify potentially harmful cyanobacterial blooms and to post public health alerts as needed. Results from this pilot study also provided a basis for a number of subsequent studies of cyanobacterial toxins (See section 3.1.5 above).

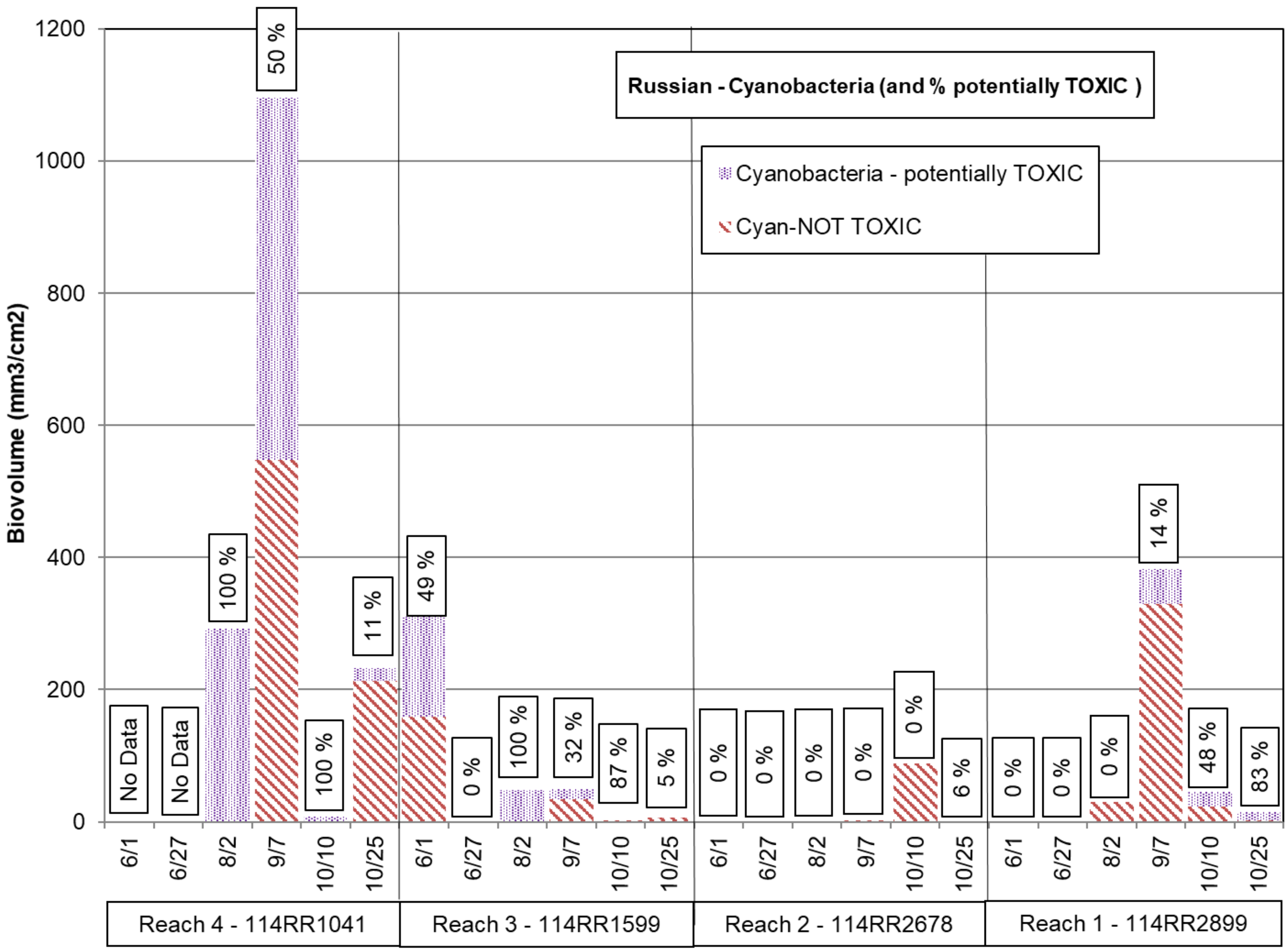


Figure 3.2-7: Biovolumes of cyanobacterial taxa groups collected in RuR in 2011, categorized by ability to produce cyanotoxins

3.3 Relationships and Comparisons

3.3.1 Relationships between indicators

Figure 3.3-1 shows the relationship between AFDM and Chl-a in SFEel and RuR. The distribution of points helps visualize how close they are to the trend line; the closer they are, the higher correlation between the two characteristics. The trend-lines indicate AFDM/Chl-a ratios that were similar to the Numeric Nutrient Endpoint (NNE) ratio (40 g/m^2 AFDM to 100 mg/m^2 Chl-a), which is often associated with a healthy algal mat. Points below the trend-line show samples that had more dead organic matter, as compared to samples that were dominated by live, chlorophyll-containing algae (represented by points above the line). Low correlations and variations in ratio are very common and are generally due to natural conditions (e.g., benthos species composition, scouring flow energies, allochthonous material from bank vegetation such as dead leaves, etc.) as well as to sampling and analysis histories (e.g., differential preservation, Chl-a loss from inside cells that still contribute AFDM, etc.). There was less scatter, i.e., less variability, in SFEel, probably reflecting the fact that SFEel sampling reaches had more uniform habitat than the reaches selected for RuR.

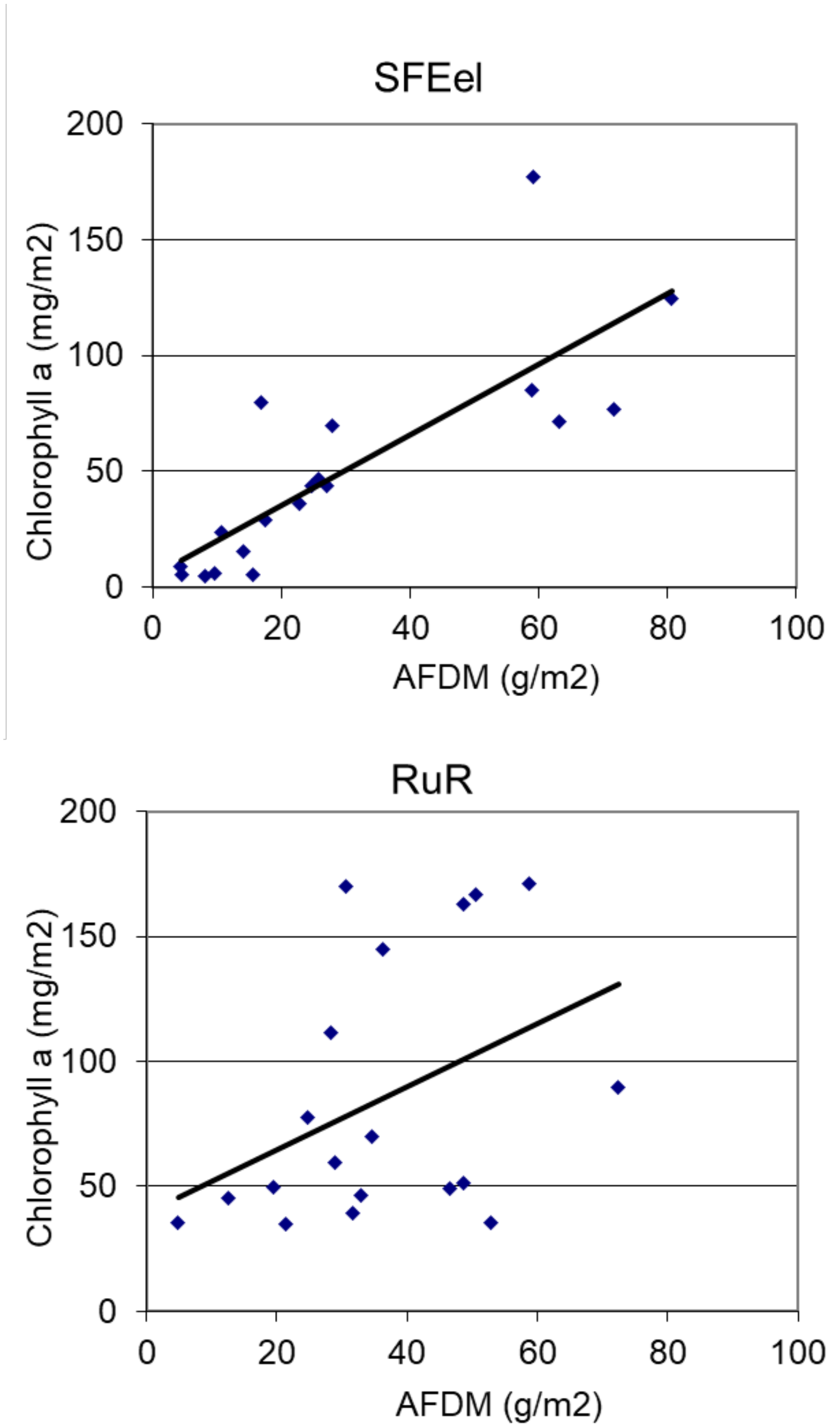


Figure 3.3-1: Relationships between AFDM and Chlorophyll *a* in the study reaches of the Algae and Nutrients Study. Top panel: SFEel. Bottom panel: RuR. (Linear trend-line added, and one outlier was removed from each plot)

Simple plots can also depict the relationship between specific conductance and concentrations of various minerals or salts. **Figure 3.3-2** presents the relationships between the specific conductance and the chloride, sulfate, and carbonate/bicarbonate anions in SFEel samples. Chloride and sulfate usually “drive” the conductivity in brackish water, but in these freshwater samples their concentrations are very low. The correlation is lower for chloride than for sulfate. Alkalinity represents the carbonate/bicarbonate system and provides information about the buffer capacity of freshwater samples. Water hardness reflects the concentration of divalent cations (such as calcium and magnesium) that leach from geologic features in the watershed. Figure 3.3-2 indicates that calcium-carbonate-type molecules “drive” the conductivity in SFEel.

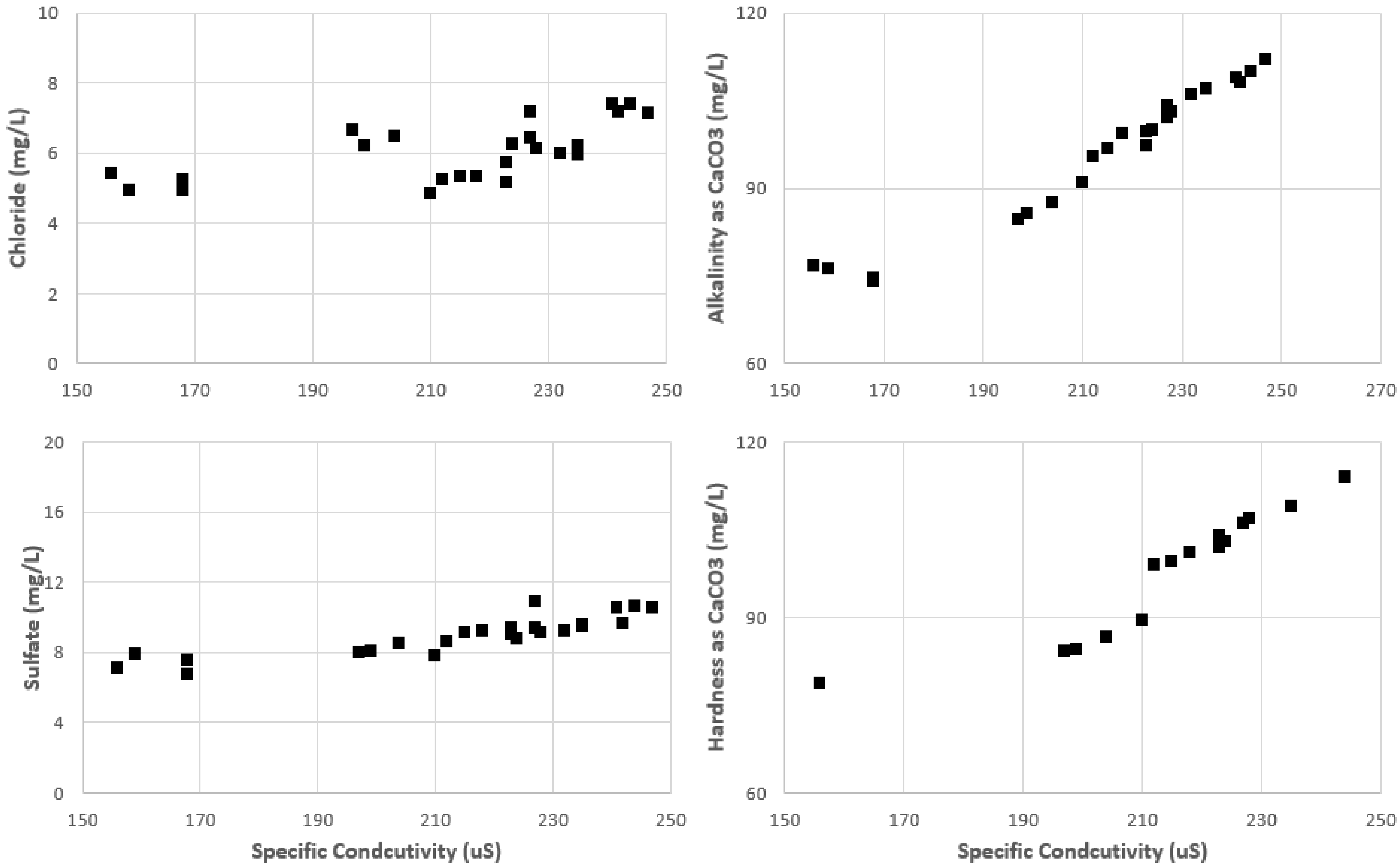


Figure 3.3-2: Relationships between specific conductance and selected minerals concentrations in SFEel samples

Figure 3.3-3 presents the RuR relationships between the specific conductance and the chloride, sulfate, and carbonate/bicarbonate anions. There does not appear to be a relationship with chloride or sulfate as the data are very scattered, probably due to the multiple sources of water flowing through the Study Area over the summer. As mentioned above (Chapter 2), RuR is periodically receiving water from Lake Sonoma, Lake Mendocino (which is augmented with water from the Eel River watershed), and the RuR tributaries that drain a variety of land uses. Results for alkalinity and hardness indicate that calcium-carbonate-type molecules “drive” the conductivity in RuR.

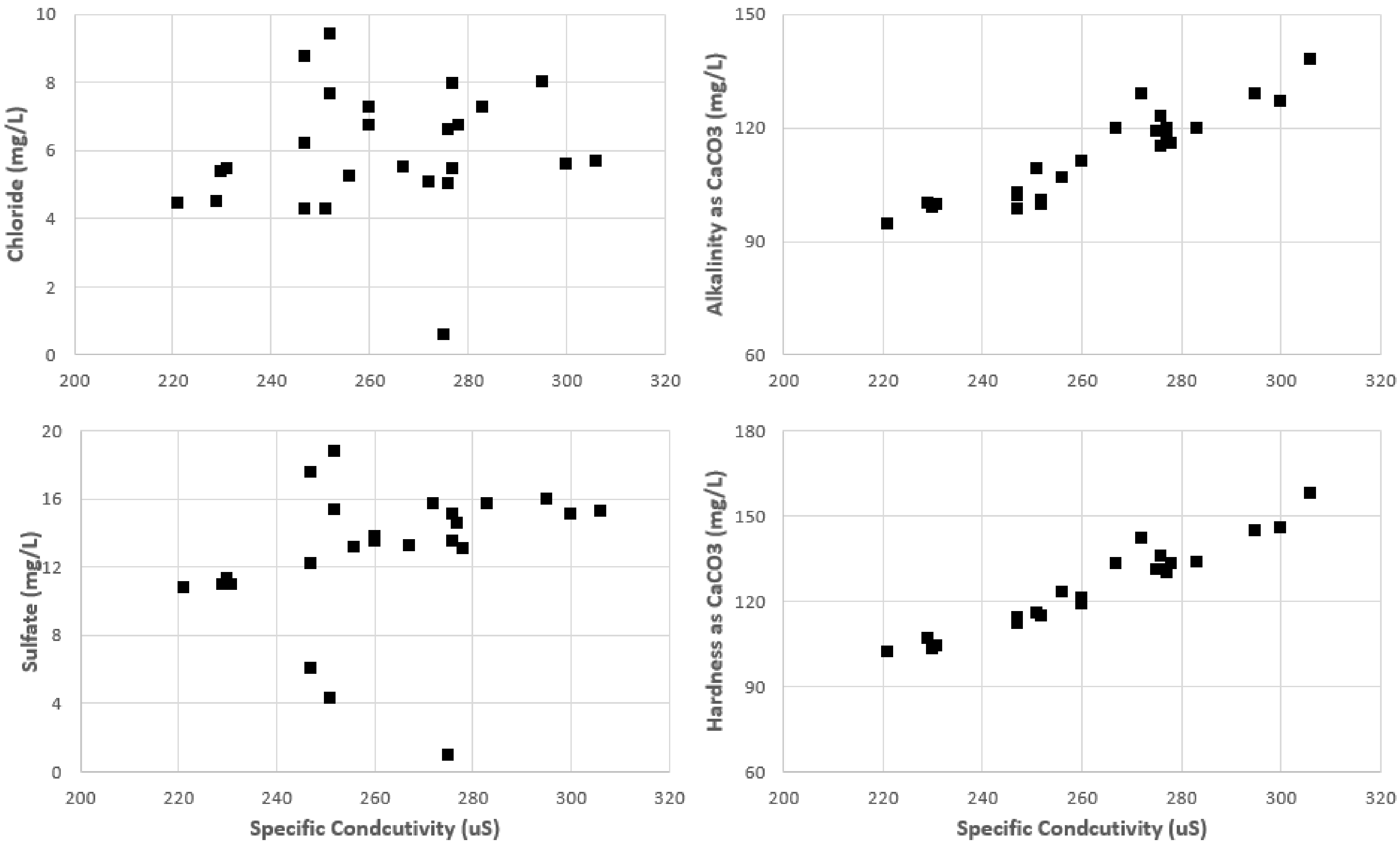


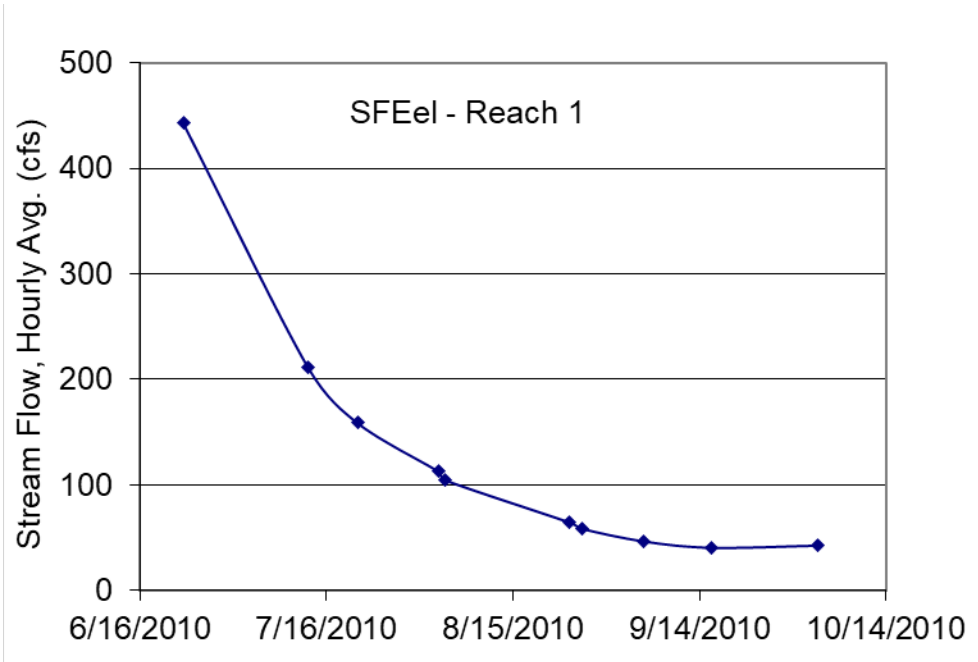
Figure 3.3-3: Relationships between specific conductance and selected minerals concentrations in RuR samples

3.3.2 Comparisons between study watersheds

The two Study Areas selected for the Algae and Nutrients Study reside in watersheds that differ from each other in many ways, including the following:

- drainage area upstream of study reaches (RuR is larger),
- streambed morphology and historic siltation (Mainstem RuR has not been filled with sediment so it flows in its original channel, while SFEel has been heavily silted from historic logging activities and is now flowing well above the original channel in a much wider streambed),
- existence of dams (two major reservoirs and several minor instream recreational dams in RuR),
- conditions of riparian corridors and input of solar radiation (SFEel has mostly intact corridor but has less shade due to channel siltation and stream widening),
- flow management practices (SFEel is free flowing, RuR is dominated by dam-releases), and
- land use activities that contribute nutrients (more widespread agricultural activities in RuR).

Figure 3.3-4 demonstrates the difference in stream flow between the SFEel and RuR Study Areas as plotted from late June to early October of each year. In SFEel, high spring flows start dissipating in June and drop to less than 50 cfs by the end of summer, while in RuR flow discharge is maintained over 120 cfs throughout the season, probably due do dam releases.



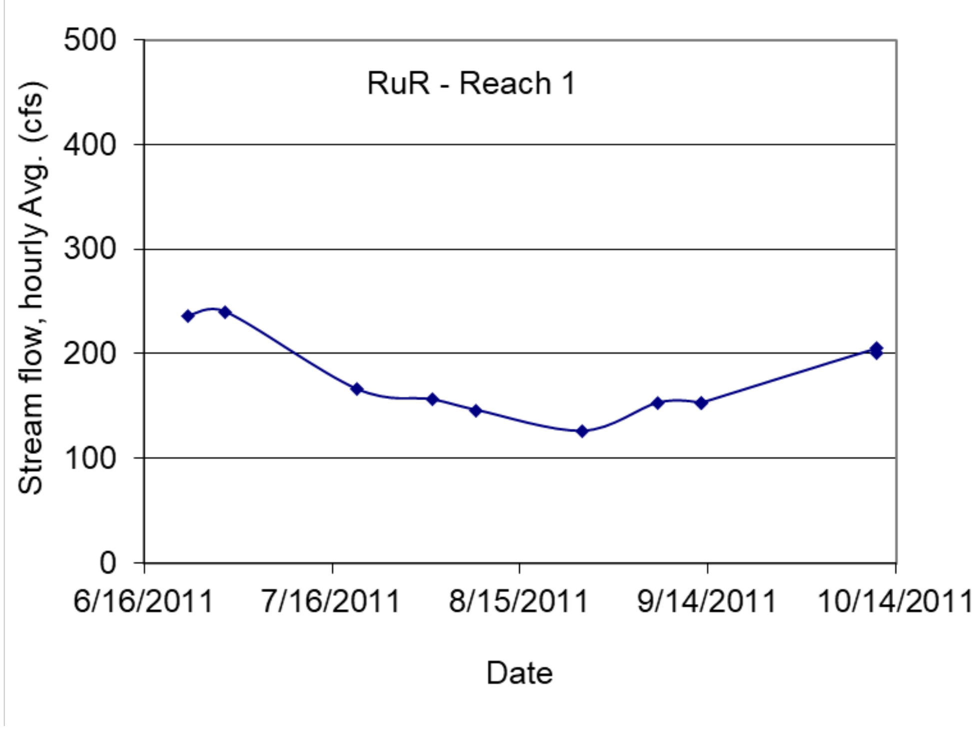
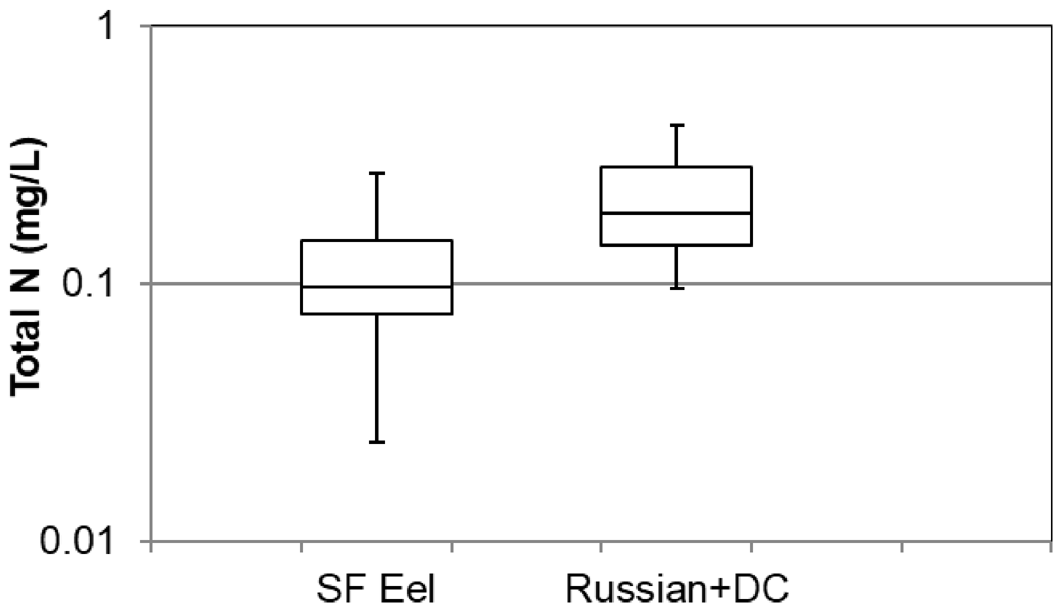


Figure 3.3-4: Stream Flow (hourly average at time of site visit) in SFEel and RuR over summer. Data source: USGS gages at Miranda and Healdsburg

Figure 3.3-5 shows box plots of nutrient concentrations in the Algae and Nutrients Study Areas. The SFEel dataset includes the 4 reaches plus the station upstream of the Study Area. RuR dataset includes 4 reaches on the Mainstem RuR plus the Tributary station located on Dry Creek. The box and whisker plots show that mainstem RuR samples had higher N and P concentrations than SFEel samples,

The biostimulatory effect of these nutrients was evident in both rivers. However, the biovolumes of benthic filamentous algae (“soft algae”) in the RuR samples were as high as 7500 mm^3/cm^2 (Figure 3.2-6 above), an order of magnitude higher than in SFEel samples (maximum of 70 and most samples below 30 mm^3/cm^2; Figure 3.1-6). This difference could be due to higher availability of nutrients in RuR, and/or to physical factors affecting the algal mats. Unfortunately, we do not have flow energy information, nor do we have any data about current velocity and scouring forces, but it could be that the substrate in SFEel reaches was under stronger shear forces than in RuR reaches (and the shear force limited mat thickness).



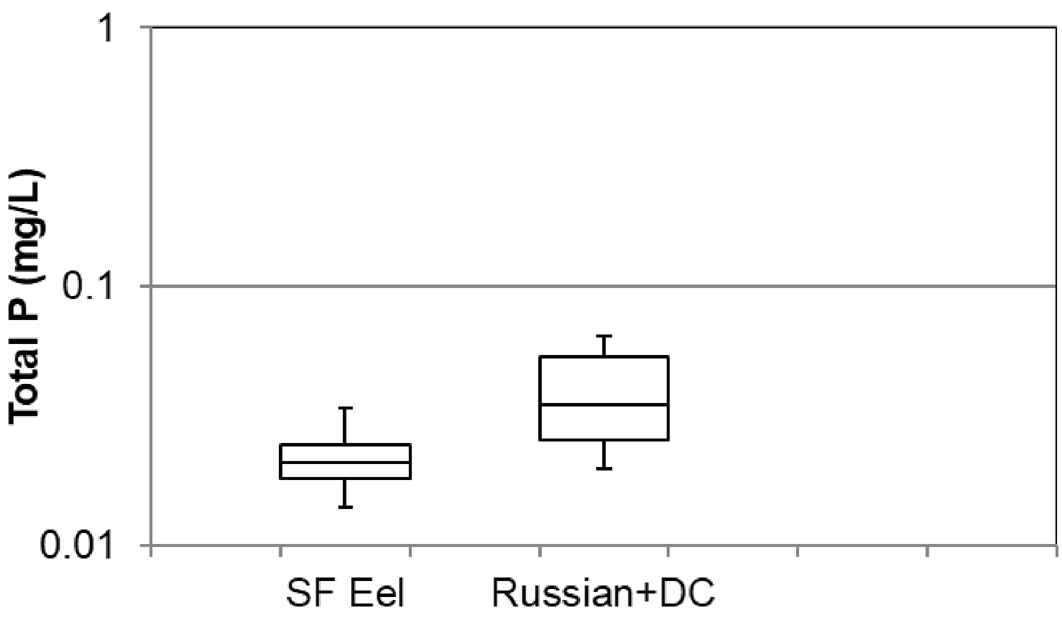


Figure 3.3-5: Nutrient concentrations in both the Algae and Nutrients Study Areas. SF Eel dataset includes the 4 reaches plus Reach 0 upstream. RuR dataset in-cludes 4 reaches on Mainstem Russian River plus Dry Creek

4 Discussion, Conclusions, and Recommendations

This report describes the results of a survey conducted in the South Fork Eel and Russian River that was spurred by reports of excessive algae, presence of cyanoHABs, and periodic dog deaths. This study was conducted as an initial survey to characterize the spatial and seasonal variations in benthic biomass and nutrients, to document evidence of biostimulatory conditions, and document the presence and distribution of potential toxin-producing cyanobacteria. The study results, intended to inform future work, have already resulted in Regional Water Board staff undertaking a study of cyanobacteria harmful algal blooms in the SFEel and RuR as well as in many other research projects (see compiled list in the Reference section 5.1). The results of this initial study provided the following conclusions and recommendations to inform subsequent studies.

4.1 Nutrient availability and the potential for biostimulatory conditions

Nitrogen and phosphorus were available in both Study Areas throughout the study period, often at concentrations exceeding water quality benchmarks. No spatial gradient in total nitrogen and total phosphorus was observed between sites within each river. Temporal gradients were observed in both rivers: in the RuR all locations showed a similar seasonal pattern of higher concentrations in the early summer and late fall, while in the SFEel total nitrogen levels peaked in the fall and total phosphorus levels peaked in the summer. The sources of these nutrients were not characterized as part of this study. Further investigation is needed to see if this seasonal pattern is consistent (by comparisons to other years).

Nutrient concentrations were compared to the USEPA's WQBs for wadeable freshwater streams located in Aggregated Nutrient Ecoregion II (SFEel) and Aggregated Nutrient Ecoregion III (RuR). Total nitrogen concentrations exceeded the WQB of 0.12 mg/L in 10 of 30 SFEel samples and exceeded the WQB of 0.38 mg/L in 1 of 43 RuR samples. Total phosphorous exceeded WQBs in 100% (30 of 30 samples) of samples in SFEel, and in 81% (35 of 43 samples) of the samples in RuR.

The consistent phosphorus exceedances in SFEel are due, in part, to the fact that the phosphorus benchmark for this ecoregion (EPA Aggregated Ecoregion II) is extremely low (0.01 mg/L), and is often surpassed under natural background conditions. The WQB used for comparison with RuR data is considerably higher (0.02 mg/L TP). Consequently, although RuR concentrations were somewhat higher than in SFEel, there were fewer exceedances of the WQB.

To assure that WQBs are realistic, appropriate, and protective of California waters, the EPA's Regional Technical Advisory Group (RTAG) and the State Regional Technical Advisory Group (STRTAG) recommended the development of alternate nutrient criteria (benchmarks), based on better understanding of the relationship between nutrients and impairing algal biomass.

The State Water Resources Control Board is in the process of developing a statewide water quality objective for biostimulatory substances and details can be found at the website Biostimulatory Substances Objective and Program to Implement Biological Integrity: (https://www.waterboards.ca.gov/water_issues/programs/biostimulatory_substances_biointegrity/)

The bioavailability of nutrients enhanced the biostimulation potential in both rivers. In the SFEel, algal mats developed profusely on streambeds, particularly in patches that are exposed to the sun where riparian vegetation did not provide shade. Mat development also appeared to be affected by water depth, substrate composition, and temperatures. Scouring events were not observed during the study period, and a buildup of benthic biomass was observed throughout the summer.

Biostimulatory conditions that can lead to enhanced growth of nuisance algae and/or aquatic plants were observed in both watersheds and were quite pronounced at times. However, multiple runs of the Benthic Biomass Spreadsheet Tool[6] did not yield any visible correlations related to nutrients and algal mass. The measured nitrogen and phosphorus concentrations cannot be correlated with measured benthic algal biomass because, whereas biomass is a cumulative property, we only have the instantaneous nutrient concentrations (though it seems as if nutrients were not limiting growth). In SFEel, algal biomass increased steadily over the summer, particularly in the upstream reach (Figure 3.1-1). RuR samples showed a Chl-a levels peak in mid to late-summer, however AFDM did not show any spatial or temporal pattern in biomass growth.

Algal biomass in the RuR was orders of magnitude higher than in the SFEel, indicating much greater proliferation of benthic mats. This difference may be attributed to higher nutrient levels, but also to physical factors and a much more stable growing environment due to the presence of dams which regulate flow.

The relationship between algal biomass and nutrient loads should be explored further. However, the dynamics of nutrient concentrations over time at the 24-hour level is unknown, and the available flow data are from stream gages that are very far from our study Reaches. Thus, it is not possible to calculate the real nutrient loads with the dataset of this study. The representativeness of nutrient concentrations in relation to diurnal cycles is further compromised due to the fact that station-visit times were directed to operations (not to the time of day); this increased variability may be significant if concentrations do follow a diurnal cycle.

It is recommended that further intensive studies be conducted to investigate the seasonal and spatial occurrence of biostimulatory conditions in the SFEel and RuR. These studies should consider all variables that influence biostimulation including flow, temperature/shade, channel depth/light availability, nutrients, as well as the risk factors for

[6] The tool is a Microsoft Excel spreadsheet, intended to be a simple but effective tool for predicting instream benthic algal density and other metrics in response to a number of inputs. The tool calculates algal density as ash free dry weight (g/m2) and benthic chlorophyll a.

harmful algal blooms (Pearl and Otten 2013).
The response variables should also be measured (e.g. diurnal pH and DO). The study should consider deploying ion-specific electrodes for selected nutrient species for continuous monitoring at sites with history of frequent algal blooms in conjunction with the deployment continuous flow-measurement devices at the same sites. The resulting data can be used to calculate nutrient loads and examine the question whether increased loads result in higher benthic biomass accumulation over time.

4.2 Cyanobacteria proliferation and the potential for toxic conditions

Cyanobacteria were observed sporadically in the benthic biomass, with variable distribution patterns. Benthic algal mats were dominated by filamentous green algae, mainly Chlorophyta (e.g., Cladophora) and Streptophyta, and by attached diatoms. Of the soft algae, cyanobacteria were present at much lower proportions than green algae in RuR, but comprised more than 50% of the biovolume in 9 of 20 SFEel samples. The seasonal bloom dynamics of the benthic algal communities differed between sites in the SFEel, but the peak growth was observed in the fall in all reaches. In the RuR, seasonal bloom dynamics were similar in all four reaches, with low levels in early June which rise and peak early August.

The presence of cyanobacterial taxa that can produce toxins (cyanotoxins) was rare in the Russian River and more frequent in the SFEel. However, cyanobacterial genera capable of producing cyanotoxins were present in very low biomass: the maximum biovolume of potential toxin-producing genera was only about 7 mm^3/cm^2 in the SFEel (Figure 3.1-7). In the RuR potential toxin-producing cyanobacteria peaked at 550 mm^3/cm^2 in Reach 4 in mid-summer, accompanied by over 4000 mm^3/cm^2 of green algae (Figure 3.2-6).

It is important to emphasize that the presence of these cyanobacterial genera only indicate the potential for cyanotoxin production; actual production and/or release of cyanotoxins was not tested in this study. Since the time this study was conducted, subsequent studies have been conducted in both watersheds to monitor the presence of toxic cyanobacterial species, conduct diagnostic DNA testing, and measure actual cyanotoxin concentrations. Additional studies attempted to understand the conditions that trigger toxin production and release to the water (Bouma-Gregson and Higgins 2015; Fetscher *et al* 2015; Anderson *et al* 2018; Howard and Fadness 2019; Kelly *et al* 2019; Conklin *et al* 2020; and other studies).

The Regional Water Board conducted a study during 2016-2019 to provide further information about the presence, distribution, and toxicity of cyanobacteria in the RuR and SFEel. Regional Water Board staff are currently working on synthesizing cyanobacteria and cyanotoxin and the final report will be available on our website once it’s completed.

4.3 Diatom communities: indicators

The presence of different species of diatoms can provide useful indicators of ecosystem conditions (Fetscher 2013). One species observed in both study areas, *Achnanthidium minutissimum*, is a cosmopolitan diatom associated with low nutrient and ionic content (Ponadera and Potapovab 2007). A. minutissima was found in relatively high proportions in SFEel – upstream and in early summer, and was also more prevalent upstream and in early summer in the RuR Study Area as well.

Nitrogen-heterotrophs

Some diatom taxa have the enzymatic mechanism to fix atmospheric nitrogen when nitrate concentrations are limiting their growth. Diatoms that are unable to do this are called nitrogen-heterotrophs, meaning they need it already fixed. Taxonomic analysis of diatom communities in both watersheds shows an increase in the relative abundance of nitrogen-fixing taxa over the summer (i.e., decrease in the proportion of nitrogen-hetero-trophs). This observation indicates that available nitrogen may be diminishing over the summer, giving an edge to taxa that can fix nitrogen from the atmosphere.

Motile diatoms

Motile diatoms flourish in areas prone to siltation (sediment deposition) and leaf litter accumulation, because they have the ability to constantly move up towards the light, photosynthesize, and grow. Non-motile taxa get buried in this environment and do not grow well. Our study did not show any spatial or seasonal patterns in the relative abundance of motile diatoms in either Study Area. The proportion of highly motile diatoms in RuR was generally higher (usually between 0.3 and 0.6) than in SFEel (in which the proportion was usually between 0.1 and 0.3; see Appendix F). The difference between study watersheds may echo the differences in flow energy and deposition patterns; RuR reaches generally had slower flow, deeper water column, and finer bed sediments. In such habitats the accumulation of sediment and leaf litter on the benthos is more likely, forcing the diatoms to constantly move to the top of the bed sediment and giving an edge to motile taxa.

4.4 Study design and sampling protocol

The two watersheds selected for this initial study provided useful information, some of which is likely relevant to the entire Region (for each of the ecoregion types studied). Although heavily silted, the South Fork Eel River is representative of free-flowing rivers in the north coast as far as hydrologic regime and riparian corridors are concerned. On the other hand, RuR is unique in its flow patterns and hydrologic regime, being augmented by reservoir releases to support anthropogenic activities. Apart from the basic 4 reaches /5 visits design, SFEel 2010 and RuR 2011 can be viewed as two independent studies carried out at different water years, different hydrologic regime, different channel characteristics (one Study Area wadeable, the other not). These differences limit the ability to make comparisons between watersheds.

The temporal study design that called for repeated visits during spring summer and fall yielded useful observations of seasonal gradients (e.g., mid-summer peak in phosphate mirrored by a dip in nitrate in SFEel). Tracking algal biomass through the growing season showed increase in some sites but not in others.

Based on the study's results it is recommended to design monitoring activities with visits at several intervals each season, i.e., obtain a time-course of change in the characteristics of interest.

The spatial study design of 4 reaches spaced (systematically) a few miles apart along the mainstem was selected to enable observations along a gradient. Variability happens at different scales for different characteristics, and spatial gradients were rarely observed. For example, Algal blooms in SFEel occurred in various reaches at different times, and the effects of tributaries and seasonal dams in RuR may have caused variable values along the Study Area. In other words, the spatial design at the scale we used did not show gradients.

For future studies, it is recommended to select fewer, but representative, monitoring locations using the directed sampling design principle (i.e., based on what we know and what we want to know). It is also highly recommended to mark each reach-origin, and each transect with a monument to assure that the same habitat units are sampled in each consecutive visit; this will reduce or eliminate spatial variability and give us a much clearer signal of seasonal changes.

The analytical suite for laboratory analysis, as well as the field measurements (instantaneous and time-series) was appropriate for the pilot study. It is recommended to have a more consistent set of nitrogen species: either total nitrogen (method QC 10107044B), or a combination of nitrate+nitrite (QC 10107041B) and Kjeldahl nitrogen (QC 10107062E). Because detections of ammonia (>0.01 mg/L) and Kjeldahl nitrogen (>0.1 mg/L) were very rare and very sporadic, the concentrations of reduced nitrogen may be negligible unless the sample is turbid with life.

Information collected in the field during station visits was often incomplete, particularly in RuR in 2011, and this lack of supporting documentation makes it harder to interpret the data.

As staff continue using the SWAMP SOP for the collection of benthic algae, more time needs to be allocated for each station-visit, ensuring time for more observations (e.g., water murkiness) and to collect physical habitat information at each transect-point (particle size group, algal mat cover, water depth) and transect plot (habitat type - pool, riffle, etc., maximum depth at transect, and canopy cover (with a densiometer).

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6 Appendices

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Appendix A: Inventory of monitoring activities performed in years 2010-2011

Table A-1: Inventory of site visits and monitoring activities in the South Fork Eel River study area, 2010

Reach Name	Station Name	Station	Total # of Station Visits	Conventional Water Quality	Nutrients	Water Column filtered biomass (Chl. a and AFDM)	Benthic Algae Samples	Visual observations	Sonde deployment period
REACH 0	SF Eel River at Redway	111SF2765	7	6	6	5		6	
(Redway)	Sonde Reach 0	111SF2683	6					6	June 23 - Oct 3
REACH 1	SF Eel River above Sylvandale	111SF2538	7	6	6	5	5	6	
(Sylvandale)	Sonde Reach 1	111SF2423	7					6	June 23 - Oct 3
REACH 2	SF Eel River below Phillipsville	111SF1944	7	6	6	5	5	6	
(Phillipsville)	Sonde Reach 2	111SF1819	6					6	June 24 - Oct 5
REACH 3	SF Eel River below Miranda	111SF1569	7	6	6	5	5	6	
(Miranda)	Sonde Reach 3	111SF1353	7					6	June 23 - Oct 4
REACH 4	SF Eel River above Myers Flat	111SF1016	5				5	4	
(Myers Flat)	SF Eel River below Myers Flat/Sonde Reach 4	111SF0875	11	6	6	5		10	June 24 - Oct 4

Site ID numerical order is from the river mouth to its headwaters, per convention. Reach order is from upstream stations to downstream stations.

Table A-2: Inventory of station visits and monitoring activities in the Russian River study area, 2011

Reach Name	Station Name	Station	Total # of Station Visits	Conventional Water Quality	Nutrients	Water Column filtered biomass (Chl. a and AFDM)	Benthic Algae Samples	Visual observations	Sonde deployment period
REACH 1	RuR at Healdsburg Memorial Beach	114RR2940	2	2	2	2		2	
(Healdsburg)	RuR below Healdsburg Memorial Beach	114RR2899	7	7	7	7	6	7	
	Sonde Reach 1 downstream of Healdsburg	114RR2861	9					9	Jun 7 - Nov 7
REACH 2	RuR above Syar Pond	114RR2769	1	1	1	1	1	1	
(Syar)	RuR at Syar Pond	114RR2678	7	7	7	7	5	7	
	Sonde Reach 2 downstream of Syar Ponds	114RR2599	10					10	Jun 7 - Oct 24
REACH 3	RuR at Odd Fellows Crossing	114RR1644	1	1	1	1		1	
(Korbel)	RuR near Korbel	114RR1599	7	6	6	6	6	7	
	Sonde Reach 3 downstream of Korbel	114RR1531	9					9	Jun 9 - Oct 10
Reach 4A*	RuR at Johnson's Beach	114RR1325	4	4	4	4		4	
(Johnson's)	RuR below Johnson's Beach	114RR1310	2	2	2	2	1	2	
Reach 4*	RuR at Vacation Beach	114RR1159	1	1	1	1		1	
(Vacation)	RuR below Vacation Beach/Sonde Reach 4	114RR1041	9	4	4	4	4	9	Aug 2 - Oct 25
Russian River Tributaries									
Dry Creek	Dry Creek above RuR confuence	114DC0037	14	8	8	8		14	Jun 23 - Oct 24

Site ID numerical order is from the river mouth to its headwaters, per convention. Reach order is from upstream stations to downstream stations.

* Summer dam installations in April and removal of the summer dams in October occurred at Johnsons Beach and Vacation Beach. Monitoring sites changed above, between and below the dams as the flow changed.

Appendix B: Nutrients and benthic algal biomass indicators

Table B-1a: Concentrations of nutrients and benthic algal biomass in the South Fork Eel River study area, 2010

Reach Name [Note 1]	StationCode	Sample Date	Sample Time	Ammonia as N; Dissolved; mg/L	Nitrite as N; Dissolved; mg/L	Nitrate as N; Dissolved; mg/L	Nitrogen, Total; Total; mg/L [Note 2]	OrthoPhosphate as P; Dissolved; mg/L	Phosphorus as P; Total; mg/L [Note 3]	AFDM_Algae; benthic (Particulate); g/m2	Chlorophyll *a*; benthic (Particulate); mg chl-a/m2 [Note 4]	Pheophytin *a*; benthic (Particulate); mg/m2
REACH 0	111SF2765	6/23/2010	10:15	ND	ND	ND	0.056	**0.014**	**0.013**			
(Redway)	111SF2765	7/14/2010	7:00	0.017	ND	0.036	**0.142**	**0.019**	**0.019**			
	111SF2765	8/3/2010	17:45	0.013	ND	0.009	ND	**0.026**	**0.023**			
	111SF2765	8/25/2010	19:35	ND	ND	0.024	0.076	**0.024**	**0.017**			
	111SF2765	9/15/2010	18:15	ND	ND	0.011	0.120	**0.023**	0.009			
	111SF2765	10/3/2010	17:15	ND	ND	0.016	**0.220**	**0.019**	**0.020**			
REACH 1	111SF2538	6/23/2010	13:00	ND	ND	ND	0.062	**0.014**	**0.014**			
(Sylvandale)	111SF2538	7/13/2010	12:10	0.017	ND	0.037	**0.139**	**0.019**	**0.020**			
	111SF2538	7/15/2010	11:00							9.7	6.3	1.8
	111SF2538	8/3/2010	10:00	0.013	ND	0.010	0.063	**0.029**	**0.021**	10.6	23.7	5.1
	111SF2538	8/24/2010	11:30	ND	0.002	0.037	0.077	**0.022**	**0.026**	25.8	46.6	8.9
	111SF2538	9/15/2010	11:30	ND	ND	0.022	0.108	**0.023**	0.008	59.2	**177.0**	26.9
	111SF2538	10/3/2010	13:00	ND	ND	0.022	**0.252**	**0.020**	**0.021**	139.3	84.6	76.9

Notes

1. Site order is from upstream stations to downstream stations, as the Field Crew moved.
2. Results highlighted in **Bold** indicate exceedance of EPA Nutrient Ecoregion II, for total nitrogen (0.12 mg/L)
3. Results highlighted in **Bold** indicate exceedance of EPA Nutrient Ecoregion II, for total phosphorus (0.01 mg/L)
4. Results highlighted in **Bold** indicate exceedance of Chlorophyll *a*

Table B-1b: Concentrations of nutrients and benthic algal biomass in the South Fork Eel River study area, 2010

Reach Name [Note 1]	StationCode	Sample Date	Sample Time	Ammonia as N; Dissolved; mg/L	Nitrite as N; Dissolved; mg/L	Nitrate as N; Dissolved; mg/L	Nitrogen, Total; Total; mg/L [Note 2]	OrthoPhosphate as P; Dissolved; mg/L	Phosphorus as P; Total; mg/L [Note 3]	AFDM_Algae; benthic (Particulate); g/m2	Chlorophyll *a* ; benthic (Particulate); mg chl-a/m2 [Note 4]	Pheophytin *a* ; benthic (Particulate); mg/m2
REACH 2 (Phillipsville	111SF1944	6/24/2010	9:00	ND	ND	ND	0.056	**0.015**	**0.017**			
	111SF1944	7/13/2010	15:00	0.017	ND	0.033	**0.146**	**0.017**	**0.017**			
	111SF1944	7/15/2010	16:00							4.5	5.4	1.6
	111SF1944	8/3/2010	14:00	0.011	ND	0.011	**0.157**	**0.030**	**0.022**	17.6	29.3	5.8
	111SF1944	8/24/2010	17:00	ND	ND	0.021	0.087	**0.023**	**0.019**	24.8	43.6	4.6
	111SF1944	9/15/2010	16:30	ND	ND	0.013	0.113	**0.025**	0.008	58.8	85.2	8.5
	111SF1944	10/5/2010	13:00	ND	ND	0.012	**0.223**	**0.022**	**0.021**	80.7	**124.5**	ND
REACH 3 (Miranda)	111SF1569	6/23/2010	18:40	ND	ND	ND	0.077	**0.015**	**0.018**			
	111SF1569	7/13/2010	18:00	0.015	ND	0.018	0.113	**0.017**	**0.016**			
	111SF1569	7/14/2010	13:00							4.4	8.8	2.2
	111SF1569	8/2/2010	13:30	0.012	ND	ND	0.091	**0.031**	**0.026**	27.0	43.6	16.1
	111SF1569	8/25/2010	11:45	ND	ND	0.024	ND	**0.025**	**0.018**	22.7	35.8	7.4
	111SF1569	9/14/2010	10:30	ND	ND	0.012	**0.163**	**0.019**	**0.014**	28.0	69.9	10.0
	111SF1569	10/4/2010	9:45	0.013	ND	0.015	**0.265**	**0.016**	**0.019**	71.6	77.0	62.3

Notes
1. Site order is from upstream stations to downstream stations, as the Field Crew moved.
2. Results highlighted in **Bold** indicate exceedance of EPA Nutrient Ecoregion II, for total nitrogen (0.12 mg/L)
3. Results highlighted in **Bold** indicate exceedance of EPA Nutrient Ecoregion II, for total phosphorus (0.01 mg/L)
4. Results highlighted in **Bold** indicate exceedance of Chlorophyll *a*

Table B-1c: Concentrations of nutrients and benthic algal biomass in the South Fork Eel River study area, 2010

Reach Name [Note 1]	StationCode	Sample Date	Sample Time	Ammonia as N; Dissolved; mg/L	Nitrite as N; Dissolved; mg/L	Nitrate as N; Dissolved; mg/L	Nitrogen, Total; Total; mg/L [Note 2]	OrthoPhosphate as P; Dissolved; mg/L	Phosphorus as P; Total; mg/L [Note 3]	AFDM_Algae; benthic (Particulate); g/m2	Chlorophyll *a* ; benthic (Particulate); mg chl-a/m2 [Note 4]	Pheophytin *a* ; benthic (Particulate); mg/m2
REACH 4	111SF0875	6/24/2010	12:30	ND	ND	ND	0.061	**0.015**	**0.017**			
(Myers Flat)	111SF0875	7/13/2010	20:00	0.016	ND	0.013	0.091	**0.018**	**0.014**			
	111SF1016*	7/14/2010	16:15							8.2	5.0	4.3
	111SF0875	8/2/2010	18:30	ND	ND	0.011	0.052	**0.031**	**0.034**			
	111SF1016*	8/2/2010	17:30							15.6	5.6	4.6
	111SF0875	8/25/2010	17:15	ND	ND	0.017	0.097	**0.025**	**0.022**			
	111SF1016*	8/25/2010	15:30							14.2	15.3	6.6
	111SF0875	9/14/2010	16:30	ND	ND	0.010	0.090	**0.019**	**0.021**			
	111SF1016*	9/14/2010	15:30							16.8	79.9	11.9
	111SF0875	10/4/2010	15:30	ND	ND	0.010	**0.222**	**0.016**	**0.020**			
	111SF1016*	10/4/2010	14:15							63.3	71.4	46.3

Notes
1. Site order is from upstream stations to downstream stations, as the Field Crew moved.
2. Results highlighted in **Bold** indicate exceedance of EPA Nutrient Ecoregion II, for total nitrogen (0.12 mg/L)
3. Results highlighted in **Bold** indicate exceedance of EPA Nutrient Ecoregion II, for total phosphorus (0.01 mg/L)
4. Results highlighted in **Bold** indicate exceedance of Chlorophyll *a*
* Field Crew collected benthic sample at a different location in Reach 4

Table B-2a: Concentrations of nutrients and benthic algal biomass in the Russian River study area, 2011

Reach Name [Note 1]	StationCode	Sample Date	Sample Time	Ammonia as N; Total; mg/L	Nitrate + Nitrite as N; Not Recorded; mg/L	Nitrite as N; Dissolved; mg/L	Nitrogen, Total; Total; mg/L [Note 2]	OrthoPhosphate as P; Dissolved; mg/L	Phosphorus as P; Total; mg/L [Note 3]	AFDM_Algae; benthic (Particulate); g/m2	Chlorophyll *a* ; benthic (Particulate); mg chl-a/m2 [Note 4]	Pheophytin *a* ; benthic (Particulate); mg/m2
REACH 1	114RR2940	4/11/2011	15:30	ND	0.394	0.007	**0.409**	**0.034**	0.018			
(Healdsburg)	114RR2899	6/1/2011	10:50	ND	0.249	ND	0.349	**0.023**	0.020	52.8	35.4	25.0
	114RR2899	6/29/2011	9:45	0.063	0.216	0.003	0.363	**0.031**	0.021	ND	ND	ND
	114RR2899	8/1/2011	9:30	ND	ND	ND	0.151	0.020	0.010	58.6	**171.0**	45.7
	114RR2899	9/6/2011	10:15	ND	0.008	ND	0.155	0.019	**0.035**			
	114RR2899	9/13/2011	10:00	ND	ND	ND	0.142	0.016	**0.026**	46.6	**239.9**	173.7
	114RR2899	10/11/2011	10:45	ND	ND	ND	0.096	**0.025**	0.021	48.6	**163.1**	48.9
	114RR2899	10/24/2011	9:30	ND	0.073	0.004	0.187	**0.059**	**0.063**	46.5	48.9	19.0
	114RR2940	11/29/2011	14:15	ND	0.147	0.003	0.278	**0.026**	**0.023**			
REACH 2	114RR2769	6/1/2011	13:45	ND	0.242	ND	0.324	**0.024**	0.022	12.5	45.4	8.3
(Syar)	114RR2678	6/29/2011	13:00	0.033	0.175	ND	0.311	**0.030**	0.021	ND	ND	ND
	114RR2678	8/1/2011	13:00	0.060	0.014	ND	0.139	0.021	0.012	34.6	69.9	37.9
	114RR2678	9/6/2011	12:15	ND	0.016	ND	0.200	0.021	**0.046**			
	114RR2678	9/13/2011	14:00	ND	0.014	ND	0.119	0.018	0.022	19.4	49.8	19.6
	114RR2678	10/11/2011	14:30	ND	0.030	0.003	0.117	**0.028**	0.020	36.3	**145.2**	43.6
	114RR2678	10/24/2011	12:30	ND	0.063	0.004	0.199	**0.052**	**0.060**	29.0	59.6	31.1
	114RR2678	11/29/2011	10:45	0.012	0.139	0.003	0.286	**0.023**	**0.024**			

Notes
1. Site order is from upstream stations to downstream stations, as the Field Crew moved.
2. Results highlighted in **Bold** indicate exceedance of EPA Nutrient Ecoregion III, for total nitrogen (0.38 mg/L)
3. Results highlighted in **Bold** indicate exceedance of EPA Nutrient Ecoregion III, for total phosphorus (0.02 mg/L)
4. Results highlighted in **Bold** indicate exceedance of Chlorophyll *a*

Table B-2b: Concentrations of nutrients and benthic algal biomass in the Russian River study area, 2011

Reach Name [Note 1]	StationCode	Sample Date	Sample Time	Ammonia as N; Total; mg/L	Nitrate + Nitrite as N; Not Recorded; mg/L	Nitrite as N; Dissolved; mg/L	Nitrogen, Total; Total; mg/L [Note 2]	OrthoPhosphate as P; Dissolved; mg/L	Phosphorus as P; Total; mg/L [Note 3]	AFDM_Algae; benthic (Particulate); g/m2	Chlorophyll *a* ; benthic (Particulate); mg chl-a/m2 [Note 4]	Pheophytin *a* ; benthic (Particulate); mg/m2
REACH 3 (Korbel)	114RR1599	6/2/2011	10:45	ND	0.207	ND	0.322	**0.050**	**0.053**	72.5	89.8	6.5
	114RR1599	6/27/2011	12:45	ND	0.145	0.004	0.298	**0.056**	**0.044**	2.3	ND	ND
	114RR1599	8/2/2011	10:30	ND	ND	ND	0.102	**0.037**	**0.037**	4.8	35.7	8.1
	114RR1599	9/7/2011	10:30	ND	ND	ND	0.140	**0.026**	**0.037**	21.4	35.1	15.9
	114RR1599	10/10/2011	11:30	0.015	0.050	0.003	0.176	**0.058**	**0.055**	28.4	**111.3**	32.9
	114RR1599	10/25/2011	10:30	0.012	0.046	0.003	0.186	**0.052**	**0.060**	31.6	39.5	17.6
	114RR1644	12/1/2011	13:15	ND	0.074	ND	0.216	**0.038**	**0.046**			

Notes

1. Site order is from upstream stations to downstream stations, as the Field Crew moved.
2. Results highlighted in **Bold** indicate exceedance of EPA Nutrient Ecoregion III, for total nitrogen (0.38 mg/L)
3. Results highlighted in **Bold** indicate exceedance of EPA Nutrient Ecoregion III, for total phosphorus (0.02 mg/L)
4. Results highlighted in **Bold** indicate exceedance of Chlorophyll *a*

Table B-2c: Concentrations of nutrients and benthic algal biomass in the Russian River study area, 2011

Reach Name [Note 1]	StationCode	Sample Date	Sample Time		Ammonia as N; Total; mg/L	Nitrate + Nitrite as N; Not Recorded; mg/L	Nitrite as N; Dissolved; mg/L	Nitrogen, Total; Total; mg/L [Note 2]	OrthoPhosphate as P; Dissolved; mg/L	Phosphorus as P; Total; mg/L [Note 3]	AFDM_Algae; benthic (Particulate); g/m2	Chlorophyll *a* ; benthic (Particulate); mg chl-a/m2 [Note 4]	Pheophytin *a* ; benthic (Particulate); mg/m2
Reach 4A*	114RR1325	4/11/2011	11:30		ND	0.255	0.005	0.292	**0.049**	**0.052**			
(Johnson's)	114RR1310	6/2/2011	13:15		ND	0.193	0.003	0.324	**0.052**	**0.056**	24.8	77.9	17.4
	114RR1310	6/27/2011	15:20		ND	0.127	0.004	0.298	**0.057**	**0.047**			
	114RR1325	10/12/2011	12:30		0.015	0.022	0.003	0.138	**0.064**	**0.062**			
	114RR1325	10/26/2011	12:30		ND	0.032	0.004	0.132	**0.049**	**0.054**			
	114RR1325	12/1/2011	11:30		ND	0.079	ND	0.226	**0.038**	**0.035**			
REACH 4*	114RR1041	8/2/2011	15:30		ND	ND	ND	0.125	**0.042**	**0.045**	48.7	51.4	25.9
(Vacation)	114RR1041	9/7/2011	13:30		ND	ND	ND	0.135	**0.035**	**0.035**	50.5	**166.9**	42.7
	114RR1041	10/10/2011	15:30		ND	0.080	0.003	0.175	**0.057**	**0.049**	30.7	**170.0**	71.3
	114RR1041	10/25/2011	13:30		ND	0.058	ND	0.181	**0.053**	**0.060**	32.8	46.6	31.0
	114RR1159	12/1/2011	10:45		ND	0.079	ND	0.229	**0.037**	**0.041**			

Notes

1. Site order is from upstream stations to downstream stations, as the Field Crew moved.
2. Results highlighted in **Bold** indicate exceedance of EPA Nutrient Ecoregion III, for total nitrogen (0.38 mg/L)
3. Results highlighted in **Bold** indicate exceedance of EPA Nutrient Ecoregion III, for total phosphorus (0.02 mg/L)
4. Results highlighted in **Bold** indicate exceedance of Chlorophyll *a*

* Summer dam installations in April and removal of the summer dams in October occurred at Johnsons Beach and Vacation Beach. Monitoring sites changed above, between and below the dams as the flow changed.

Table B-2d: Concentrations of nutrients and benthic algal biomass in the Russian River study area, 2011

Reach Name [Note 1]	StationCode	Sample Date	Sample Time		Ammonia as N; Total; mg/L	Nitrate + Nitrite as N; Not Recorded; mg/L	Nitrite as N; Dissolved; mg/L	Nitrogen, Total; Total; mg/L [Note 2]	OrthoPhosphate as P; Dissolved; mg/L	Phosphorus as P; Total; mg/L [Note 3]	AFDM_Algae; benthic (Particulate); g/m2	Chlorophyll *a* ; benthic (Particulate); mg chl-a/m2 [Note 4]	Pheophytin *a* ; benthic (Particulate); mg/m2
Russian River Tributaries													
Dry Creek	114DC0037	4/13/2011	12:45		ND	0.231	0.002	0.278	**0.029**	0.015			
	114DC0037	6/1/2011	12:50		ND	0.159	ND	0.248	**0.028**	**0.023**			
	114DC0037	6/29/2011	11:45		0.029	0.086	ND	0.270	**0.027**	0.018			
	114DC0037	8/1/2011	11:15		ND	0.013	ND	0.132	0.020	0.011			
	114DC0037	9/6/2011	11:30		ND	0.029	ND	0.131	**0.022**	**0.025**			
	114DC0037	10/11/2011	13:00		ND	0.077	0.003	0.142	**0.031**	**0.024**			
	114DC0037	10/24/2011	11:15		ND	0.078	0.003	0.173	**0.028**	**0.028**			
	114DC0037	11/29/2011	10:15		ND	0.096	0.003	0.235	0.021	0.017			

Notes
1. Site order is from upstream stations to downstream stations, as the Field Crew moved.
2. Results highlighted in **Bold** indicate exceedance of EPA Nutrient Ecoregion III, for total nitrogen (0.38 mg/L)
3. Results highlighted in **Bold** indicate exceedance of EPA Nutrient Ecoregion III, for total phosphorus (0.02 mg/L)
4. Results highlighted in **Bold** indicate exceedance of Chlorophyll *a*

Appendix C: Conventional water quality characteristics

Table C-1a: Concentrations of conventional Water Quality characteristics in the SFEel River study area, 2010

Reach Name	StationCode	Sample Date	Sample Time	Alkalinity as CaCO3; Dissolved; mg/L	Hardness as CaCO3; Dissolved; mg/L	Chloride; Dissolved; mg/L	Total Dissolved Solids; Dissolved; mg/L	Silica as SiO2; Dissolved; mg/L	Sulfate; Dissolved; mg/L	Total Organic Carbon; (TOC) Total; mg/L	Dissolved Organic Carbon; (DOC) Dissolved;
REACH 0	111SF2765	6/23/2010	10:15	74.1		4.92	93	12.9	6.74	1.02	R
(Redway)	111SF2765	7/14/2010	7:00	84.7	84.2	6.64	115	13.7	7.97	1.14	1.44
	111SF2765	7/15/2010	17:00								
	111SF2765	8/3/2010	17:45	95.3	99	5.25	118	16.4	8.63	0.92	1.07
	111SF2765	8/25/2010	19:35	100	103	6.27	131	14	8.75	0.81	0.93
	111SF2765	9/15/2010	18:15	104		6.43	157	13.2	9.36	0.91	0.86
	111SF2765	10/3/2010	17:15	108		7.16	240	13.4	9.65	**12.6**	0.75
REACH 1	111SF2538	6/23/2010	13:00	74.6		5.25	89	12.4	7.52	0.91	R
(Sylvandale)	111SF2538	7/13/2010	12:10	85.8	84.6	6.21	115	13.5	8.05	1.17	0.96
	111SF2538	7/15/2010	11:00								
	111SF2538	8/3/2010	10:00	96.8	99.5	5.32	117	15.7	9.1	0.72	0.85
	111SF2538	8/24/2010	11:30	97.4	102	5.73	135	14.6	9.37	0.91	1.43
	111SF2538	9/15/2010	11:30	106		6	121	13.1	9.23	0.91	0.73
	111SF2538	10/3/2010	13:00	109		7.4	245	13.4	10.5	0.59	0.74
REACH 2	111SF1944	6/24/2010	9:00	76.7	78.7	5.44	94	12.1	7.13	0.75	R
(Phillipsville)	111SF1944	7/13/2010	15:00	87.6	86.7	6.48	123	13.5	8.49	1.13	1.13
	111SF1944	7/15/2010	16:00								
	111SF1944	8/3/2010	14:00	99.3	101	5.33	116	16	9.22	1.09	0.8
	111SF1944	8/24/2010	17:00	103	107	6.14	148	14.5	9.14	0.79	1.22
	111SF1944	9/15/2010	16:30	102	106	7.16	138	12.8	10.9	0.68	0.6
	111SF1944	10/5/2010	13:00	110	114	7.39	129	12.5	10.6	1.12	1.33

Site order is from upstream stations to downstream stations.
R = data rejected

Table C-1b: Concentrations of conventional Water Quality characteristics in the SFEel River study area, 2010

Reach Name	StationCode	Sample Date	Sample Time	Alkalinity as CaCO3; Dissolved; mg/L	Hardness as CaCO3; Dissolved; mg/L	Chloride; Dissolved; mg/L	Total Dissolved Solids; Dissolved; mg/L	Silica as SiO2; Dissolved; mg/L	Sulfate; Dissolved; mg/L	Total Organic Carbon; (TOC) Total; mg/L	Dissolved Organic Carbon; (DOC) Dissolved;
REACH 3	111SF1569	6/23/2010	18:40	76.3		4.94	82	12.4	7.88	1.13	R
(Miranda)	111SF1569	7/13/2010	18:00	90.9	89.6	4.87	123	13.4	7.84	1.09	1.05
	111SF1569	7/14/2010	13:00								
	111SF1569	8/2/2010	13:30	99.6	104	5.14	126	16.2	9.01	1.23	1.95
	111SF1569	8/25/2010	11:45	107	109	6.2	147	14.9	9.44	0.9	1.1
	111SF1569	9/14/2010	10:30	107		5.95	110	13.3	9.58	1.92	1.22
	111SF1569	10/4/2010	9:45	112		7.15	200	13.1	10.5	0.66	0.89
REACH 4	111SF0875	6/24/2010	12:30	78.9		4.99	113	12.7	7.89	0.76	R
(Myers Flat)	111SF0875	7/13/2010	20:00	92.2	90.9	5.12	120	13.2	9.1	1.22	0.95
	111SF0875	7/14/2010	17:00								
	111SF0875	8/2/2010	18:30	104	105	5.24	125	16.4	9.27	1	1.07
	111SF0875	8/25/2010	17:15	107	113	6.07	131	15.1	9.54	0.98	0.91
	111SF0875	9/14/2010	16:30	113		6.23	147	13.7	10.4	1.42	1.21
	111SF0875	10/4/2010	15:30	116		6.61	80	14.2	10.3	3.45	0.83

Site order is from upstream stations to downstream stations.
R = data rejected

Table C-2a: Concentrations of conventional Water Quality characteristics in the Russian River study area, 2011

Reach Name	StationCode	Sample Date	Sample Time	Alkalinity as CaCO3; Dissolved; mg/L	Hardness as CaCO3; Total; mg/L	Chloride; Dissolved; mg/L	Total Dissolved Solids; Dissolved; mg/L	Silica as SiO2; Dissolved; mg/L	Sulfate; Dissolved; mg/L	Total Organic Carbon; Total; mg/L	Dissolved Organic Carbon; Dissolved; mg/L
REACH 1	114RR2940	4/11/2011	15:30	128	148	6.61	166		19.0	1.60	
(Healdsburg)	114RR2899	6/1/2011	10:50	129	142	5.05	168	15.5	15.7	2.06	1.74
	114RR2899	6/29/2011	9:45	138	158	5.69	169	17.3	15.3	3.78	2.05
	114RR2899	8/1/2011	9:30	127	146	5.59	167	14.7	15.1	2.16	2.58
	114RR2899	9/6/2011	10:15	120	130	5.46	149	15.1	14.6	1.93	1.64
	114RR2899	9/13/2011	10:00	119	131	0.58	153	15.1	**1.0**	1.61	1.65
	114RR2899	10/11/2011	10:45	118	131	7.99	147	13.1	20.2	2.19	2.00
	114RR2899	10/24/2011	9:30	100	107	4.52	127	13.4	11.0	1.55	1.54
	114RR2940	11/29/2011	14:15	111		5.62	156	13.4	13.6	1.82	1.80
REACH 2	114RR2769	6/1/2011	13:45	123	136	5.04	120	15.2	15.1	1.85	1.70
(Syar)	114RR2678	6/29/2011	13:00	120	133	5.53	150	16.6	13.3	4.77	1.81
	114RR2678	8/1/2011	13:00	107	123	5.25	145	15.2	13.2	**14.40**	2.20
	114RR2678	9/6/2011	12:15	111	121	7.28	138	1.47	13.8	1.69	1.65
	114RR2678	9/13/2011	14:00	102	112	4.27	138	16	**6.0**	1.95	1.58
	114RR2678	10/11/2011	14:30	103	114	8.77	128	14.4	17.6	2.09	1.84
	114RR2678	10/24/2011	12:30	94.5	102	4.47	128	13	10.8	1.44	1.58
	114RR2678	11/29/2011	10:45	98.5		6.2	144	14.3	12.2	1.82	1.64

Site order is from upstream stations to downstream stations.

Table C-2b: Concentrations of conventional Water Quality characteristics in the Russian River study area, 2011

Reach Name	StationCode	Sample Date	Sample Time	Alkalinity as CaCO3; Dissolved; mg/L	Hardness as CaCO3; Total; mg/L	Chloride; Dissolved; mg/L	Total Dissolved Solids; Dissolved; mg/L	Silica as SiO2; Dissolved; mg/L	Sulfate; Dissolved; mg/L	Total Organic Carbon; Total; mg/L	Dissolved Organic Carbon; Dissolved; mg/L
REACH 3 (Korbel)	114RR1599	6/2/2011	10:45	120	134	7.28	158	18.3	15.7	2.28	2.65
	114RR1599	6/27/2011	12:45	129	145	8.03	121	17.7	16.0	2.30	2.70
	114RR1599	8/2/2011	10:30	115	131	6.62	162	16.2	13.5	2.08	2.16
	114RR1599	9/7/2011	10:30	109	116	4.29	133	15.8	**4.3**	1.43	1.38
	114RR1599	10/10/2011	11:30	101	115	9.41	133	14.6	18.8	2.74	2.93
	114RR1599	10/25/2011	10:30	99.1	103	5.37	113	13.8	11.3	1.68	1.53
	114RR1644	12/1/2011	13:15	103		7.13	146	16.3	12.0	2.60	2.74
Reach 4A* (Johnson's Beach)	114RR1325	4/11/2011	11:30	110	127	6.49	153		13.8	2.73	
	114RR1310	6/2/2011	13:15	124	135	7.5	170	18.3	15.1	2.65	2.49
	114RR1310	6/27/2011	15:20	130	145	8.1	174	18.3	16.1	2.11	2.07
	114RR1325	10/12/2011	12:30	105	118	10.6	142	15	18.3	2.89	3.13
	114RR1325	10/26/2011	12:30	99.7	103	6.36	112	13.7	10.8		1.42
	114RR1325	12/1/2011	11:30	105		7.41	144	15.7	12.1	2.52	2.55
REACH 4* (Vacation)	114RR1041	8/2/2011	15:30	116	133	6.74	168	16.7	13.1		2.23
	114RR1041	9/7/2011	13:30	111	119	6.72	138	17.5	13.5	1.61	1.42
	114RR1041	10/10/2011	15:30	99.7	115	7.65	121	14.7	15.4	2.87	2.81
	114RR1041	10/25/2011	13:30	99.6	104	5.46	115	14.1	11.0	1.67	1.60
	114RR1159	12/1/2011	10:45	105		7.44	144	15.7	12.1	2.70	3.09

Site order is from upstream stations to downstream stations.

* Summer dam installations in April and removal of the summer dams in October occurred at Johnsons Beach and Vacation Beach. Monitoring sites changed above, between and below the dams as the flow changed.

Table C-2c: Concentrations of conventional Water Quality characteristics in the Russian River study area, 2011

Reach Name	StationCode	Sample Date	Sample Time	Alkalinity as CaCO3; Dissolved; mg/L	Hardness as CaCO3; Total; mg/L	Chloride; Dissolved; mg/L	Total Dissolved Solids; Dissolved; mg/L	Silica as SiO2; Dissolved; mg/L	Sulfate; Dissolved; mg/L	Total Organic Carbon; Total; mg/L	Dissolved Organic Carbon; Dissolved; mg/L
Russian River Tributaries											
Dry Creek	114DC0037	4/13/2011	12:45	80.8	92.8	4.87	121		13.8	2.06	
	114DC0037	6/1/2011	12:50	81.5	88	5.35	113	18.2	12.5	2.58	1.9
	114DC0037	6/29/2011	11:45	75.4	81.8	4.39	113	17.3	9.04	2.15	2.33
	114DC0037	8/1/2011	11:15	67.7	74.4	3.87	100	14.8	8.92	2.17	2.54
	114DC0037	9/6/2011	11:30	68.8	73.6	14	108	16.8	9.34	1.28	1.27
	114DC0037	10/11/2011	13:00	64.9	71.8	5.65	90	14.2	11.4	2.4	2.46
	114DC0037	10/24/2011	11:15	65.8	71.7	3.83	98	16.2	8.4	1.69	1.6
	114DC0037	11/29/2011	10:15	64.1		6.64	104	16.2	8.15	2.04	1.92

Site order is from upstream stations to downstream stations.

Appendix D: Visual observations and field measurements

Table D-1a: Visual observations and field measurements recorded during visits to South Fork Eel sites in 2010

Reach Name	Station	Date	Time	Estimated Wetted Width (m)	USGS Flow (Note 1)	Estimated Flow (cfs)	Dissolved Oxygen (mg/L)	pH	Spec. Cond. (uS/cm)	Temp. (Deg C)
REACH 0 (Redway)	111SF2683	6/23/2010	10:15	20	448	>200	10.07	8.13	169	17.9
	111SF2765	6/23/2010	10:15	20	448	>200	9.93	8.27	168	17.3
	111SF2765	7/14/2010	7:00	30	209	50-200	7.88	7.97	197	20.9
	111SF2683	7/21/2010	13:00	25	159	50-200	8.97	8.35	203	23.2
	111SF2765	8/3/2010	17:45	25	111	50-200	10.41	8.51	212	25.8
	111SF2683	8/4/2010	16:00	35	107	50-200	10.62	8.37	214	25.0
	111SF2765	8/25/2010	19:35	35	61	NR	9.13	8.39	224	25.6
	111SF2683	8/26/2010	10:30	**8**	59	20-50	9.31	8.27	225	22.3
	111SF2765	9/15/2010	18:15	30	41	20-50	10.68	8.66	227	22.2
	111SF2683	9/16/2010	13:45	25	43	20-50	10.68	8.12	230	21.9
	111SF2683	10/3/2010	11:30	35	44	20-50	9.1	8.16	242	19.1
	111SF2765	10/3/2010	17:15	25	41	20-50	10.29	8.34	242	20.7
REACH 1 (Sylvandale)	111SF2423	6/23/2010	13:00	20	443	>200	10.02	8.48	169	19.6
	111SF2538	6/23/2010	13:00	40	443	>200	10.29	8.49	168	19.1
	111SF2538	7/13/2010	12:10	35	212	50-200	9.19	8.33	199	23.4
	111SF2423	7/21/2010	15:30	18	159	50-200	8.49	8.53	200	24.3
	111SF2538	8/3/2010	10:00	15	113	50-200	10.31	8.09	215	21.1
	111SF2423	8/4/2010	18:30	20	105	50-200	10.19	8.45	215	24.8
	111SF2538	8/24/2010	11:30	20	65	50-200	11.34	8.3	223	22.5
	111SF2423	8/26/2010	12:45	18	59	50-200	11.54	8.7	223	23.4
	111SF2538	9/5/2010	11:30	35	47	20-50	11.68	8.48	232	19.6
	111SF2423	9/16/2010	16:15	20	41	5-20	14.56	9.01	222	23.1
	111SF2538	10/3/2010	13:00	40	43	20-50	12.62	8.62	241	20.1
	111SF2423	10/3/2010	15:35	25	43	20-50	13.42	8.68	238	21.0

NR = Not Recorded; Spec. Cond. = Specific conductance; Temp. = Temperature
The water was colorless and clear on all visits. Measured turbidity did not exceed 2.2 NTU during all visits.
Site and water were odorless on all visits.
There was no precipitation on visit days or during the antecedent 24-hour periods.

Table D-1b: Visual observations and field measurements recorded during visits to South Fork Eel sites in 2010

Reach Name	Station	Date	Time	Estimated Wetted Width (m)	USGS Flow (Note 1)	Estimated Flow (cfs)	Dissolved Oxygen (mg/L)	pH	Spec. Cond. (uS/cm)	Temp. (Deg C)
REACH 2	111SF1944	6/24/2010	9:00	50	425	>200	9.38	8.24	156	18.0
(Phillipsville)	111SF1819	6/24/2010	9:00	20	425	>200	9.52	8.26	157	18.0
	111SF1944	7/13/2010	15:00	50	212	50-200	8.9	8.35	204	25.7
	111SF1819	7/21/2010	9:45	14	159	50-200	9.19	8.28	209	21.1
	111SF1944	8/3/2010	14:00	30	111	50-200	10.57	8.32	218	23.8
	111SF1819	8/5/2010	11:00	20	107	50-200	10.26	8.13	220	21.1
	111SF1944	8/24/2010	17:00	12	64	50-200	10.71	8.35	228	24.9
	111SF1819	8/26/2010	17:45	20	59	50-200	10.51	8.64	228	25.9
	111SF1944	9/15/2010	16:00	20	41	20-50	10.65	8.52	227	23.1
	111SF1819	9/16/2010	11:30	25	43	20-50	10.2	8.04	237	20.4
	111SF1944	10/5/2010	13:00	18	41	20-50	10.28	8.38	244	19.4
	111SF1819	10/5/2010	14:40	25	40	20-50	11.94	8.31	248	18.0
REACH 3	111SF1569	6/23/2010	18:40	35	443	>200	9.97	8.53	159	21.0
(Miranda)	111SF1353	6/23/2010	18:40		443	>200	9.42	8.41	180	20.6
	111SF1569	7/13/2010	18:00	40	212	50-200	8.79	8.36	210	25.6
	111SF1353	7/20/2010	13:00	35	164	50-200	8.91	8.31	219	24.0
	111SF1569	8/2/2010	13:30	35	115	50-200	10.37	8.38	223	24.6
	111SF1353	8/4/2010	13:00	25	109	50-200	10.78	7.9	228	22.3
	111SF1569	8/25/2010	11:45	65	62	50-200	9.82	8.15	235	23.9
	111SF1353	8/26/2010	15:40	25	58	50-200	9.81	8.44	237	24.3
	111SF1569	9/14/2010	10:30	65	43	20-50	9.62	8.33	235	21.5
	111SF1353	9/16/2010	8:45	25	43	20-50	9.6	7.73	240	19.7
	111SF1569	10/4/2010	9:45	65	43	20-50	9.63	8.07	247	17.1
	111SF1353	10/4/2010	11:40	25	41	20-50	10.43	7.93	257	17.1

NR = Not Recorded; Spec. Cond. = Specific conductance; Temp. = Temperature

The water was colorless and clear on all visits. Measured turbidity did not exceed 2.2 NTU during all visits.

Site and water were odorless on all visits.

There was no precipitation on visit days or during the antecedent 24-hour periods.

Note 1: USGS data from Gage # 11476500 at MIRANDA are reported as hourly average at the time of the site visit

Table D-1c: Visual observations and field measurements recorded during visits to South Fork Eel sites in 2010

Reach Name	Station	Date	Time	Estimated Wetted Width (m)	USGS Flow (Note 1)	Estimated Flow (cfs)	Dissolved Oxygen (mg/L)	pH	Spec. Cond. (uS/cm)	Temp. (Deg C)
REACH 4	111SF0875	6/24/2010	12:30	30	420	>200	9.39	8.09	173	19.4
(Myers Flat)	111SF0875	7/13/2010	20:00	20	212	50-200	8.53	8.2	212	25.1
	111SF0875	7/20/2010	16:50	16	164	50-200	8.93	8.14	220	23.6
	111SF1016	8/2/2010	17:30		113	50-200	10.4	8.05	229	24.1
	111SF0875	8/2/2010	18:30	35	113	50-200	9.68	8	230	23.5
	111SF0875	8/4/2010	10:00	35	109	50-200	9.63	8	230	21.0
	111SF1016	8/25/2010	15:30	30	62	50-200	10.4	7.92	241	25.5
	111SF0875	8/25/2010	17:15	50	62	NR	10.77	8.25	241	26.3
	111SF0875	8/27/2010	11:10	35	56	50-200	9.72	8.16	242	21.3
	111SF0875	9/13/2010	16:30	25	43	20-50	10.79	8.26	244	21.6
	111SF1016	9/14/2010	15:30	80	41	20-50	10.56	8.22	244	21.9
	111SF0875	9/14/2010	16:30	30	41	20-50	12.21	8.3	245	22.1
	111SF1016	10/4/2010	14:15	15	43	20-50	10.69	8.18	254	18.3
	111SF0875	10/4/2010	15:30	35	41	20-50	12	8.2	253	19.2

NR = Not Recorded; Spec. Cond. = Specific conductance; Temp. = Temperature
The water was colorless and clear on all visits. Measured turbidity did not exceed 2.2 NTU during all visits.
Site and water were odorless on all visits.
There was no precipitation on visit days or during the antecedent 24-hour periods.

Table D-2a: Visual observations and field measurements recorded during visits to Russian River sites in 2011

Reach Name	Station	Date	Time	Estimated Wetted Width (m)	USGS Flow (Note 1)	USGS Gauge (Note 2)	Estimated Flow (cfs)	Dissolved Oxygen (mg/L)	pH	Spec. Cond. (uS/cm)	Temp. (Deg C)
REACH 1	114RR2940	4/11/2011	15:30	80	1210	1	>200	9.7	7.9	284	14.7
(Healdsburg)	114RR2899	6/1/2011	10:50	25	408	1	>200	9.9	8.0	272	16.1
	114RR2861	6/7/2011	10:45	30	719	1	>200	9.3	7.9	265	15.5
	114RR2861	6/23/2011	11:45	25	236	1	>200	8.2	8.0	322	23.5
	114RR2899	6/29/2011	9:45	12	240	1	>200	8.3	8.0	306	19.5
	114RR2861	7/20/2011	9:00	25	166	1	50-200	8.1	8.0	307	24.0
	114RR2899	8/1/2011	9:30	5	156	1	50-200	7.4	8.2	300	22.8
	114RR2861	8/8/2011	10:20	25	146	1	>200	8.9	7.7	304	22.7
	114RR2861	8/25/2011	10:50	20	126	1	50-200	8.4	8.2	290	24.0
	114RR2899	9/6/2011	10:15	10	153	1	50-200	7.5	8.0	277	21.9
	114RR2899	9/13/2011	10:00	6	153	1	50-200	8.5	8.0	275	20.8
	114RR2861	9/13/2011	10:30	20	153	1	50-200	10.3	7.9	282	21.6
	114RR2899	10/11/2011	10:45	12	205	1	>200	10.0	8.0	277	18.5
	114RR2861	10/11/2011	11:15	25	201	1	>200	10.8	8.0	281	18.9
	114RR2899	10/24/2011	9:30	20	453	1	>200	9.5	7.9	229	16.9
	114RR2861	10/24/2011	10:30	25	453	1	>200	9.8	8.0	232	17.0
	114RR2940	11/29/2011	14:15	100	297	1	>200	12.9	8.4	266	13.3

NR = Not Recorded; Spec. Cond. = Specific conductance; Temp. = Temperature

Rain or drizzle were noted on 3 of the visit days (on 6/1/2011; 6/29/2011, and 10/10/2011)

Note 1 USGS data - hourly average cfs at the time of the site visit

Note 2 USGS gages 1 = Healdsburg Gage; 2 = Healdsburg Gage and Dry Creek gage; 3 = Guerneville Gage; 4 = Dry Creek Gage

Table D-2b: Visual observations and field measurements recorded during visits to Russian River sites in 2011

Reach Name	Station	Date	Time	Estimated Wetted Width (m)	USGS Flow (Note 1)	USGS Gauge (Note 2)	Estimated Flow (cfs)	Dissolved Oxygen (mg/L)	pH	Spec. Cond. (uS/cm)	Temp. (Deg C)
REACH 2	114RR2769	6/1/2011	13:45	20	568	2	>200	9.8	7.9	276	16.2
(Syar)	114RR2599	6/7/2011	12:15	30	861	2	>200	9.6	7.9	256	16.0
	114RR2599	6/23/2011	15:00	25	335	2	50-200	10.0	8.1	238	23.4
	114RR2678	6/29/2011	13:00	50	350	2	>200	9.1	7.9	267	18.2
	114RR2599	7/20/2011	13:00	30	259	2	50-200	9.5	8.1	262	22.9
	114RR2599	7/28/2011	10:20	30	237	2	>200	8.4	8.0	253	20.5
	114RR2678	8/1/2011	13:00	40	245	2	50-200	8.5	8.0	256	20.3
	114RR2599	8/8/2011	13:45	30	228	2	>200	10.7	7.9	255	21.5
	114RR2599	8/25/2011	14:00	25	203	2	50-200	9.2	8.1	249	22.9
	114RR2678	9/6/2011	12:15	65	231	2	50-200	8.4	8.0	260	20.7
	114RR2678	9/13/2011	14:00	40	238	2	50-200	9.9	8.0	247	20.4
	114RR2599	9/13/2011	14:30	35	237	2	50-200	10.2	8.1	248	21.4
	114RR2599	9/26/2011	13:20	30	258	2	50-200	10.0	8.0	236	19.0
	114RR2678	10/11/2011	14:30	45	300	2	>200	11.1	8.1	247	18.6
	114RR2599	10/11/2011	15:00	25	296	2	>200	11.0	8.1	248	18.9
	114RR2678	10/24/2011	12:30	60	548	2	>200	10.3	7.8	221	17.0
	114RR2599	10/24/2011	13:15	30	548	2	>200	10.5	8.0	221	17.2
	114RR2678	11/29/2011	10:45	60	418	2	>200	11.5	8.0	247	11.9

NR = Not Recorded; Spec. Cond. = Specific conductance; Temp. = Temperature

Rain or drizzle were noted on 3 of the visit days (on 6/1/2011; 6/29/2011, and 10/10/2011)

Note 1 USGS data - hourly average cfs at the time of the site visit

Note 2 USGS gages 1 = Healdsburg Gage; 2 = Healdsburg Gage and Dry Creek gage; 3 = Guerneville Gage; 4 = Dry Creek Gage

Table D-2c: Visual observations and field measurements recorded during visits to Russian River sites in 2011

Reach Name	Station	Date	Time		Estimated Wetted Width (m)	USGS Flow (Note 1)	USGS Gauge (Note 2)	Estimated Flow (cfs)	Dissolved Oxygen (mg/L)	pH	Spec. Cond. (uS/cm)	Temp. (Deg C)
REACH 3	114RR1599	6/2/2011	10:45		50	619	3	>200	9.6	7.8	283	15.7
(Korbel)	114RR1531	6/9/2011	10:30		75	797	3	>200	8.1	7.8	272	18.1
	114RR1599	6/27/2011	12:45		45	309	3	>200	8.4	8.0	295	21.6
	114RR1599	6/30/2011	11:15		45	366	3	>200	8.2	7.8	281	19.5
	114RR1531	6/30/2011	12:55		60	368	3	>200	8.4	7.8	281	19.9
	114RR1531	7/19/2011	11:30		65	201	3	>200	8.2	7.9	283	21.8
	114RR1599	8/2/2011	10:30		40	169	3	50-200	8.2	8.0	276	21.3
	114RR1531	8/9/2011	11:00		60	136	3	50-200	8.7	7.7	278	21.8
	114RR1531	8/18/2011	11:45		40	123	3	50-200	8.0	7.9	274	23.9
	114RR1531	9/1/2011	11:00		65	123	3	50-200	7.6	7.8	262	20.9
	114RR1599	9/7/2011	10:30		25	149	3	50-200	7.5	7.9	251	20.1
	114RR1531	9/15/2011	12:30		60	136	3	50-200	8.3	8.0	253	20.6
	114RR1531	9/27/2011	11:45		60	141	3	50-200	10.5	7.9	248	19.5
	114RR1599	10/10/2011	11:30		50	258	3	>200	9.0	7.7	252	16.9
	114RR1599	10/25/2011	10:30		50	484	3	>200	9.6	7.7	230	16.8
	114RR1644	12/1/2011	13:15		45	400	3	>200	12.0	8.0	257	10.9

NR = Not Recorded; Spec. Cond. = Specific conductance; Temp. = Temperature

Rain or drizzle were noted on 3 of the visit days (on 6/1/2011; 6/29/2011, and 10/10/2011)

Note 1 USGS data - hourly average cfs at the time of the site visit

Note 2 USGS gages 1 = Healdsburg Gage; 2 = Healdsburg Gage and Dry Creek gage; 3 = Guerneville Gage; 4 = Dry Creek Gage

Table D-2d: Visual observations and field measurements recorded during visits to Russian River sites in 2011

Reach Name	Station	Date	Time		Estimated Wetted Width (m)	USGS Flow (Note 1)	USGS Gauge (Note 2)	Estimated Flow (cfs)	Dissolved Oxygen (mg/L)	pH	Spec. Cond. (uS/cm)	Temp. (Deg C)
Reach 4A*	114RR1325	4/11/2011	11:30		60	2590	3	>200	9.7	7.7	251	13.0
(Johnson's)	114RR1310	6/2/2011	13:15		55	616	3	>200	10.2	7.9	285	16.6
	114RR1310	6/27/2011	15:20		50	274	3	>200	8.4	8.0	299	23.3
	114RR1325	10/12/2011	12:30		30	278	3	>200	10.6	8.0	261	19.0
	114RR1325	10/26/2011	12:30		40	495	3	>200	10.5	8.0	234	16.0
	114RR1325	12/1/2011	11:30		45	402	3	>200	11.6	8.0	259	10.9
Reach 4*	114RR1041	8/2/2011	15:30		20	169	3	50-200	9.6	8.1	278	23.8
(Vacation)	114RR1041	8/9/2011	14:50		18	121	3	50-200	10.3	8.0	279	24.6
	114RR1041	8/18/2011	15:15		20	121	3	50-200	10.4	8.2	277	25.2
	114RR1041	9/1/2011	13:15		25	121	3	50-200	9.0	7.7	266	23.3
	114RR1041	9/7/2011	13:30		15	147	3	50-200	8.7	7.9	260	23.4
	114RR1041	9/15/2011	15:15		10	134	3	50-200	9.8	8.0	252	22.4
	114RR1041	9/27/2011	15:10		25	139	3	50-200	10.4	7.9	250	21.4
	114RR1041	10/10/2011	15:30		15	256	3	>200	11.6	8.0	252	17.7
	114RR1041	10/25/2011	13:30		30	484	3	>200	10.5	8.1	231	16.6
	114RR1159	12/1/2011	10:45		30	402	3	>200	11.6	8.1	259	11.0

NR = Not Recorded; Spec. Cond. = Specific conductance; Temp. = Temperature

Rain or drizzle were noted on 3 of the visit days (on 6/1/2011; 6/29/2011, and 10/10/2011)

Note 1 USGS data - hourly average cfs at the time of the site visit

Note 2 USGS gages 1 = Healdsburg Gage; 2 = Healdsburg Gage and Dry Creek gage; 3 = Guerneville Gage; 4 = Dry Creek Gage

* Summer dam installations in April and removal of the summer dams in October occurred at Johnsons Beach and Vacation Beach. Monitoring sites changed above, between and below the dams as the flow changed.

Table D-2e: Visual observations and field measurements recorded during visits to Russian River sites in 2011

Reach Name	Station	Date	Time		Estimated Wetted Width (m)	USGS Flow (Note 1)	USGS Gauge (Note 2)	Estimated Flow (cfs)	Dissolved Oxygen (mg/L)	pH	Spec. Cond. (uS/cm)	Temp. (Deg C)
Russian River Tributaries												
Dry Creek	114DC0037	4/13/2011	12:45		30	592	4	>200	10.0	7.6	346	12.5
	114DC0037	6/1/2011	12:50		10	154	4	20-50	10.7	7.6	194	12.9
	114DC0037	6/23/2011	13:15		25	97	4	>200	10.8	8.1	177	16.7
	114DC0037	6/29/2011	11:45		6	106	4	50-200	9.5	7.7	177	14.4
	114DC0037	7/20/2011	11:00		20	94	4	50-200	9.8	7.6	171	16.2
	114DC0037	8/1/2011	11:15		5	91	4	50-200	9.1	7.8	169	15.2
	114DC0037	8/8/2011	11:30		20	91	4	50-200	11.9	7.9	168	16.3
	114DC0037	8/25/2011	12:00		20	77	4	50-200	9.9	8.0	168	17.1
	114DC0037	9/6/2011	11:30		8	77	4	50-200	9.4	7.8	197	15.2
	114DC0037	9/13/2011	12:00		12	88	4	50-200	11.1	7.9	186	15.8
	114DC0037	9/26/2011	11:05		9	91	4	20-50	10.2	7.7	166	14.5
	114DC0037	10/11/2011	13:00		8	95	4	50-200	11.0	7.7	174	14.8
	114DC0037	10/24/2011	11:15		7	95	4	50-200	10.8	7.8	164	13.0
	114DC0037	11/29/2011	10:15		7	124	4	50-200	11.0	7.7	178	11.1

NR = Not Recorded; Spec. Cond. = Specific conductance; Temp. = Temperature

Rain or drizzle were noted on 3 of the visit days (on 6/1/2011; 6/29/2011, and 10/10/2011)

Note 1 USGS data - hourly average cfs at the time of the site visit

Note 2 USGS gages 1 = Healdsburg Gage; 2 = Healdsburg Gage and Dry Creek gage; 3 = Guerneville Gage; 4 = Dry Creek Gage

Appendix E: Inventory of sonde deployments, associated data quality and time-series (continuous) monitoring bi-weekly data

Table E-1a: Inventory of sonde deployments and associated data quality in the South Fork Eel River study area, 2010

Reach name	Station ID	Visit date	Deployment Period	Sonde ID	Actions (Note 1)	SC (uS/cm) MQO ±5%	pH 7.0 MQO ±0.3	pH 10.0 MQO ±0.3	DO (mg/L) MQO ±0.5
						INSTRUMENT DRIFT (Notes 2,3)			
REACH 0 (Redway)	111SF2638	06/23/10	06/23/10-07/21/10	02B0212AB	CalAdjust, Deploy	*n/a*	*n/a*	*n/a*	*n/a*
		07/21/10	07/21/10-08/04/10	02B0212AB	Check, CalAdjust	0.42	0.15	0.09	**0.51**
		08/04/10	08/04/10-08/26/10	02B0212AB	Check, CalAdjust	-0.50	0.07	0.05	0.29
		08/26/10	08/26/10-09/16/10	02B0212AB	Check, CalAdjust	-0.92	0.00	0.04	-0.39
		09/16/10	09/16/10-10/03/10	02B0212AB	Check, CalAdjust	0.50	0.01	0.00	0.33
		10/03/10	n/a	02B0212AB	Retrieve, Check	-0.78	0.10	0.16	-0.35
REACH 1 (Sylvandale)	111SF2423	06/23/10	06/23/10-07/21/10	08D100634	CalAdjust, Deploy	*n/a*	*n/a*	*n/a*	*n/a*
		07/21/10	n/a	08D100634	Retrieve, Check	0.07	0.17	0.13	0.40
		07/21/10	07/21/10-08/04/10	02A1256AC	CalAdjust, Deploy	*n/a*	*n/a*	*n/a*	*n/a*
		08/04/10	08/04/10-08/26/10	02A1256AC	Check, CalAdjust	0.85	0.13	0.06	**0.60**
		08/26/10	08/26/10-09/16/10	02A1256AC	Check, CalAdjust	0.85	0.03	0.03	0.05
		09/16/10	09/16/10-09/22/10	02A1256AC	Check, CalAdjust	**PF**	0.16	0.10	0.27
		09/22/10	n/a	02A1256AC	Retrieve, Check	**PF**	0.02	-0.02	0.27
		09/22/10	09/22/10-10/04/10	01F0960AA	CalAdjust, Deploy	*n/a*	*n/a*	*n/a*	*n/a*
		10/04/10	n/a	01F0960AA	Retrieve, Check	0.50	0.24	0.22	0.10
REACH 2 (Phillipsville)	111SF1819	06/24/10	06/24/10-07/21/10	08D100635	CalAdjust, Deploy	*n/a*	*n/a*	*n/a*	*n/a*
		07/21/10	07/21/10-08/05/10	08D100635	Check, CalAdjust	-2.41	0.22	0.09	0.37
		08/05/10	08/05/10-08/26/10	08D100635	Check, CalAdjust	1.13	0.18	0.15	0.06
		08/26/10	08/26/10-09/16/10	08D100635	Check, CalAdjust	-1.77	0.25	0.14	-0.20
		09/16/10	09/16/10-10/05/10	08D100635	Check, CalAdjust	0.57	0.26	0.22	0.37
		10/05/10	n/a	08D100635	Retrieve, Check	1.63	**0.40**	**0.42**	-0.20

Abbreviations: SC-Specific Conductance. DO-Dissolved Oxygen. MQO-Measurement Quality Objective. n/a-not applicable
PF-Probe Failure. NR-Not Recorded.

Note1. Activity types: Check = Accuracy check; CalAdj = Calibration Adjustment

Note2. Drift values highlighted in red font exceeded Measurement Quality Objectives (MQOs)

Note3. Drift of Temperature sensors was checked once a year against an NIST thermometer; MQO of ±0.5°C never exceeded.

Table E-1b: Inventory of sonde deployments and associated data quality in the South Fork Eel River study area, 2010

Reach name	Station ID	Visit date	Deployment Period	Sonde ID	Actions (Note 1)	SC (uS/cm) MQO ±5%	pH 7.0 MQO ±0.3	pH 10.0 MQO ±0.3	DO (mg/L) MQO ±0.5
						INSTRUMENT DRIFT (Notes 2,3)			
REACH 3 (Miranda)	111SF1353	06/23/10	06/23/10-07/20/10	02A1256AC	CalAdjust, Deploy	*n/a*	*n/a*	*n/a*	*n/a*
		07/20/10	n/a	02A1256AC	Retrieve, Check	-2.12	**0.47**	0.16	**PF**
		07/20/10	07/20/10-08/04/10	01F0960AC	CalAdjust, Deploy	*n/a*	*n/a*	*n/a*	*n/a*
		08/04/10	08/04/10-08/26/10	01F0960AC	Check, CalAdjust	0.00	0.00	0.00	0.00
		08/26/10	08/26/10-09/16/10	01F0960AC	Check, CalAdjust	-0.50	0.07	0.04	-0.08
		09/17/10	09/16/10-10/04/10	01F0960AC	Check, CalAdjust	0.00	0.03	0.07	0.13
		10/04/10	n/a	01F0960AC	Retrieve, Check	-0.35	0.07	0.07	-0.22
REACH 4 (Myers Flat)	111SF0875	06/24/10	06/24/10-07/20/10	02A1256AA	CalAdjust, Deploy	*n/a*	*n/a*	*n/a*	*n/a*
		07/20/10	07/20/10-08/04/10	02A1256AA	Check, CalAdjust	-2.12	0.18	0.12	0.26
		08/04/10	08/04/10-08/27/10	02A1256AA	Check, CalAdjust	-0.64	0.03	0.06	0.29
		08/27/10	08/27/10-09/13/10	02A1256AA	Check, CalAdjust	0.14	0.05	0.03	0.01
		09/13/10	09/13/10-10/03/10	02A1256AA	Check, CalAdjust	-0.42	0.00	0.03	0.12
		10/03/10	n/a	02A1256AA	Retrieve, Check	2.41	0.09	0.09	-0.06

Abbreviations: SC-Specific Conductance. DO-Dissolved Oxygen. MQO-Measurement Quality Objective. n/a-not applicable
PF-Probe Failure. NR-Not Recorded.

Note1. Activity types: Check = Accuracy check; CalAdj = Calibration Adjustment

Note2. Drift values highlighted in red font exceeded Measurement Quality Objectives (MQOs)

Note3. Drift of Temperature sensors was checked once a year against an NIST thermometer; MQO of ±0.5^{o}C never exceeded.

Table E-2a: Inventory of sonde deployments and associated data quality in the Russian River study area, 2011

Reach name	**Station ID**	**Visit date**	**Deployment Period**	**Sonde ID**	**Actions** (Note 1)	**SC (uS/cm)** MQO ±5%	**pH 7.0** MQO ±0.3	**pH 10.0** MQO ±0.3	**DO (mg/L)** MQO ±0.5
						INSTRUMENT DRIFT (Notes 2,3)			
REACH 1 (Healdsburg)	114RR2861	06/07/11	06/07/11-06/23/11	02B0212AB	CalAdjust, Deploy	*n/a*	*n/a*	*n/a*	*n/a*
		06/23/11	06/23/11-07/20/11	02B0212AB	Check, CalAdjust	-0.57	0.04	0.08	-0.01
		07/20/11	07/20/11-08/08/11	02B0212AB	Check, CalAdjust	-0.50	0.21	0.13	**-0.56**
		08/08/11	08/08/11-08/25/11	02B0212AB	Check, CalAdjust	-0.57	0.04	0.01	0.00
		08/25/11	08/25/11-09/13/11	02B0212AB	Check, CalAdjust	0.00	-0.05	-0.01	0.24
		09/13/11	09/13/11-10/11/11	02B0212AB	Check, CalAdjust	-3.26	0.11	0.07	0.00
		10/11/11	10/11/11-10/24/11	02B0212AB	Check, CalAdjust	-0.14	0.07	0.06	-0.02
		10/24/11	*n/a*	02B0212AB	Retrieve, Check	1.49	-0.12	-0.21	0.17
REACH 2 (Syar)	114RR2599	06/07/11	06/07/11-06/23/11	02B0212AA	CalAdjust, Deploy	*n/a*	*n/a*	*n/a*	*n/a*
		06/23/11	06/23/11-07/20/11	02B0212AA	Check, CalAdjust	-0.35	0.06	0.00	0.13
		07/20/11	07/20/11-7/28/11	02B0212AA	Check, CalAdjust	1.49	0.14	-0.06	0.08
		07/28/11	*n/a*	02B0212AA	Retrieve, Check	0.35	0.01	-0.02	0.07
		07/28/11	07/28/11-08/08/11	09D100548	CalAdjust, Deploy	*n/a*	*n/a*	*n/a*	*n/a*
		08/08/11	08/08/11-08/25/11	09D100548	Check, CalAdjust	0.78	-0.04	-0.02	0.16
		08/25/11	08/25/11-09/13/11	09D100548	Check, CalAdjust	-0.50	0.09	-0.03	-0.12
		09/13/11	09/13/11-09/26/11	09D100548	Check, CalAdjust	-1.84	0.04	0.01	0.00
		09/26/11	09/26/11-10/11/11	09D100548	Check, CalAdjust	-0.78	0.14	0.30	-0.03
		10/11/11	10/11/11-10/24/11	09D100548	Check, CalAdjust	-0.57	0.07	0.03	0.00
		10/24/11	*n/a*	09D100548	Retrieve, Check	1.63	0.04	0.03	-0.05

Abbreviations: SC-Specific Conductance. DO-Dissolved Oxygen. MQO-Measurement Quality Objective. n/a-not applicable
PF-Probe Failure. NR-Not Recorded.

Note1. Activity types: Check = Accuracy check; CalAdj = Calibration Adjustment

Note2. Drift values highlighted in red font exceeded Measurement Quality Objectives (MQOs)

Note3. Drift of Temperature sensors was checked once a year against an NIST thermometer; MQO of ±0.5^{o}C never exceeded.

Table E-2b: Inventory of sonde deployments and associated data quality in the Russian River study area, 2011

Reach name	Station ID	Visit date	Deployment Period	Sonde ID	Actions (Note 1)	SC (uS/cm) MQO ±5%	pH 7.0 MQO ±0.3	pH 10.0 MQO ±0.3	DO (mg/L) MQO ±0.5
						INSTRUMENT DRIFT (Notes 2,3)			
(Korbel)		06/30/11	06/30/11-07/19/11	02A1256AA	Check, CalAdjust	-0.35	0.07	0.04	-0.01
		07/19/11	07/19/11-08/09/11	02A1256AA	Check, CalAdjust	-0.42	0.30	0.18	-0.13
		08/09/11	08/09/11-8/18/11	02A1256AA	Check, CalAdjust	0.14	0.10	0.09	0.07
		08/18/11	08/18/11-09/1/11	02A1256AA	Check, CalAdjust	0.64	0.08	0.03	0.05
		09/01/11	09/01/11-09/15/11	02A1256AA	Check, CalAdjust	**-9.92**	0.00	-0.01	-0.37
		09/15/11	09/15/11-09/27/11	02A1256AA	Check, CalAdjust	-0.78	0.07	0.05	0.02
		09/27/11	09/27/11-10/10/11	02A1256AA	Check, CalAdjust	0.07	0.09	0.02	-0.04
		10/10/11	*n/a*	02A1256AA	Retrieve, Check	0.85	0.17	0.07	0.07
Reach 4 (Vacation)	114RR1041	08/02/11	08/02/11-08/09/11	08D100635	CalAdjust, Deploy	*n/a*	*n/a*	*n/a*	*n/a*
		08/09/11	08/09/11-08/18/11	08D100635	Check, CalAdjust	0.14	0.10	0.09	0.00
		08/18/11	08/18/11-09/01/11	08D100635	Check, CalAdjust	0.64	0.12	0.05	-0.18
		09/01/11	09/01/11-09/15/11	08D100635	Check, CalAdjust	**-7.44**	0.11	0.06	-0.09
		09/15/11	09/15/11-09/27/11	08D100635	Check, CalAdjust	-1.42	0.05	0.03	0.03
		09/27/11	09/27/11-10/10/11	08D100635	Check, CalAdjust	0.07	0.04	0.01	0.03
		10/10/11	10/10/11-10/25/11	08D100635	Check, CalAdjust	-0.99	0.13	0.04	-0.16
		10/25/11	*n/a*	08D100635	Retrieve, Check	-0.35	0.04	0.10	0.00

Abbreviations: SC-Specific Conductance. DO-Dissolved Oxygen. MQO-Measurement Quality Objective. n/a-not applicable
PF-Probe Failure. NR-Not Recorded.

Note1. Activity types: Check = Accuracy check; CalAdj = Calibration Adjustment

Note2. Drift values highlighted in red font exceeded Measurement Quality Objectives (MQOs)

Note3. Drift of Temperature sensors was checked once a year against an NIST thermometer; MQO of ±0.5°C never exceeded.

Table E-2c: Inventory of sonde deployments and associated data quality in the Russian River study area, 2011

Reach name	Station ID	Visit date	Deployment Period	Sonde ID	**Actions** (Note 1)	**SC (uS/cm)** MQO ±5%	**pH 7.0** MQO ±0.3	**pH 10.0** MQO ±0.3	**DO (mg/L)** MQO ±0.5
						INSTRUMENT DRIFT (Notes 2,3)			
Dry Creek	114DC0037	06/23/11	06/23/11-07/20/10	02A1256AD	CalAdjust, Deploy	*n/a*	*n/a*	*n/a*	*n/a*
		07/20/11	07/20/11-08/08/11	02A1256AD	Check, CalAdjust	0.21	0.06	0.08	0.37
		08/08/11	08/08/11-08/25/11	02A1256AD	Check, CalAdjust	-0.57	0.04	0.04	-0.10
		08/25/11	08/25/11-09/13/11	02A1256AD	Check, CalAdjust	-0.42	0.04	-0.04	-0.07
		09/13/11	09/13/11-9/26/11	02A1256AD	Check, CalAdjust	**-5.81**	0.03	0.04	-0.20
		09/26/11	09/26/11-10/11/11	02A1256AD	Check, CalAdjust	-0.50	0.04	0.05	0.08
		10/11/11	10/11/11-10/24/11	02A1256AD	Check, CalAdjust	-2.76	0.08	0.04	-0.22
		10/24/11	*n/a*	02A1256AD	Retrieve, Check	2.48	0.00	-0.01	0.00

Abbreviations: SC-Specific Conductance. DO-Dissolved Oxygen. MQO-Measurement Quality Objective. n/a-not applicable
PF-Probe Failure. NR-Not Recorded.

Note1. Activity types: Check = Accuracy check; CalAdj = Calibration Adjustment

Note2. Drift values highlighted in red font exceeded Measurement Quality Objectives (MQOs)

Note3. Drift of Temperature sensors was checked once a year against an NIST thermometer; MQO of ±0.5^{o}C never exceeded.

Figure E-3: Reach 0 (Redway) South Fork Eel River Time-Series (continuous) monitoring bi-weekly data, 2010

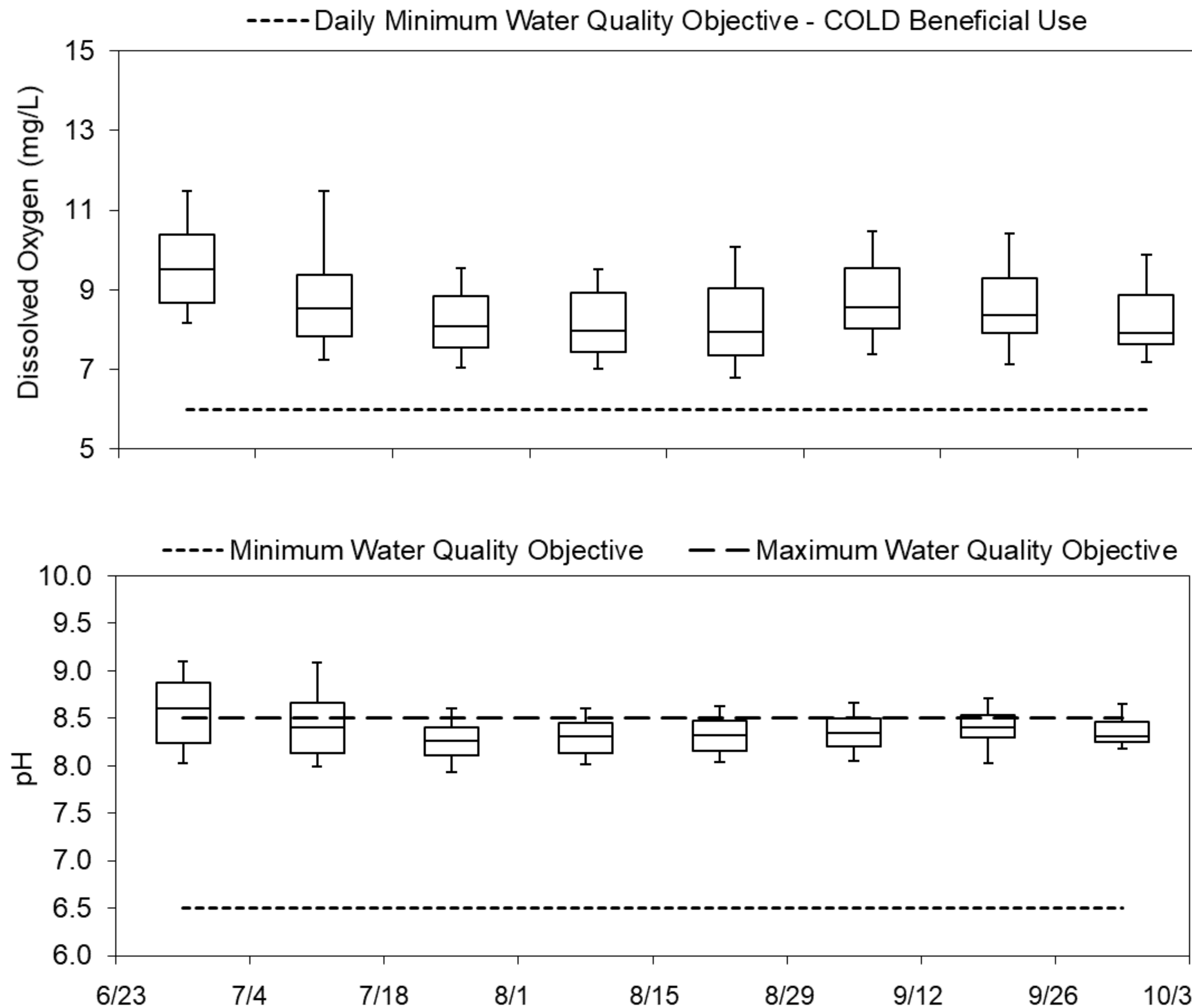


Figure E-3: Reach 0 (Redway) South Fork Eel River Time-Series (continuous) monitoring bi-weekly data, 2010

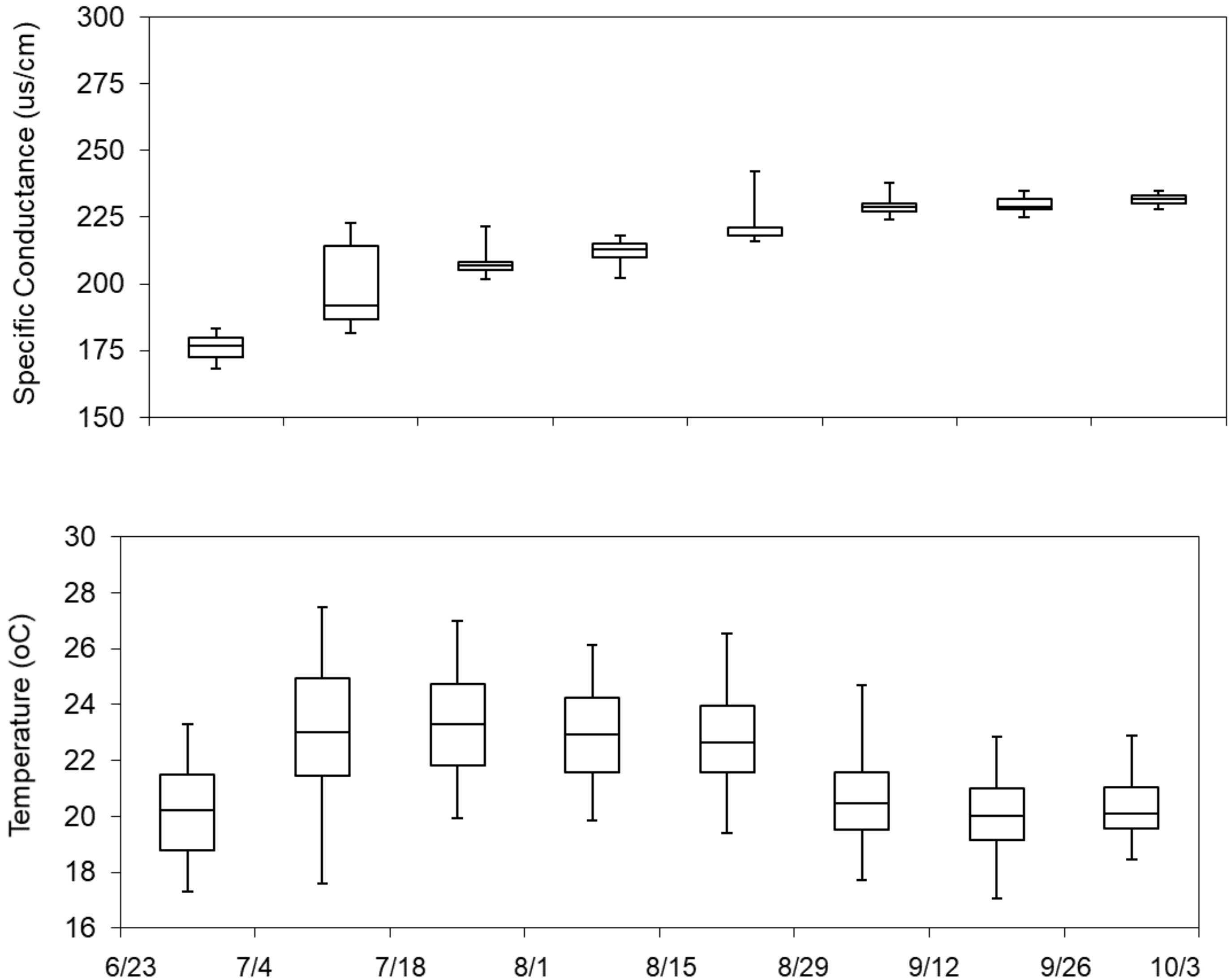


Figure E-3: Reach 1 (Sylvandale) South Fork Eel River Time-Series (continuous) monitoring bi-weekly data, 2010

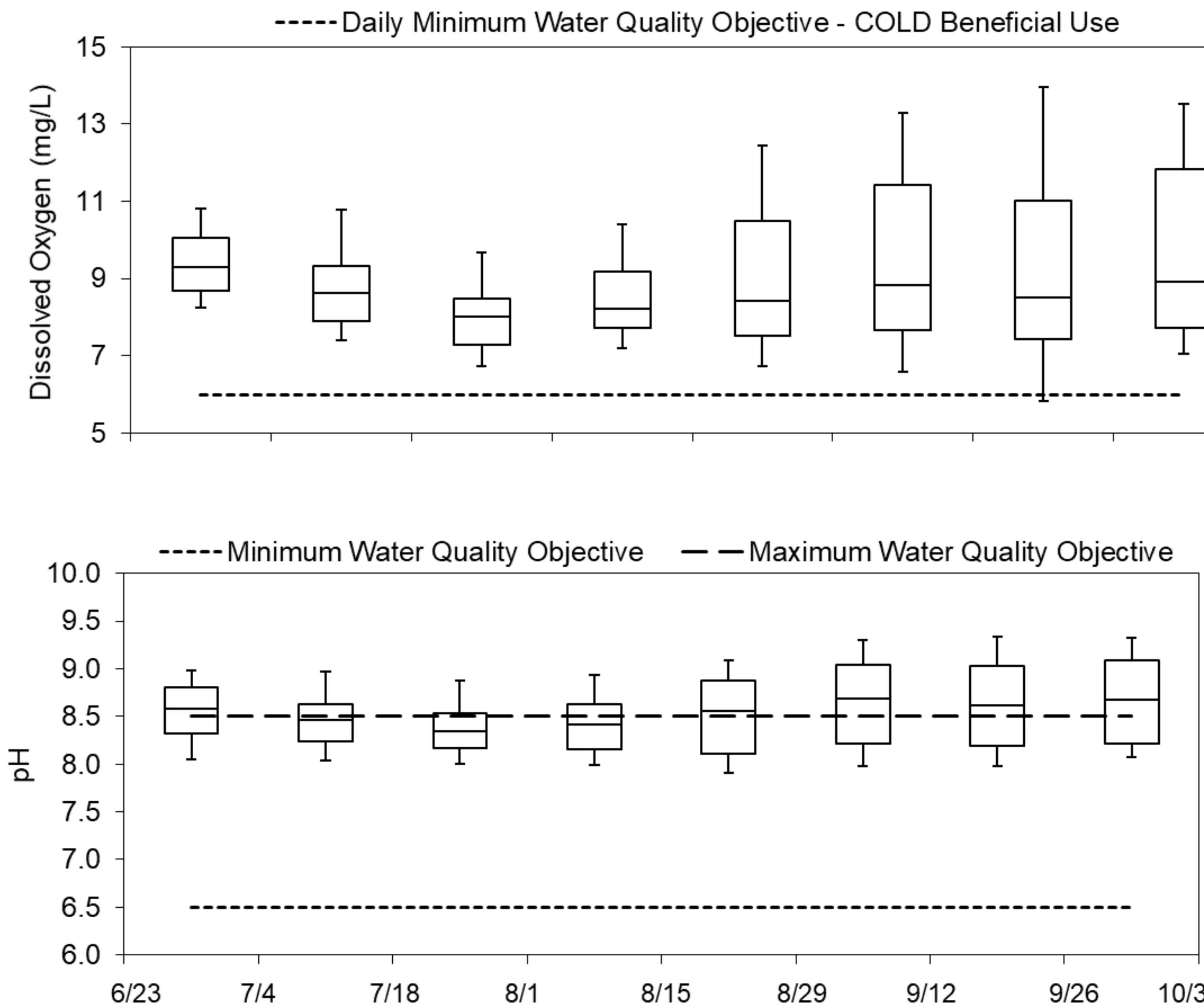
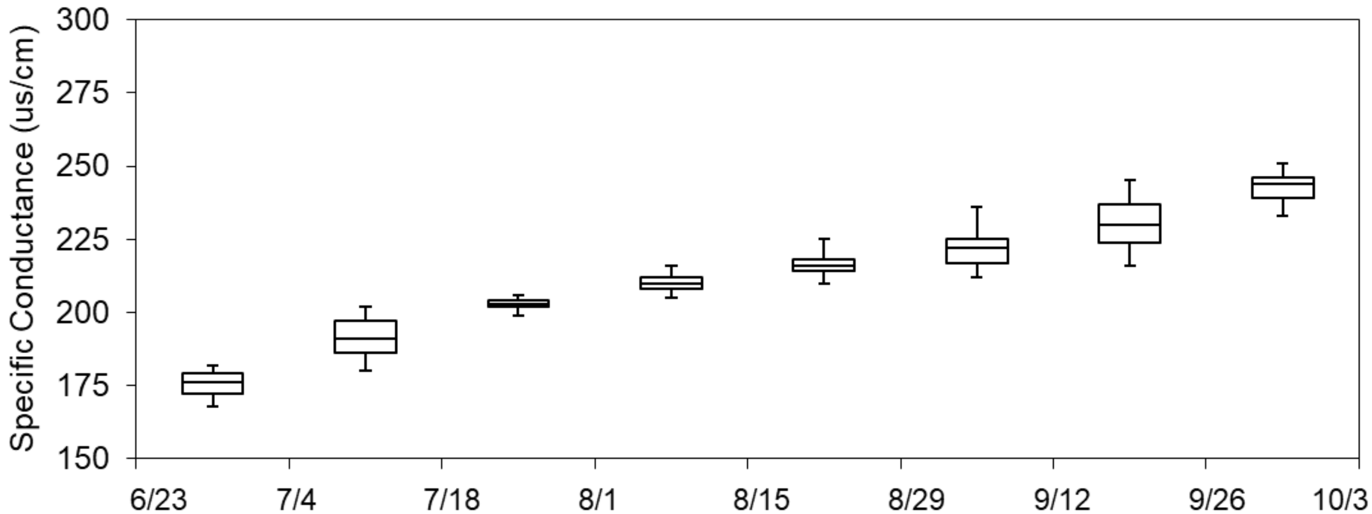


Figure E-3: Reach 1 (Sylvandale) South Fork Eel River Time-Series (continuous) monitoring bi-weekly data, 2010



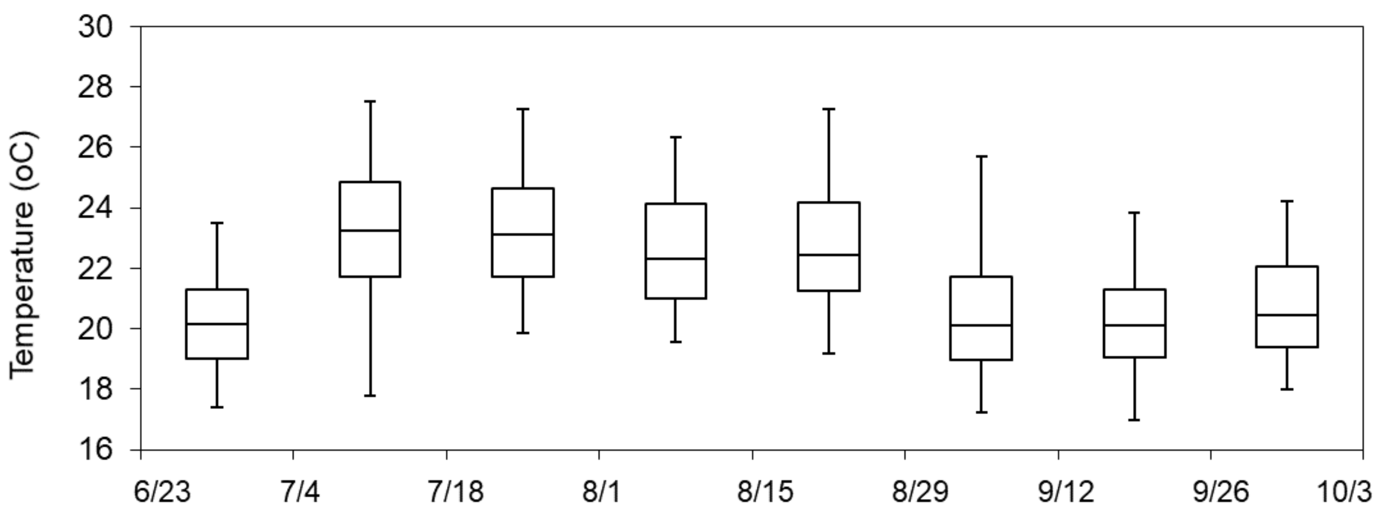


Figure E-3: Reach 2 (Phillipsville) South Fork Eel River Time-Series (continuous) monitoring bi-weekly data, 2010

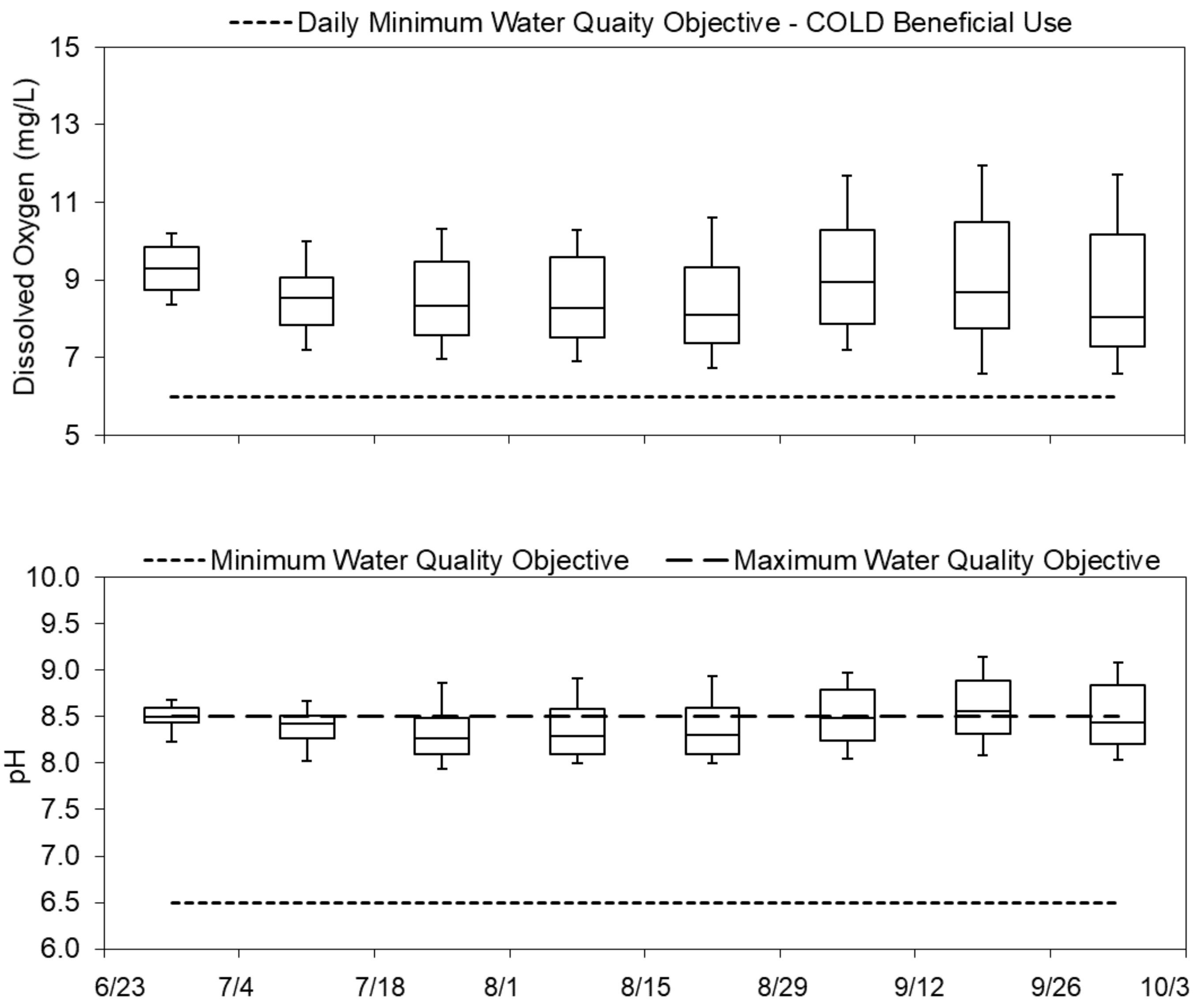


Figure E-3: Reach 2 (Phillipsville) South Fork Eel River Time-Series (continuous) monitoring bi-weekly data, 2010

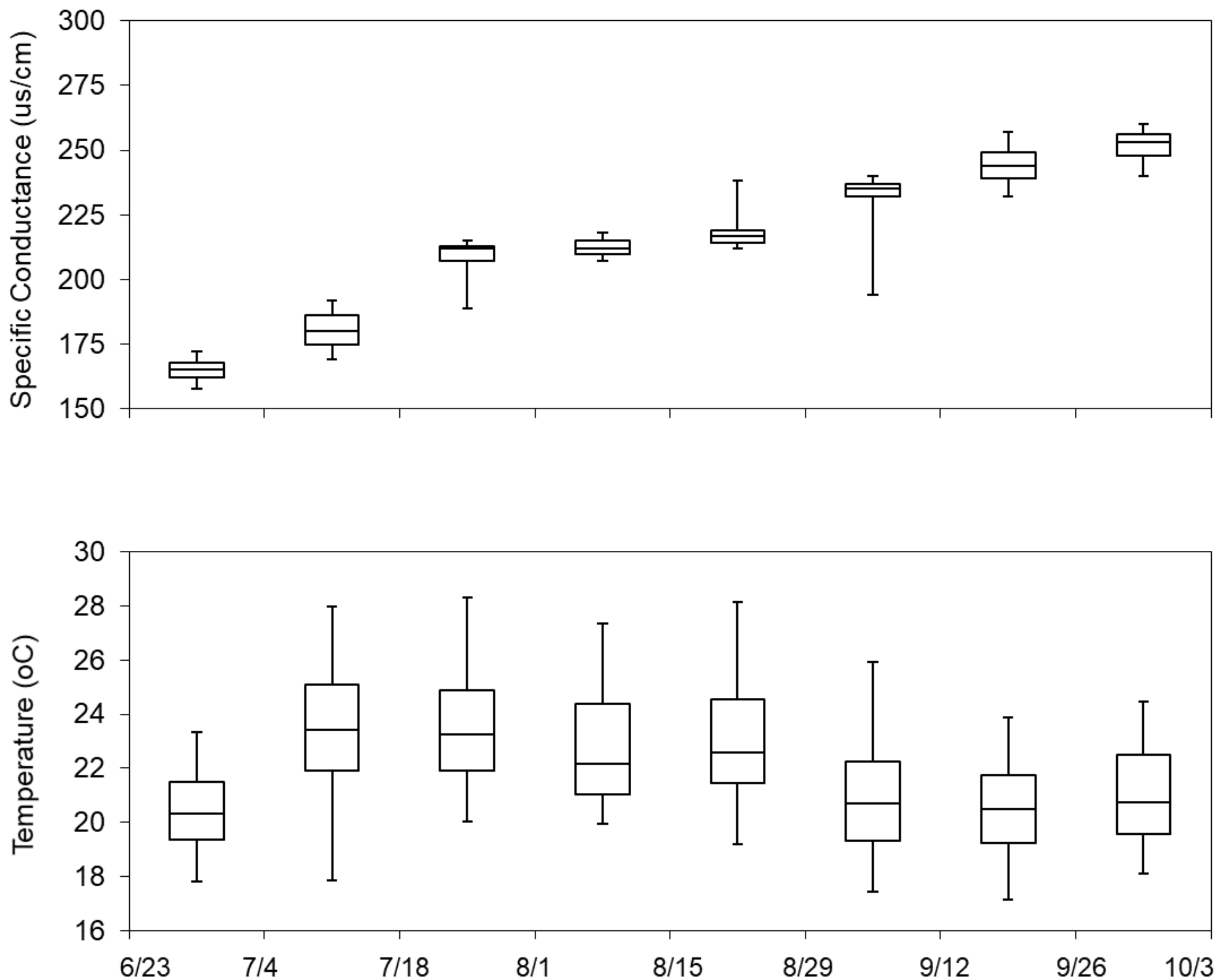


Figure E-3: Reach 3 (Miranda) South Fork Eel River Time-Series (continuous) monitoring bi-weekly data, 2010

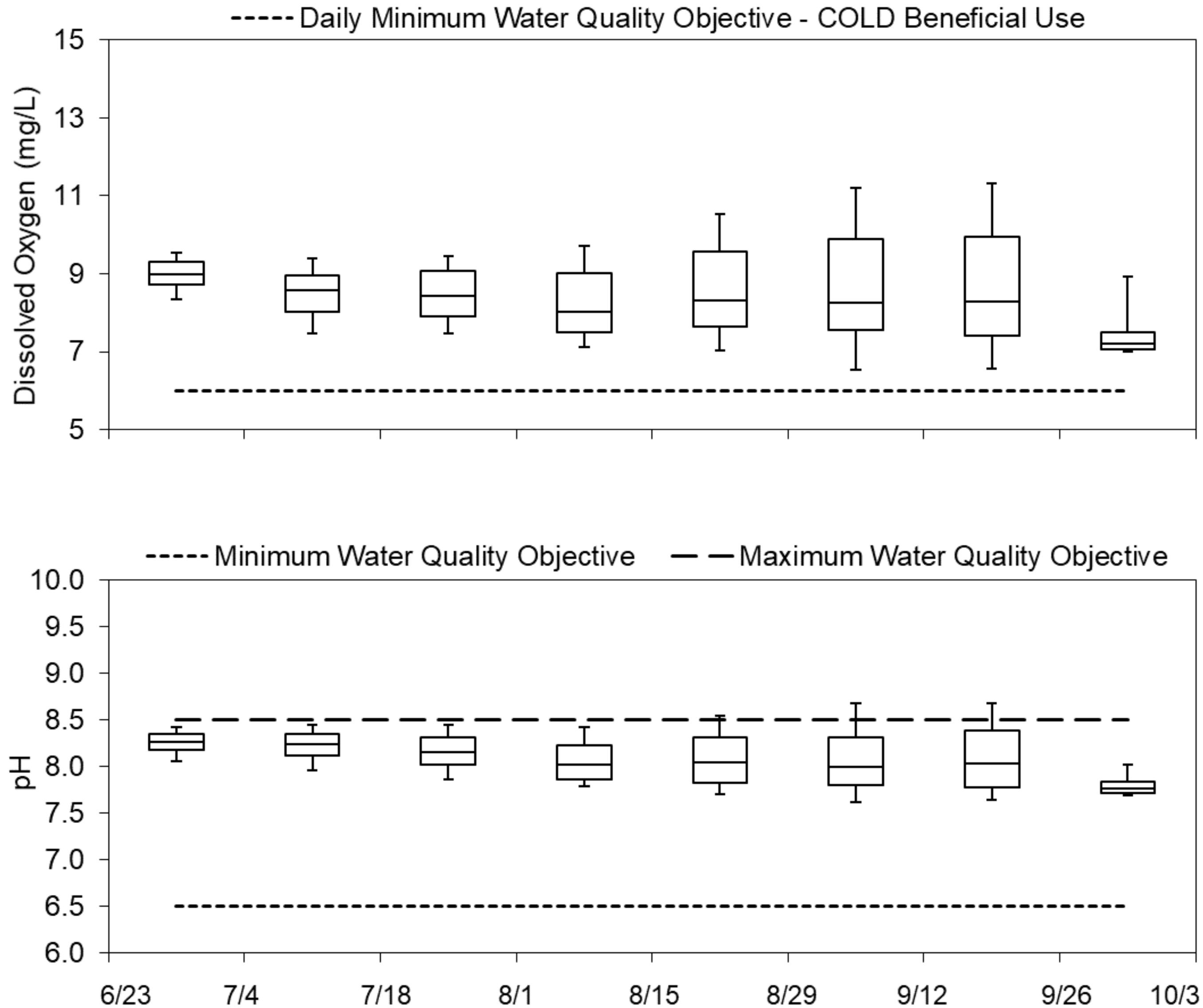


Figure E-3: Reach 3 (Miranda) South Fork Eel River Time-Series (continuous) monitoring bi-weekly data, 2010

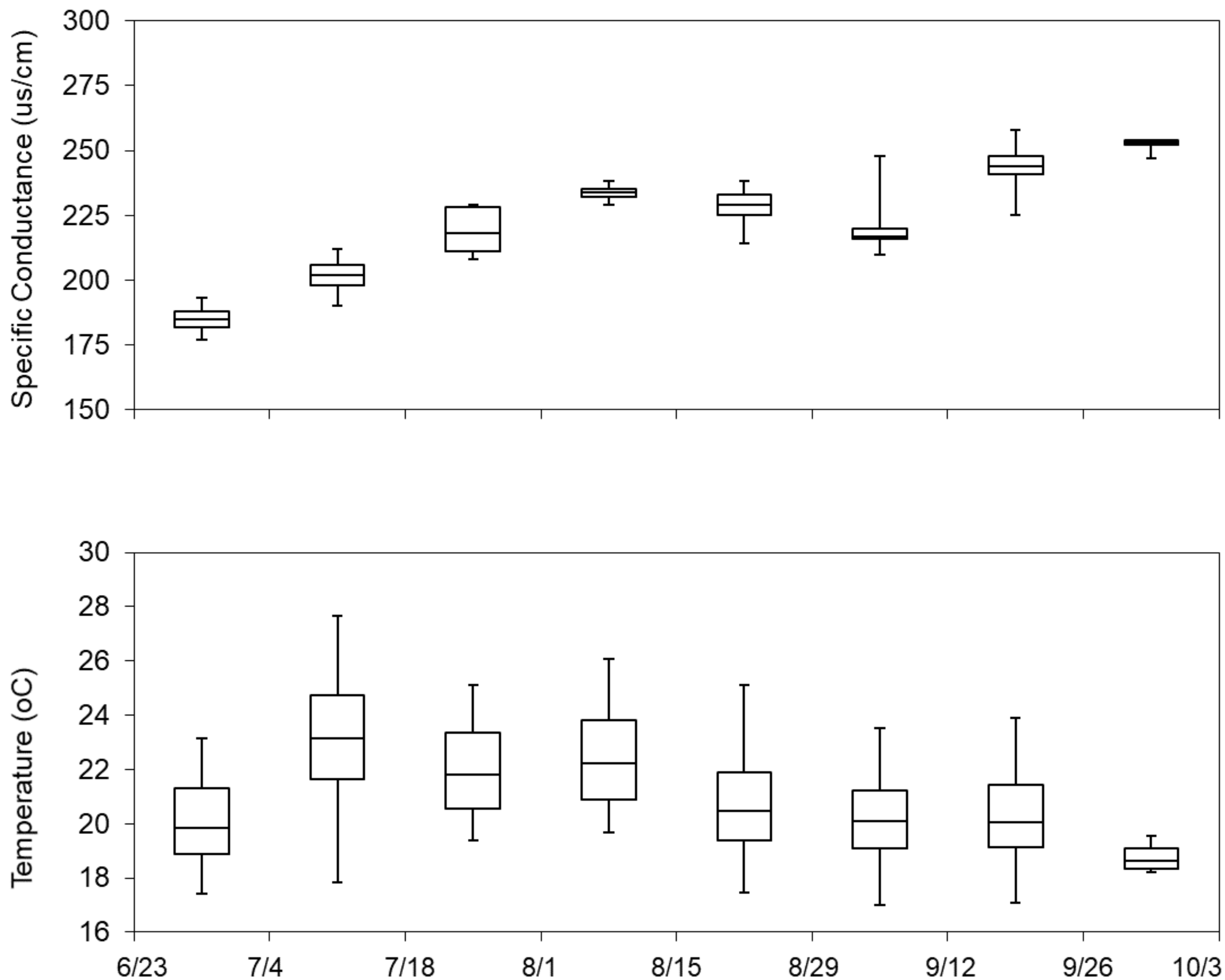
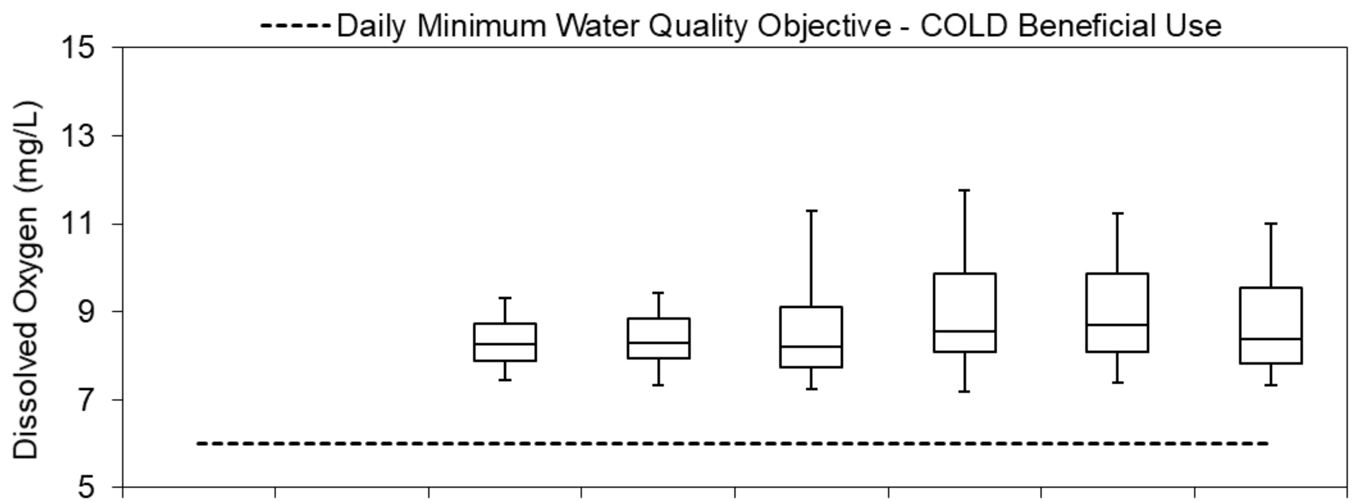


Figure E-3: Reach 4 (Meyers Flat) South Fork Eel River Time-Series (continuous) monitoring bi-weekly data, 2010



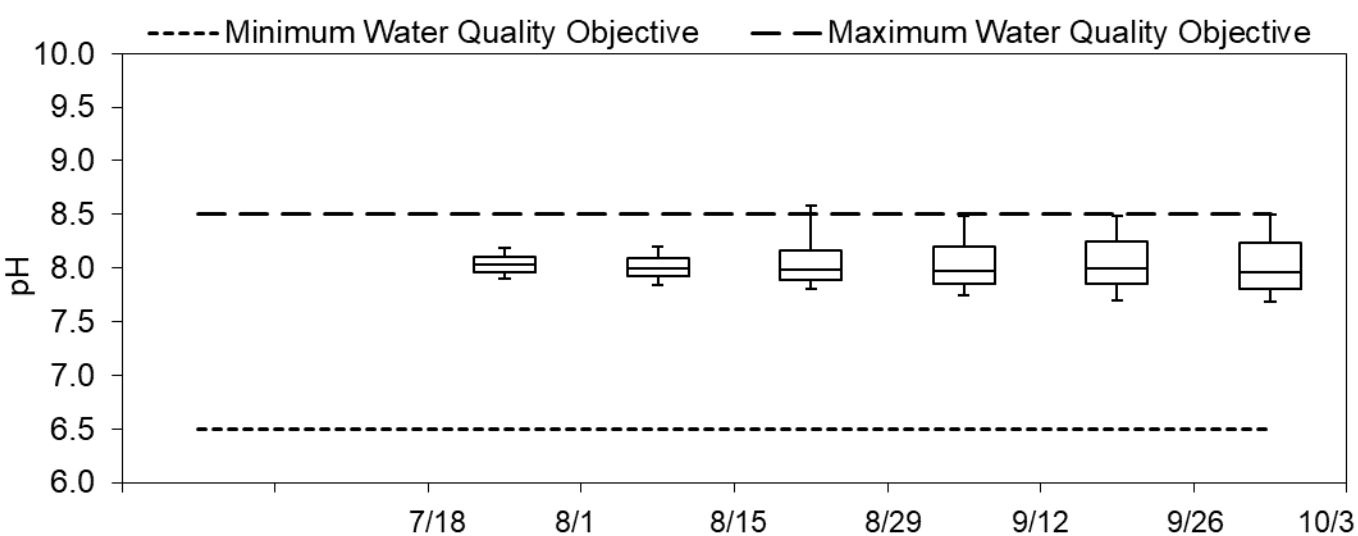


Figure E-3: Reach 4 (Meyers Flat) South Fork Eel River Time-Series (continuous) monitoring bi-weekly data, 2010

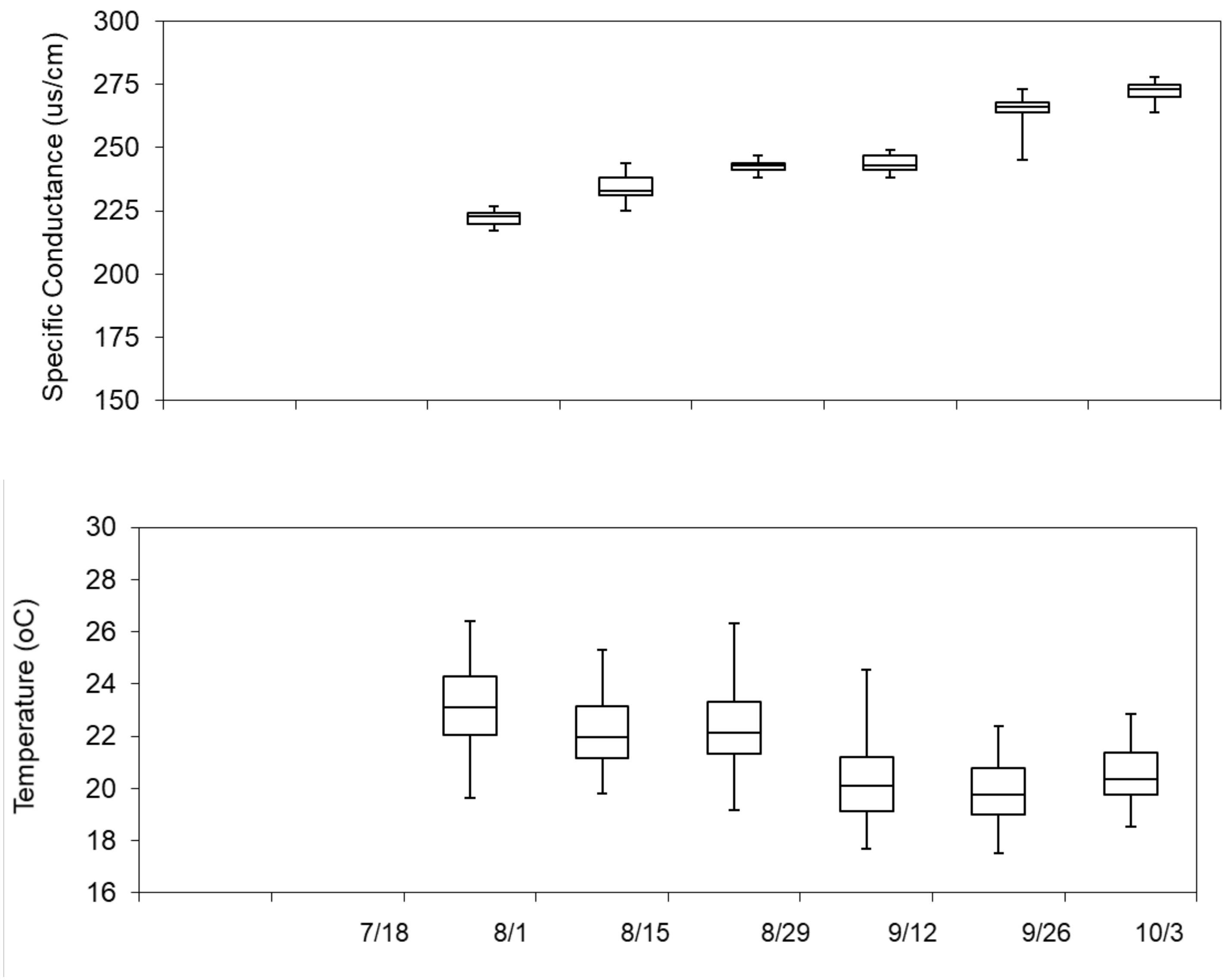


Figure E-4: Reach 1 (Healdsburg) Russian River (RuR) Time-Series (continuous) monitoring bi-weekly data, 2011

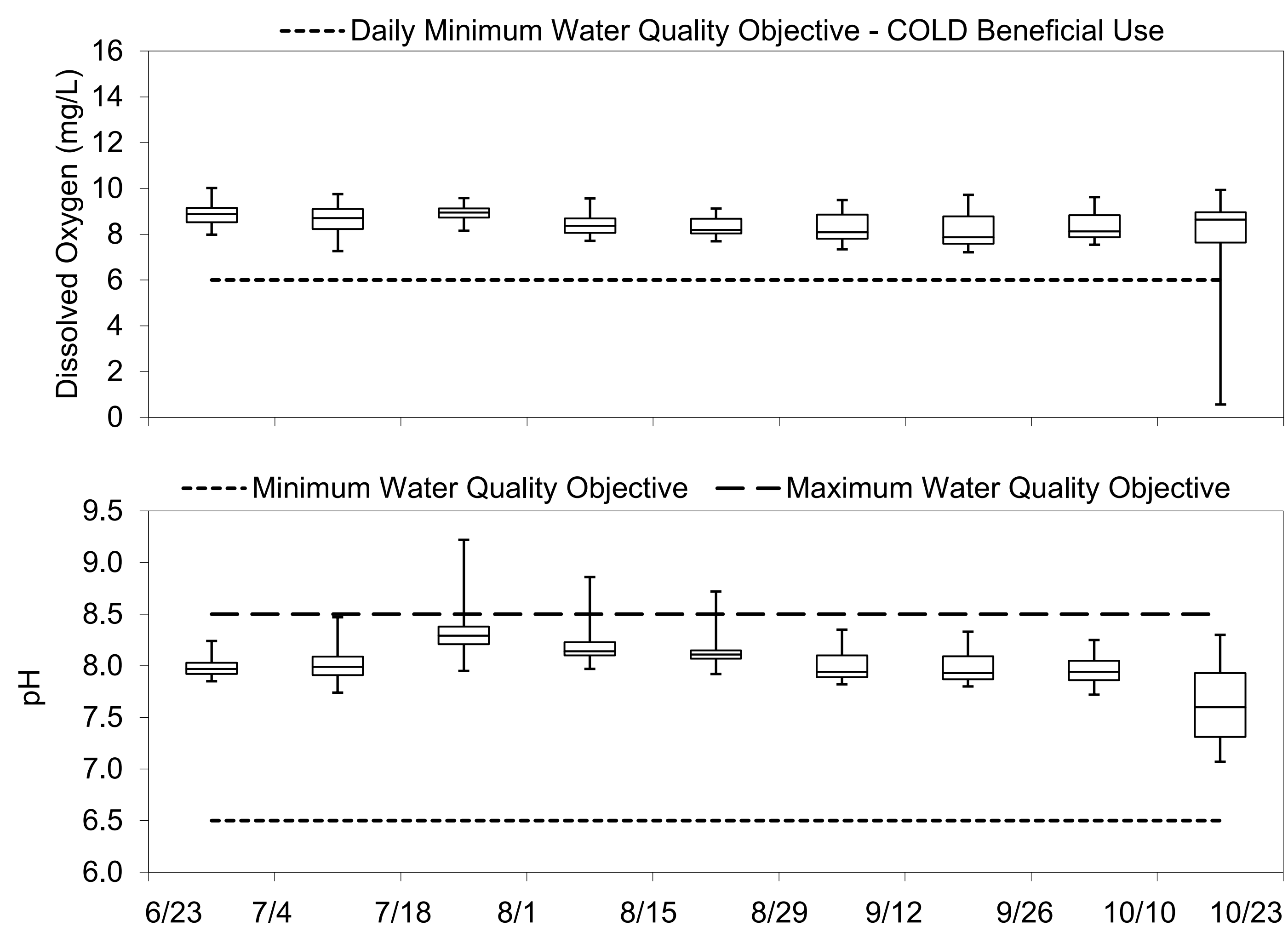


Figure E-4: Reach 1 (Healdsburg) Russian River (RuR) Time-Series (continuous) monitoring bi-weekly data, 2011

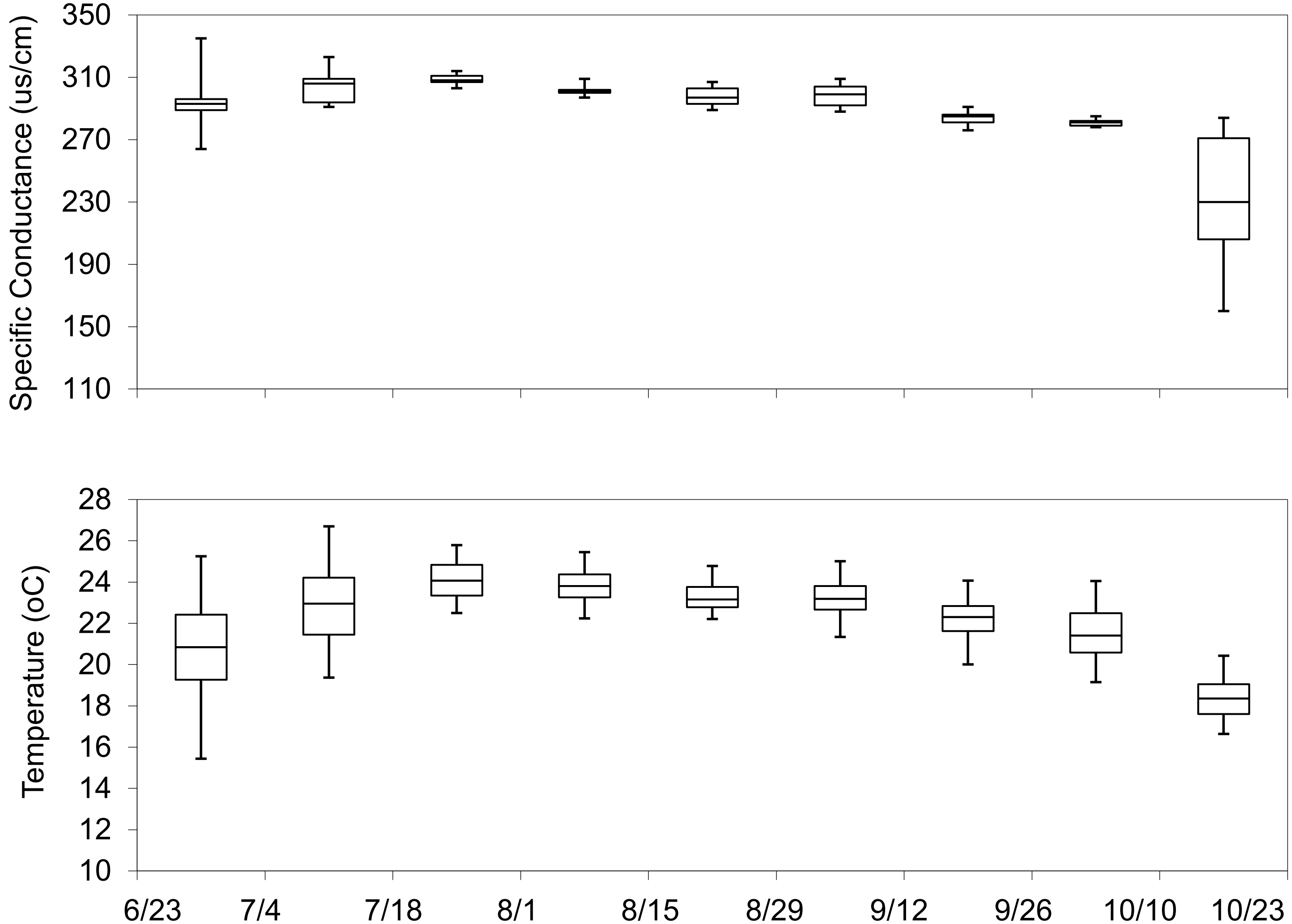


Figure E-4: Reach 2 (Syar) Russian River (RuR) Time-Series (continuous) monitoring bi-weekly data, 2011

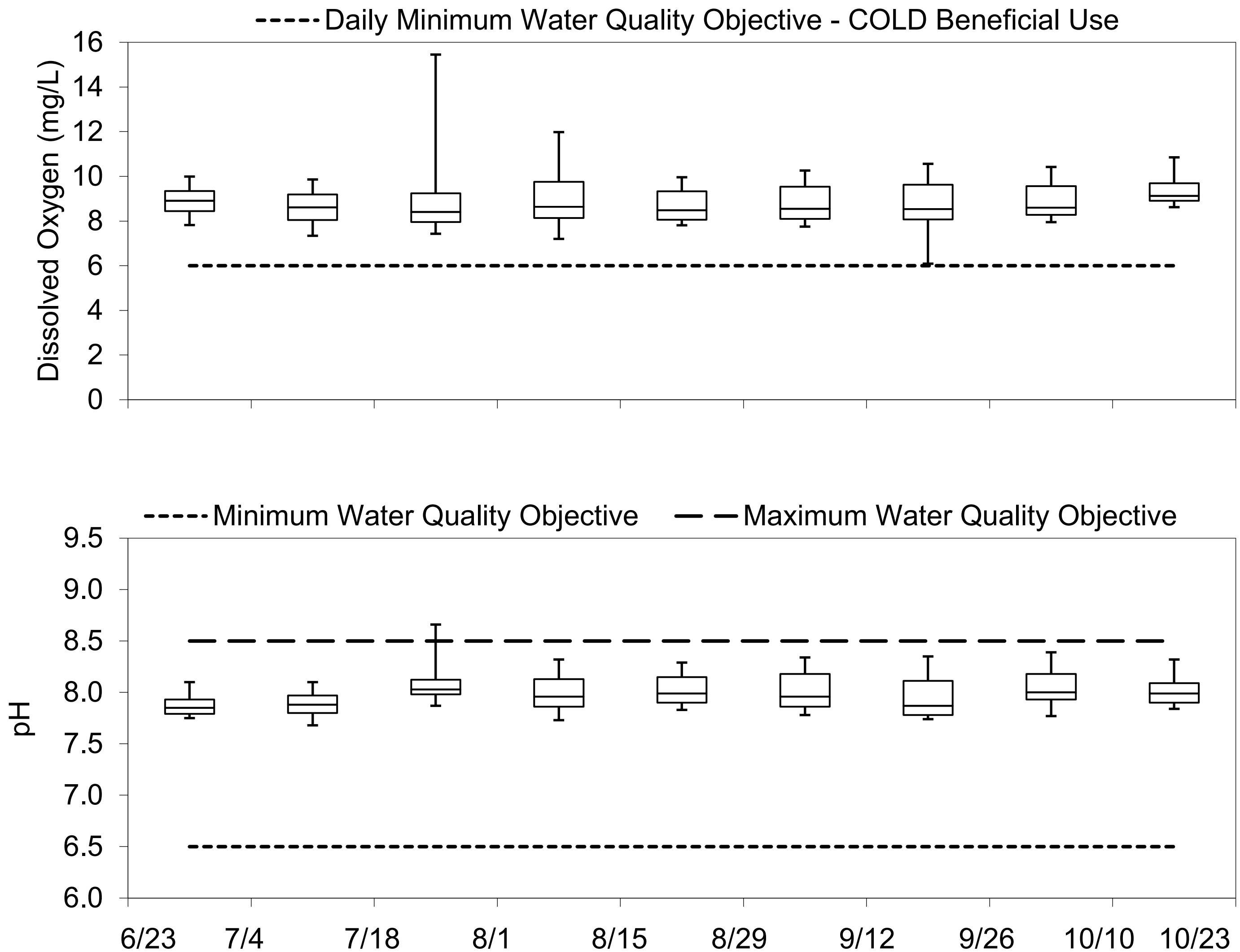


Figure E-4: Reach 2 (Syar) Russian River (RuR) Time-Series (continuous) monitoring bi-weekly data, 2011

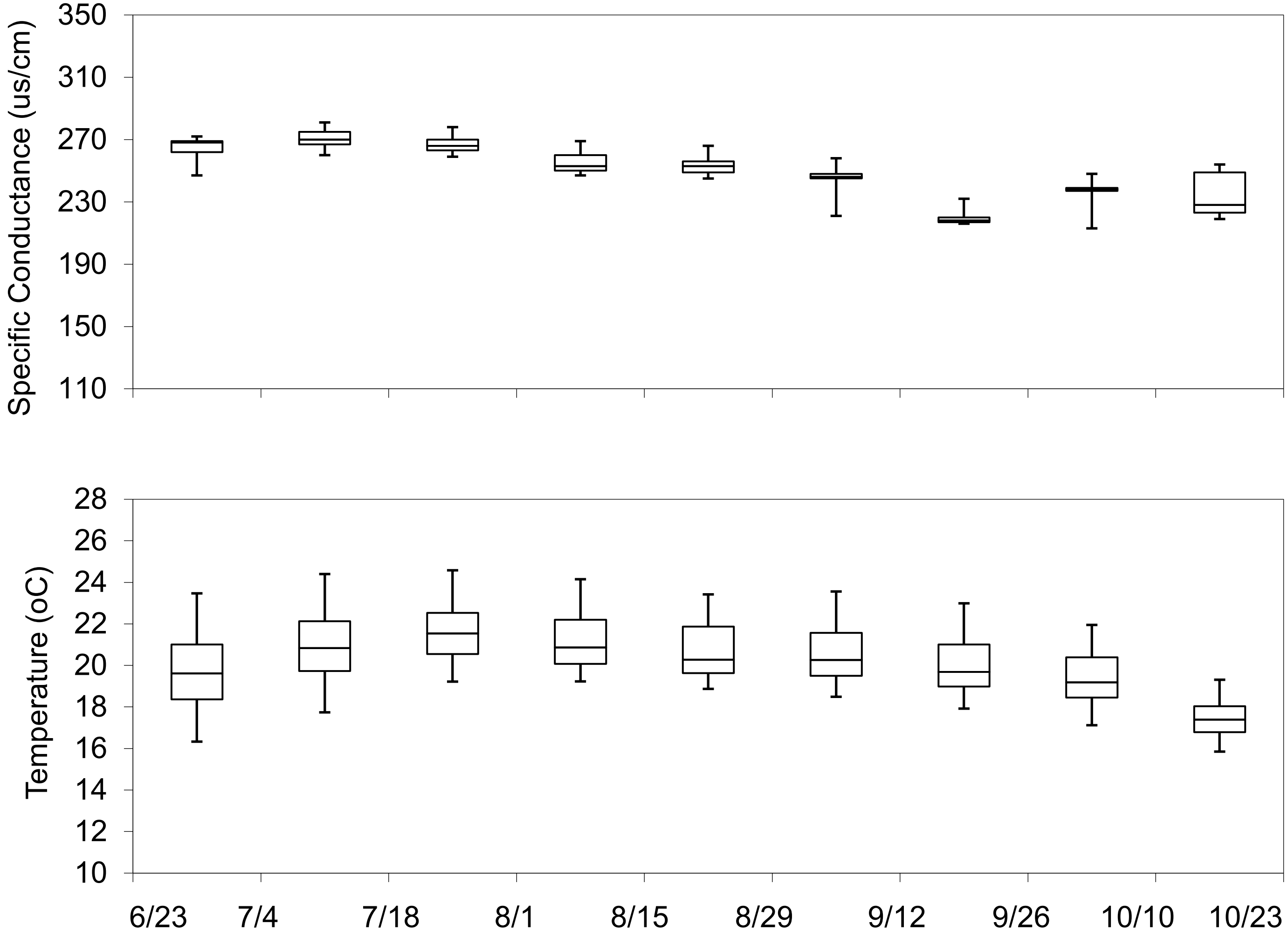


Figure E-4: Reach 3 (Korbel) Russian River (RuR) Time-Series (continuous) monitoring bi-weekly data, 2011

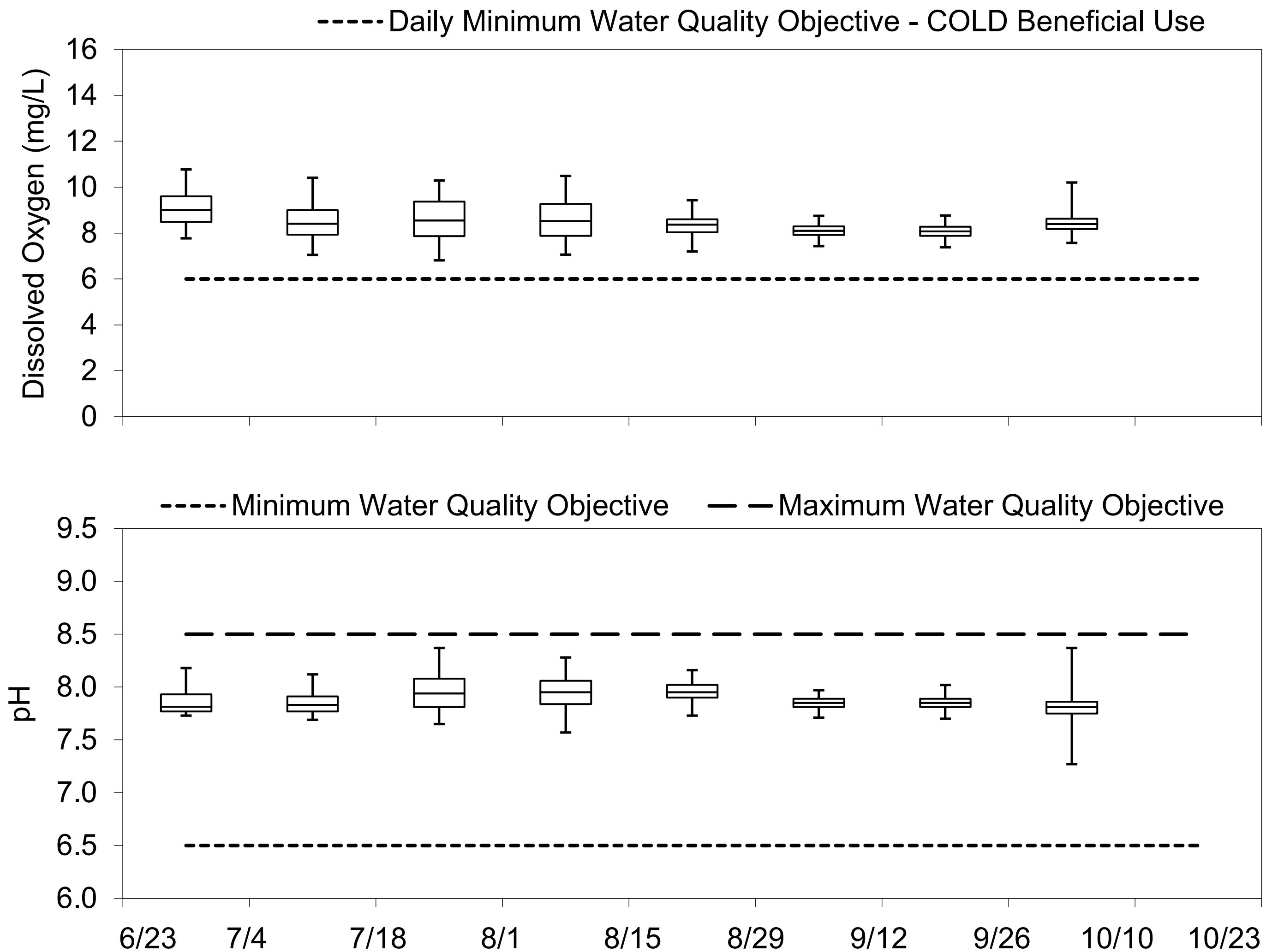


Figure E-4: Reach 3 (Korbel) Russian River (RuR) Time-Series (continuous) monitoring bi-weekly data, 2011

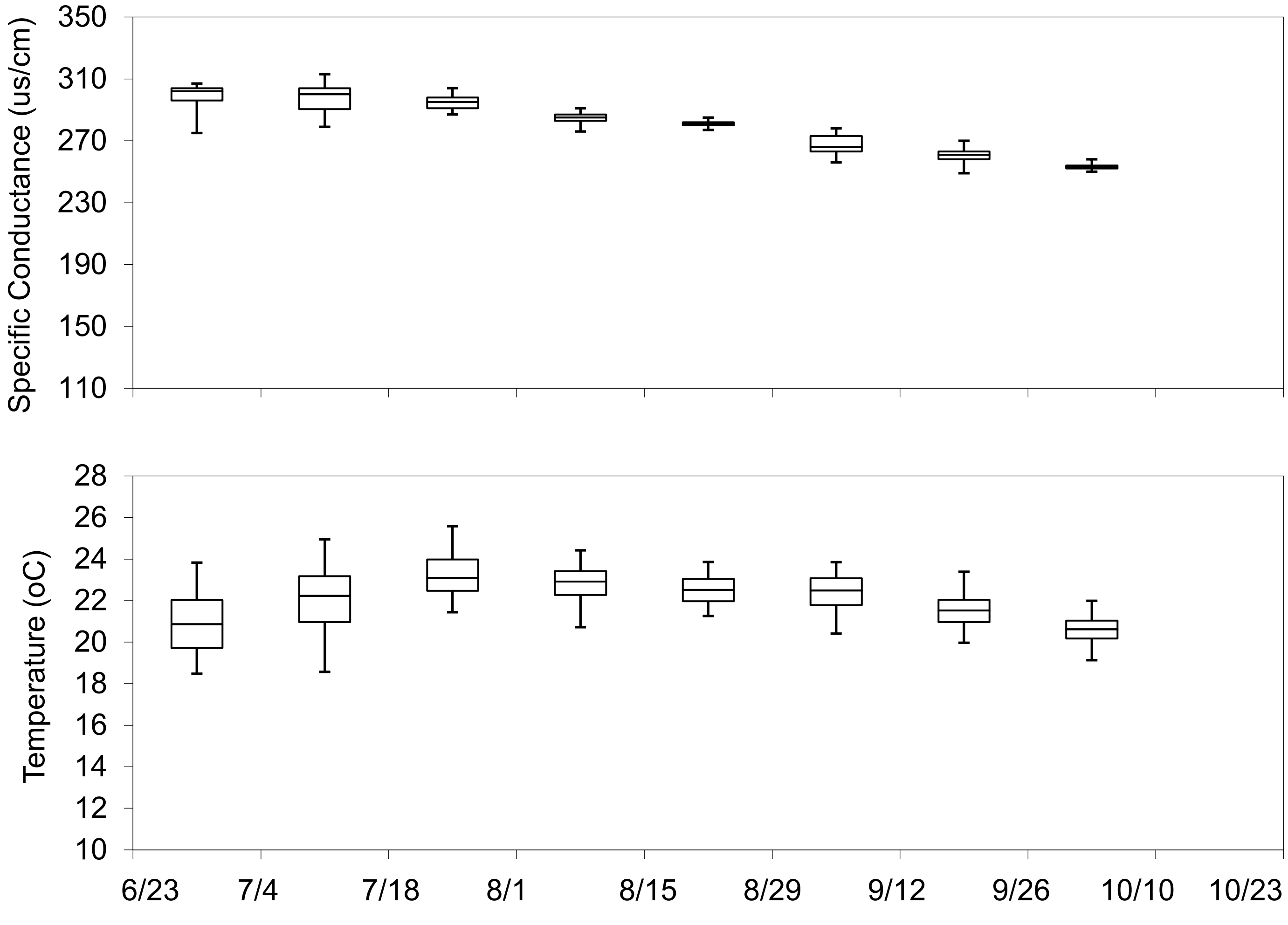


Figure E-4: Reach 4 (Vacation) Russian River (RuR) Time-Series (continuous) monitoring bi-weekly data, 2011

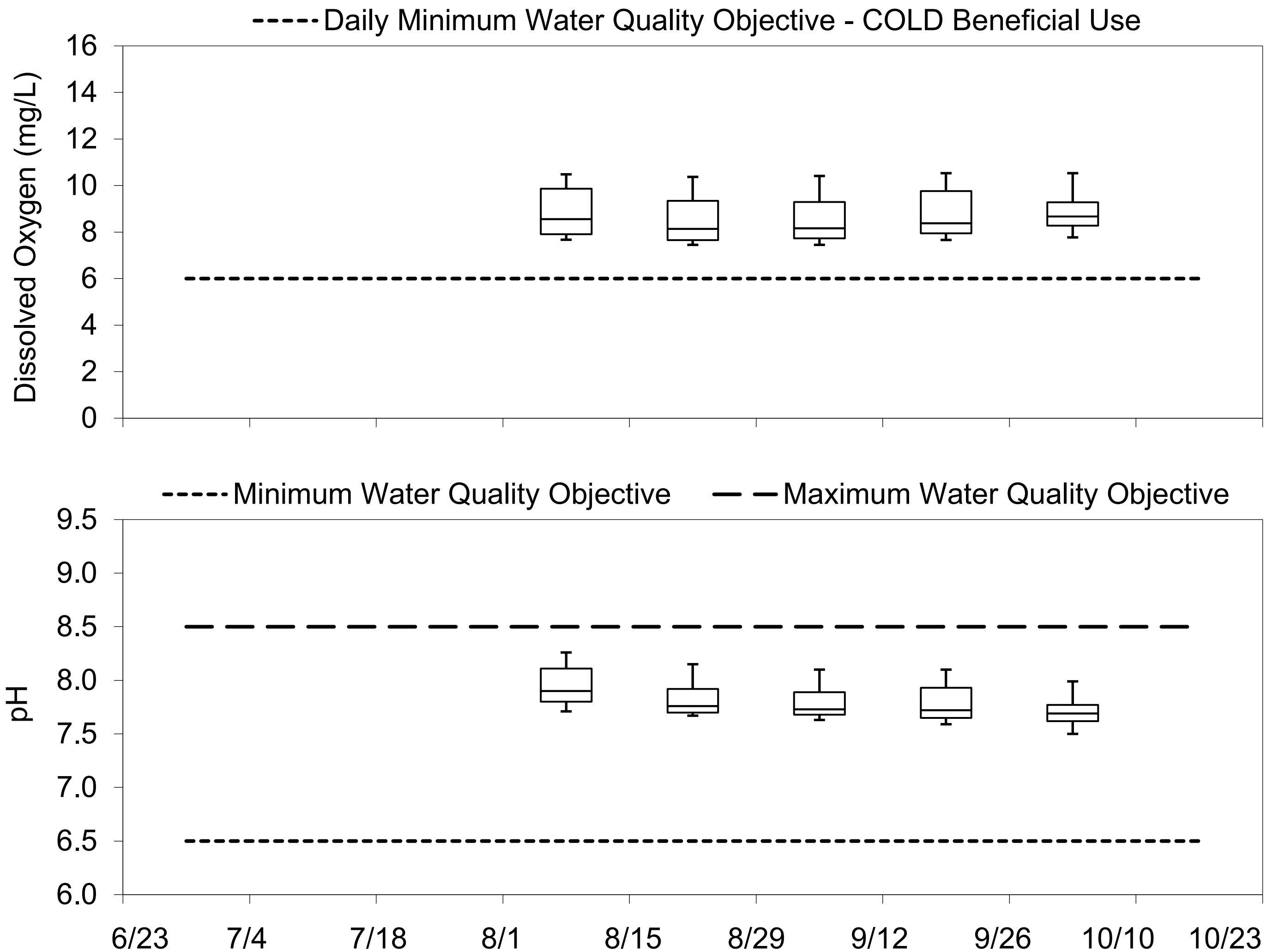


Figure E-4: Reach 4 (Vacation) Russian River (RuR) Time-Series (continuous) monitoring bi-weekly data, 2011

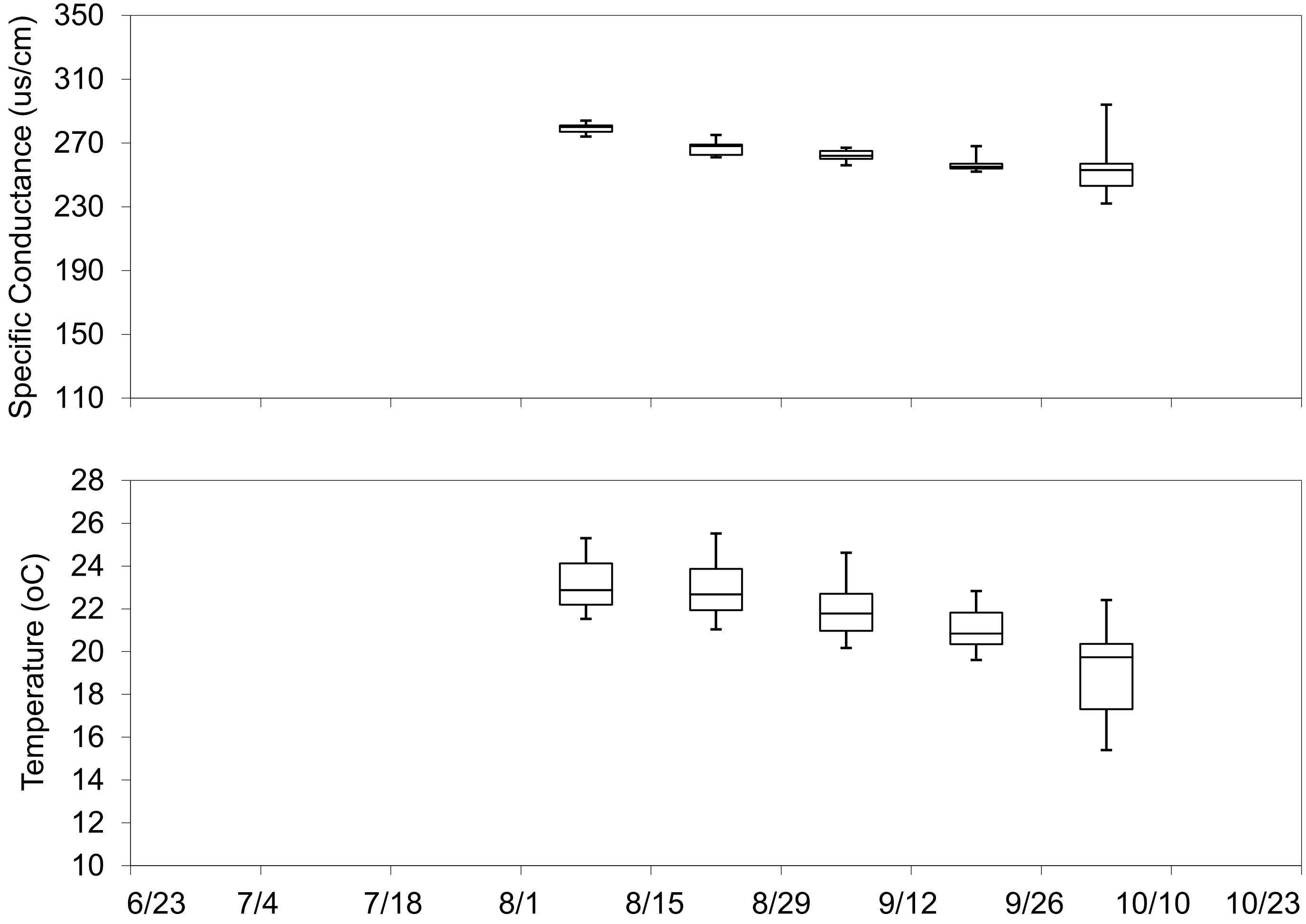


Figure E-4: Dry Creek Tributary to Russian River (RuR) Time-Series (continuous) monitoring bi-weekly data, 2011

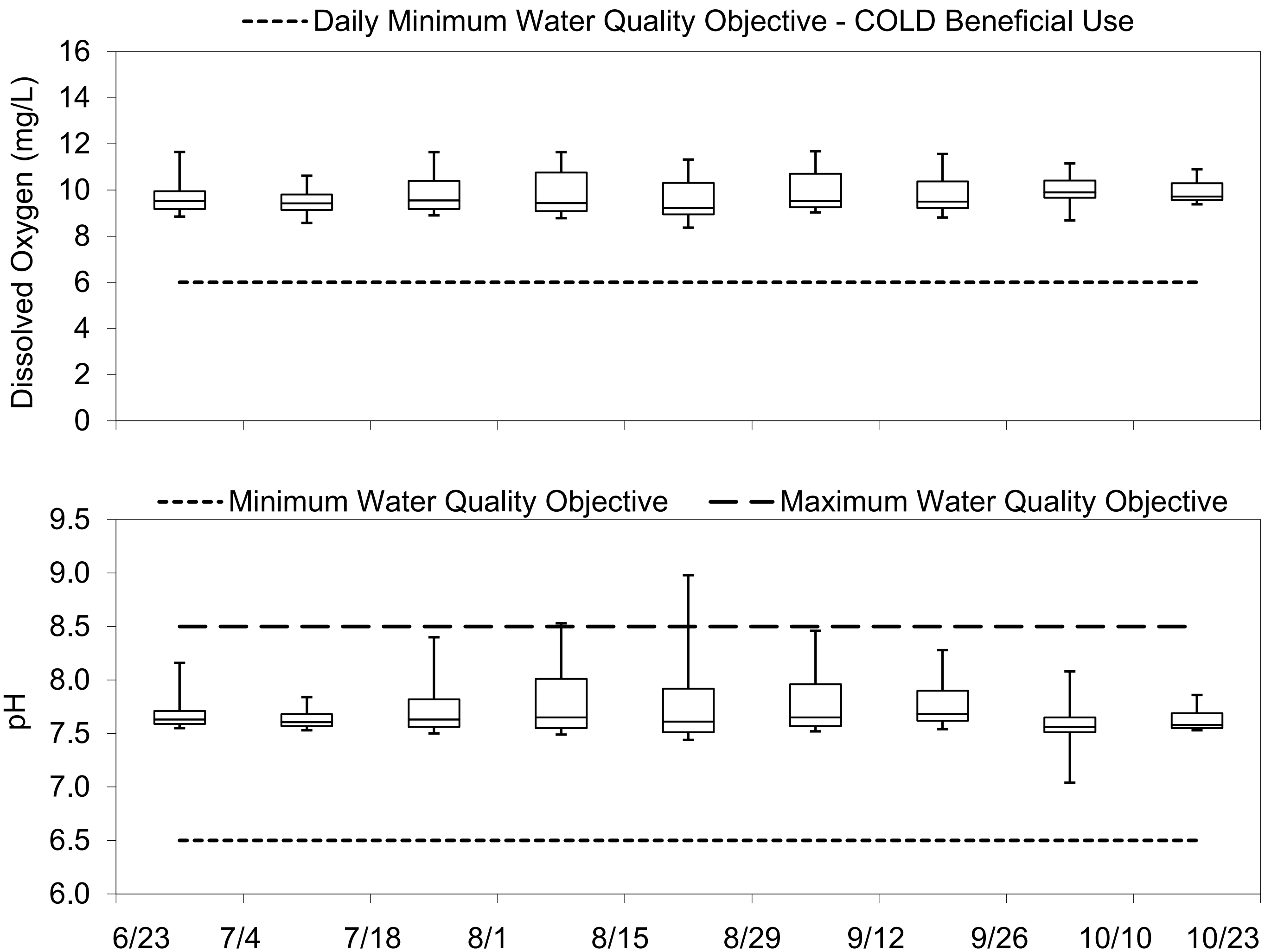
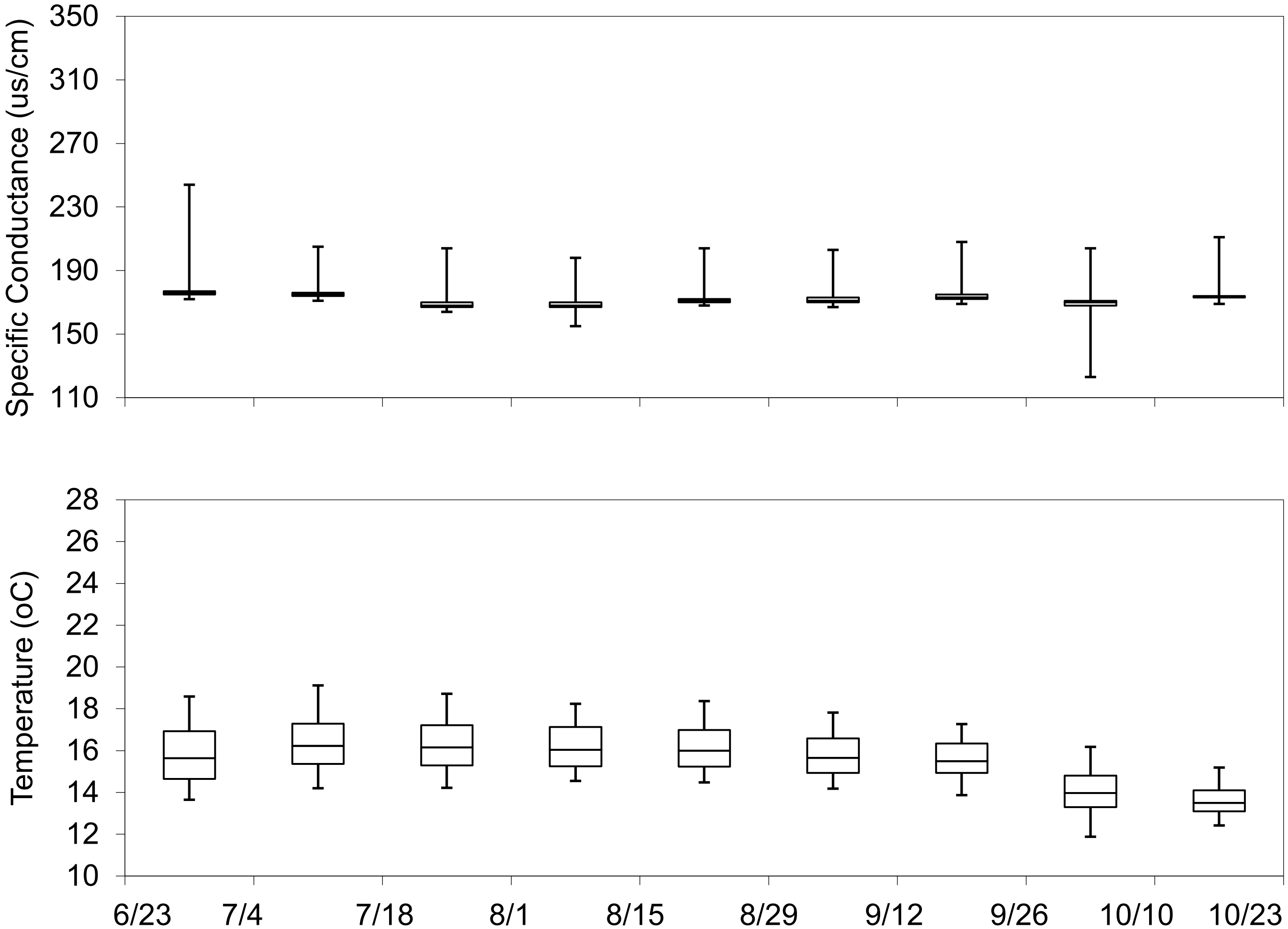


Figure E-4: Dry Creek Tributary to Russian River (RuR) Time-Series (continuous) monitoring bi-weekly data, 2011



Appendix F: Benthic algae taxonomy metrics

Table F-1: Benthic Algae Taxonomy metrics calculated for South Fork Eel River sites in 2010

Reach	Reach 1 (Sylvandale)					Reach 2 (Phillipsville)					Reach 3 (Miranda)					Reach 4 (Myers Flat)				
Station	111SF2538					111SF1944					111SF1569					111SF1016				
Sample Date	15-Jul	3-Aug	24-Aug	15-Sep	3-Oct	15-Jul	3-Aug	24-Aug	15-Sep	5-Oct	14-Jul	2-Aug	25-Aug	14-Sep	4-Oct	14-Jul	2-Aug	25-Aug	14-Sep	4-Oct
Diatom Metrics																				
Proportion *A. minutissimum* (d)	0.10	0.22	0.16	0.15	0.03	0.09	0.13	0.15	0.07	0.18	0.04	0.02	0.08	0.03	0.04	0.02	0.03	0.01	0.01	0.00
Proportion halobiontic (d)	0.55	0.30	0.19	0.42	0.37	0.32	0.22	0.07	0.09	0.10	0.18	0.44	0.15	0.04	0.24	0.28	0.14	0.09	0.08	0.08
Proportion highly motile (d)	0.34	0.18	0.32	0.25	0.12	0.25	0.15	0.05	0.19	0.13	0.15	0.03	0.11	0.33	0.06	0.29	0.12	0.08	0.06	0.08
Proportion low TN indicators (d)	0.26	0.40	0.37	0.28	0.37	0.32	0.34	0.51	0.28	0.58	0.41	0.10	0.28	0.28	0.48	0.37	0.13	0.14	0.35	0.62
Proportion low TP indicators (d)	0.36	0.51	0.40	0.41	0.61	0.33	0.38	0.53	0.29	0.61	0.41	0.18	0.34	0.32	0.61	0.37	0.14	0.11	0.25	0.59
Proportion N heterotrophs (d)	0.36	0.19	0.24	0.19	0.06	0.31	0.17	0.03	0.12	0.08	0.14	0.02	0.12	0.37	0.08	0.23	0.09	0.07	0.05	0.06
Proportion oligo- & beta-mesosaprobic (d)	0.65	0.78	0.79	0.85	0.95	0.67	0.81	0.96	0.84	0.97	0.81	0.98	0.83	0.61	0.93	0.69	0.79	0.87	0.90	0.89
Proportion poly- & eutrophic (d)	0.78	0.66	0.65	0.69	0.80	0.85	0.72	0.76	0.78	0.70	0.88	0.92	0.75	0.86	0.88	0.83	0.89	0.88	0.88	0.89
Proportion requiring >50% DO saturation (d)	0.99	0.99	0.91	1.00	0.99	0.97	0.99	1.00	0.96	1.00	0.98	1.00	0.91	0.97	0.99	0.95	0.96	0.96	0.99	0.98
Proportion requiring nearly 100% DO saturation (d)	0.19	0.31	0.23	0.24	0.08	0.15	0.26	0.23	0.18	0.23	0.11	0.06	0.16	0.13	0.09	0.07	0.05	0.07	0.06	0.03
Soft Algae Metrics																				
Proportion Chlorophyta (s, b)	0.97	0.37	0.58	0.54	0.66	0.21	0.14	0.02	0.44	0.00	0.00	0.69	0.75	0.78	0.56	0.00	0.00	0.60	0.74	0.26
Proportion high Cu indicators (s, sp)	0.22	0.21	0.17	0.32	0.15	0.10	0.11	0.13	0.32	0.06	0.20	0.07	0.07	0.23	0.06	0.00	0.10	0.12	0.22	0.11
Proportion high DOC indicators (s, b)	0.52	0.05	0.11	0.50	0.27	0.00	0.00	0.00	0.65	0.00	0.01	0.09	0.00	0.70	0.26	0.89	0.66	0.60	0.71	0.05
Proportion high DOC indicators (s, sp)	0.40	0.29	0.27	0.32	0.20	0.33	0.21	0.18	0.31	0.09	0.38	0.24	0.11	0.29	0.23	0.50	0.18	0.16	0.20	0.24
Proportion low TP indicators (s, sp)	0.10	0.06	0.05	0.03	0.09	0.08	0.07	0.09	0.03	0.05	0.13	0.06	0.11	0.06	0.00	0.25	0.36	0.16	0.00	0.05
Proportion non-reference indicators (s, b)	0.52	0.05	0.11	0.51	0.29	0.00	0.00	0.00	0.65	0.00	0.00	0.09	0.01	0.90	0.26	0.55	0.37	0.60	0.74	0.05
Proportion non-reference indicators (s, sp)	0.30	0.18	0.18	0.23	0.13	0.25	0.07	0.09	0.14	0.05	0.25	0.12	0.08	0.17	0.15	0.25	0.09	0.16	0.20	0.14
Proportion of green algae belonging to CRUS (s, b)	0.54	1.00	0.21	0.49	0.29	1.00	1.00	0.04	1.00	0.00	0.00	0.15	0.01	0.74	0.33	0.00	0.00	0.87	0.75	0.07
Proportion ZHR (s, b)	0.03	0.32	0.05	0.46	0.34	0.67	0.86	0.90	0.54	0.95	0.99	0.31	0.16	0.20	0.44	0.00	0.00	0.37	0.12	0.74
Proportion ZHR (s, m)	0.11	0.27	0.15	0.35	0.29	0.54	0.60	0.63	0.40	0.58	0.62	0.39	0.27	0.22	0.35	0.13	0.18	0.45	0.16	0.59
Proportion ZHR (s, sp)	0.18	0.22	0.25	0.24	0.24	0.42	0.33	0.36	0.27	0.21	0.25	0.47	0.37	0.24	0.26	0.25	0.36	0.52	0.20	0.44
*MMI_SoCal_H20_2012 Score	39	56	51	46	62	52	62	75	55	74	61	62	69	52	68	61	75	70	65	74

Notes
DO =Dissolved Oxygen; TP =Total Phosphorus; TN =Total Nitrogen; DOC =Dissolved Organic Carbon; MMI = multi-metric index
CRUS =Cladophora glomerata+Rhizoclonium hieroglyphicum+Ulva flexuosa+Stigeoclonium spp; ZHR =Zygnemataceae+heterocystous cyanobacteria+Rhodophyta;
"d" =derived from the diatom assemblage; "s" = derived from soft algae; "sp" =based on species presence; "b" =based on biovolume; "m" = average of the "b" and "sp" counterpart metric values.
*Fetscher et al 2014a

Table F-2: Benthic Algae taxonomy metrics calculated for Russian River sites in 2011

Reach	Reach 1 (Healdsburg)						RR2769[1]	Reach 2 (Syar)					Reach 3 (Korbel)						Reach 4 (Vacation)			
Station	114RR2899							114RR2678					114RR1599						114RR1041			
Sample Date	1-Jun	29-Jun	1-Aug	13-Sep	11-Oct	24-Oct	1-Jun	29-Jun	1-Aug	13-Sep	11-Oct	24-Oct	2-Jun	27-Jun	2-Aug	7-Sep	10-Oct	25-Oct	2-Aug	7-Sep	10-Oct	25-Oct
Diatom Metrics																						
Proportion *A. minutissimum* (d)	0.23	0.28	0.37	0.13	0.01	0.12	0.46	0.27	0.26	0.06	0.00	0.20	0.13	0.14	0.15	0.10	0.07	0.04	0.12	0.05	0.08	0.01
Proportion halobiontic (d)	0.24	0.26	0.20	0.08	0.46	0.16	0.34	0.45	0.21	0.23	0.11	0.14	0.62	0.51	0.33	0.16	0.08	0.25	0.30	0.19	0.18	0.30
Proportion highly motile (d)	0.29	0.24	0.15	0.30	0.40	0.20	0.36	0.48	0.21	0.34	0.17	0.19	0.62	0.51	0.46	0.38	0.18	0.38	0.29	0.31	0.30	0.36
Proportion low TN indicators (d)	0.36	0.36	0.48	0.33	0.10	0.30	0.53	0.32	0.48	0.15	0.72	0.40	0.17	0.20	0.29	0.40	0.34	0.27	0.26	0.36	0.16	0.18
Proportion low TP indicators (d)	0.38	0.37	0.58	0.42	0.09	0.32	0.55	0.33	0.52	0.17	0.73	0.43	0.17	0.22	0.32	0.40	0.36	0.20	0.29	0.35	0.17	0.15
Proportion N heterotrophs (d)	0.27	0.25	0.12	0.32	0.19	0.13	0.35	0.50	0.21	0.22	0.11	0.08	0.67	0.54	0.43	0.31	0.17	0.11	0.34	0.31	0.10	0.17
Proportion oligo- & beta-mesosaprobic (d)	0.62	0.69	0.78	0.56	0.26	0.54	0.61	0.44	0.71	0.61	0.79	0.74	0.27	0.33	0.46	0.56	0.63	0.52	0.48	0.56	0.61	0.53
Proportion poly- & eutrophic (d)	0.52	0.59	0.50	0.55	0.85	0.64	0.46	0.64	0.53	0.68	0.88	0.55	0.77	0.76	0.62	0.69	0.66	0.64	0.70	0.80	0.63	0.69
Proportion requiring >50% DO saturation (d)	0.93	0.98	0.95	0.89	0.65	0.92	0.97	0.96	0.96	0.98	0.91	0.92	0.91	0.91	0.93	0.86	0.92	0.83	0.86	0.88	0.89	0.83
Proportion requiring nearly 100% DO saturation (d)	0.36	0.37	0.47	0.33	0.07	0.26	0.53	0.30	0.40	0.17	0.05	0.34	0.17	0.19	0.29	0.19	0.25	0.22	0.21	0.15	0.15	0.21
Soft Algae Metrics																						
Proportion Chlorophyta (s, b)	1.00	0.99	0.58	0.47	0.55	0.60	1.00	0.99	0.98	0.71	0.57	0.81	0.61	0.94	0.39	0.11	0.35	0.23	0.45	0.32	0.34	0.68
Proportion high Cu indicators (s, sp)	0.25	0.14	0.16	0.23	0.31	0.14	0.20	0.15	0.14	0.20	0.17	0.23	0.19	0.25	0.08	0.11	0.15	0.14	0.06	0.07	0.12	0.15
Proportion high DOC indicators (s, b)	1.00	0.99	0.53	0.41	0.49	0.50	1.00	0.98	0.97	0.68	0.55	0.79	0.55	0.94	0.00	0.00	0.13	0.15	0.25	0.04	0.33	0.44
Proportion high DOC indicators (s, sp)	0.75	0.27	0.24	0.24	0.28	0.21	0.33	0.27	0.23	0.29	0.16	0.20	0.22	0.23	0.27	0.13	0.22	0.17	0.18	0.13	0.19	0.27
Proportion low TP indicators (s, sp)	0.00	0.00	0.09	0.05	0.06	0.08	0.00	0.05	0.05	0.03	0.08	0.13	0.06	0.00	0.00	0.04	0.15	0.10	0.14	0.06	0.09	0.09
Proportion non-reference indicators (s, b)	1.00	0.99	0.54	0.41	0.50	0.51	1.00	0.99	0.97	0.70	0.56	0.81	0.55	0.94	0.01	0.01	0.15	0.18	0.27	0.09	0.35	0.46
Proportion non-reference indicators (s, sp)	0.50	0.20	0.15	0.14	0.19	0.21	0.20	0.27	0.18	0.19	0.16	0.17	0.22	0.23	0.20	0.09	0.19	0.13	0.18	0.13	0.16	0.18
Proportion of green algae belonging to CRUS (s, b)	1.00	0.99	0.54	0.50	0.50	0.48	1.00	0.98	0.97	0.66	0.58	0.79	0.89	0.94	0.00	0.00	0.00	0.00	0.23	0.00	0.31	0.47
Proportion ZHR (s, b)	0.00	0.01	0.42	0.35	0.45	0.37	0.00	0.01	0.02	0.29	0.37	0.19	0.04	0.06	0.58	0.83	0.50	0.33	0.55	0.57	0.65	0.19
Proportion ZHR (s, m)	0.00	0.11	0.35	0.27	0.35	0.28	0.00	0.05	0.08	0.22	0.24	0.20	0.05	0.07	0.41	0.61	0.45	0.33	0.56	0.50	0.52	0.22
Proportion ZHR (s, sp)	0.00	0.20	0.29	0.18	0.26	0.20	0.00	0.09	0.14	0.14	0.12	0.20	0.05	0.08	0.24	0.39	0.41	0.32	0.57	0.44	0.39	0.26
*MMI_SoCal_H20_2012 Score	39	52	64	51	31	61	45	40	60	48	70	65	30	28	42	54	65	54	54	58	59	46

Notes

(1) Syar Pond station was moved upstream from 114RR2769 to 114RR2678 after the summer dam was inflated

DO =Dissolved Oxygen; TP =Total Phosphorus; TN =Total Nitrogen; DOC =Dissolved Organic Carbon; MMI = multi-metric index

CRUS =Cladophora glomerata+Rhizoclonium hieroglyphicum+Ulva flexuosa+Stigeoclonium spp; ZHR =Zygnemataceae+heterocystous cyanobacteria+Rhodophyta;

"d" =derived from the diatom assemblage; "s" = derived from soft algae; "sp" =based on species presence; "b" =based on biovolume; "m" = average of the "b" and "sp" counterpart metric values.

*Fetscher et al 2014a

Appendix G: Physical Habitat, substrate composition and benthic algal cover observation summaries

Table G-1: Select physical habitat observations in South Fork Eel River Study area, 2010

Reach	Station Code	Date	Average water depth estimate (m)	Average estimated wetted width (m)	Estimated velocity average at sampling time (f/sec)	DOMINANT substrate estimate (percent, derived from 11 observations of size-class estimates) (Note 1)					Dominant substrate diameter Geometric mean (Dgm)
						% Cobble (64-250mm)	% Gravel - coarse (16-64mm)	% Gravel - fine (2-16mm)	% Sand (0.06-2mm)	% Fines (<0.06mm)	
REACH 1	111SF2538	7/15/2010	NR	37	1.7	NR	NR	NR	NR	NR	NR
(Sylvandale)	111SF2538	8/3/2010	0.3	42	1.7	27	73	0	0	0	46.6
	111SF2538	8/24/2010	0.3	27	1.2	0	100	0	0	0	32.0
	111SF2538	9/15/2010	0.4	31	1.1	0	100	0	0	0	32.0
	111SF2538	10/3/2010	0.3	42	0.9	45	36	18	0	0	43.6
REACH 2	111SF1944	7/15/2010	NR	32	1.7	NR	NR	NR	NR	NR	NR
(Phillipsville)	111SF1944	8/3/2010	0.3	37	1.7	0	100	0	0	0	32.0
	111SF1944	8/24/2010	0.2	37	1.5	0	82	18	0	0	23.4
	111SF1944	9/15/2010	0.2	40	0.7	0	82	18	0	0	23.4
	111SF1944	10/5/2010	0.2	45	1.1	0	100	0	0	0	32.0
REACH 3	111SF1569	7/14/2010	NR	88	1.4	NR	NR	NR	NR	NR	NR
(Miranda)	111SF1569	8/2/2010	0.2	56	1.0	9	91	0	0	0	36.3
	111SF1569	8/25/2010	0.2	91	0.9	0	36	64	0	0	10.6
	111SF1569	9/14/2010	0.3	29	0.9	0	45	55	0	0	12.4
	111SF1569	10/4/2010	0.2	40	1.0	27	36	36	0	0	24.8
REACH 4	111SF1016	7/14/2010	NR	118	1.0	NR	NR	NR	NR	NR	NR
(Myers Flat)	111SF1016	8/2/2010	0.3	71	1.0	18	55	18	0	9	14.1
	111SF1016	8/25/2010	0.3	114	1.0	0	45	45	9	0	10.7
	111SF1016	9/14/2010	0.3	83	0.6	0	64	36	0	0	17.0
	111SF1016	10/4/2010	0.2	106	0.7	9	64	9	18	0	16.8

NR = Not Recorded

Note 1: Substrate sizes other than listed were not encountered

Table G-2a: Sampled substrate composition and benthic algal cover in South Fork Eel River study area, 2010

			(Notes 1,2,3)				Sampled substrate composition, Reach-wide (percent, derived from 11 size-class determinations) (Note 4)					
Reach	**Station Code**	**Date**	Micro-Algae Average Thickness (among all transect points)	Micro-Algae Average Thickness (only where detected)	Percent presence of a micro-algae layer (any thickness)	Macroalgae-Attached - Presence frequency (all points, %)	% Cobble (64-250mm)	% Gravel - coarse (16-64mm)	% Gravel - fine (2-16mm)	% Sand (0.06-2mm)	% Fines (<0.06mm)	**Sampled** substrate diameter Geometric mean (Dgm)
REACH 1	111SF2538	7/15/2010	NR	NR	NR	NR	64	36	0	0	0	76.7
(Sylvandale)	111SF2538	8/3/2010	0.37	0.37	100	**36**	82	9	0	0	0	157.7
	111SF2538	8/24/2010	1.70	1.70	100	**55**	82	0	0	0	0	229.7
	111SF2538	9/15/2010	0.37	0.37	100	**91**	91	0	9	0	0	95.4
	111SF2538	10/3/2010	0.13	0.13	100	**100**	82	9	0	0	0	143.5
REACH 2	111SF1944	7/15/2010	NR	NR	NR	NR	36	64	0	0	0	52.7
(Phillipsville)	111SF1944	8/3/2010	0.60	0.60	100	45	73	9	9	0	0	95.4
	111SF1944	8/24/2010	0.79	0.79	100	100	91	9	0	0	0	111.6
	111SF1944	9/15/2010	1.96	1.96	100	100	64	18	18	0	0	56.0
	111SF1944	10/5/2010	0.37	0.37	100	73	91	0	9	0	0	95.4

Series of numbers in **bold font** indicate a seasonal gradient.

Notes

1. Coarse Particulate Organic Matter (CPOM) and macrophytes were absent on all substrate samples
2. Unattached macroalgae were recorded on 1 point only (of a total of 176 study points) [18% at 111SF1016 on 8/25/2010]
3. There were only 1 points with a thick micro-algae layer (>3mm) [111SF1944 on 8/24/2010]
4. Substrate sizes other than listed were not encountered, except for 3 boulders and 2 bedrock determinations

Table G-2b: Sampled substrate composition and benthic algal cover in South Fork Eel River study area, 2010

Reach	Station Code	Date	(Notes 1,2,3)				Sampled substrate composition, Reach-wide (percent, derived from 11 size-class determinations) (Note 4)					
			Micro-Algae Average Thickness (among all transect points)	Micro-Algae Average Thickness (only where detected)	Percent presence of a micro-algae layer (any thickness)	Macroalgae-Attached - Presence frequency (all points, %)	% Cobble (64-250mm)	% Gravel - coarse (16-64mm)	% Gravel - fine (2-16mm)	% Sand (0.06-2mm)	% Fines (<0.06mm)	**Sampled** substrate diameter Geometric mean (Dgm)
REACH 3 (Miranda)	111SF1569	7/14/2010	NR	NR	NR	NR	55	9	36	0	0	36.1
	111SF1569	8/2/2010	0.17	0.17	100	**45**	55	45	0	0	0	67.7
	111SF1569	8/25/2010	0.13	0.13	100	**82**	45	36	18	0	0	43.6
	111SF1569	9/14/2010	0.16	0.20	82	**91**	73	0	18	9	0	46.7
	111SF1569	10/4/2010	0.04	0.04	82	**100**	73	0	27	0	0	54.2
REACH 4 (Myers Flat)	111SF1016	7/14/2010	NR	NR	NR	NR	18	73	0	0	9	19.3
	111SF1016	8/2/2010	0.06	0.14	45	**27**	64	9	18	0	9	26.3
	111SF1016	8/25/2010	0.04	0.05	82	**55**	36	18	36	9	0	20.7
	111SF1016	9/14/2010	0.21	0.23	91	**82**	27	36	27	0	9	13.6
	111SF1016	10/4/2010	0.20	0.28	73	**82**	70	10	0	20	0	42.6

Series of numbers in **bold font** indicate a seasonal gradient.

Notes

1. Coarse Particulate Organic Matter (CPOM) and macrophytes were absent on all substrate samples
2. Unattached macroalgae were recorded on 1 point only (of a total of 176 study points) [18% at 111SF1016 on 8/25/2010]
3. There were only 1 points with a thick micro-algae layer (>3mm) [111SF1944 on 8/24/2010]
4. Substrate sizes other than listed were not encountered, except for 3 boulders and 2 bedrock determinations