Benthic Cyanobacteria and Cyanotoxin Monitoring in Northern California Rivers, 2016-2019

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Freshwater Harmful Algal Bloom (FHAB) Monitoring and Response Program
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Executive Summary

Cyanobacteria are ubiquitous in freshwater systems but are often only visible with a microscope. Cyanobacteria become harmful when planktonic or benthic forms proliferate, or bloom, and produce cyanotoxins at concentrations that can impact human and animal health. Planktonic or floating blooms in lakes and large rivers have been well-researched and have thresholds that have been developed for the protection of human and animal health. Less is known about benthic blooms, or cyanobacteria that form mats on the bottom surfaces of waterbodies, which are less recognizable and require additional research to develop comparable thresholds.

Benthic cyanobacterial blooms in California's North Coast Region pose a health risk to the recreating public and are responsible for several dog deaths in the Eel, South Fork Eel, and Russian Rivers. To better understand benthic cyanobacterial growth and cyanotoxin production in these rivers, extensive monitoring was conducted from 2016 to 2019 to determine: 1) what cyanobacterial genera are responsible for the formation of toxic benthic mats; 2) what cyanotoxins are being produced; 3) which cyanotoxins are associated with the various mat-forming cyanobacterial genera; and 4) are there spatial and seasonal patterns to mat formation and cyanotoxin production.

Using multiple monitoring approaches, the North Coast Regional Water Quality Control Board identified several toxigenic cyanobacteria of concern, most notably *Anabaena, Microcoleus* (*Phormidium*), and *Oscillatoria.* While low concentrations of all measured cyanotoxins were found in the water column, anatoxins, a class of potent neurotoxins produced by cyanobacteria, were determined to frequently occur at high concentrations within benthic mats. Cyanobacterial growth and cyanotoxin production occurred throughout all sampling sites in the Eel, South Fork Eel, and Russian Rivers, and increased during the summer months until early fall.

The North Coast Regional Water Quality Control Board assessed the efficacy of several sampling techniques and recommends a stepwise approach for benthic cyanobacterial monitoring. Visual surveillance of toxigenic cyanobacterial mats should be employed as a primary tool for monitoring potential health risks in riverine systems, focusing on benthic mats dominated by *Anabaena*, *Microcoleus* (*Phormidium*), and *Oscillatoria*. Additionally, Solid Phase Adsorption Toxin Tracking (SPATT) samplers should be deployed throughout a river beginning early in the season to document when dissolved cyanotoxins are present and increasing in concentration. As cyanotoxin concentrations in the SPATTs increase and visual observation documents the proliferation of mat forming toxigenic benthic cyanobacteria, cyanotoxin testing of mats should be employed to determine the potential health risks associated with river recreation. Riverine cyanotoxin monitoring programs should focus on anatoxins due to their prevalence. To document more fully the potential risk of exposure to humans and animals through ingestion of mat material, laboratory cyanotoxin analysis should rely on the ELISA method since it provides a more cumulative measurement of cyanotoxin congeners.

Although this report documents the presence of cyanobacteria, cyanotoxins, and their spatiotemporal patterns in the study rivers, research is needed to identify the environmental conditions and controllable factors that influence benthic bloom development.

Preface

The data and information contained within this report documents the North Coast Regional Water Quality Control Board staff's current understanding of benthic cyanobacterial conditions within the Russian, Eel, and South Fork Eel Rivers as they relate to the protection of human and pet health and provides recommendations for future monitoring efforts. This report focuses on mat-forming benthic cyanobacteria and their cyanotoxins, expanding on the research included in the North Coast Algae and Nutrients Study 2010-2011.

The North Coast Regional Water Quality Control Board Cyanobacteria Freshwater Harmful Algal Bloom (FHAB) Monitoring and Response Program was initially designed to document the presence of cyanobacteria and associated cyanotoxins in the Eel, South Fork Eel, and Russian Rivers. Since its inception, the FHAB program has expanded to include additional monitoring and research efforts focused on increasing the understanding of benthic cyanobacteria and cyanotoxin production in riverine systems. The data collected and knowledge shared among researchers throughout the United States and New Zealand has provided the Water Board and the State of California with tools necessary for the development of a robust statewide cyanobacterial monitoring program.

FHAB program staff at the North Coast Regional Water Quality Control Board have been instrumental in assisting with the development of:

- Standard Operating Procedure (SOP) for benthic cyanobacteria sample collection
- A Visual Guide to Observing Blooms
- Benthic freshwater harmful algal bloom advisory signage for posting affected waterbodies
- The State of California's Freshwater Harmful Algal Blooms (FHAB) Ambient Monitoring Strategy (currently in development)
- Three peer reviewed journal articles:
    1. Multiple cyanotoxin congeners produced by sub-dominant cyanobacterial taxa in riverine cyanobacterial and algal mats.
    2. Molecular and morphological characterization of a novel dihydroanatoxin-a producing Microcoleus species (cyanobacteria) from the Russian River, California, USA.
    3. Extracts from benthic anatoxin-producing Phormidium are toxic to three macroinvertebrate taxa at environmentally relevant concentrations.
- Two manuscripts currently under development for future publication in peer reviewed journals:

1. Monitoring for cyanotoxins in the Eel and Navarro River watersheds using in situ toxicity tests.
2. The use of DNA metabarcoding for the identification of cyanobacteria in Northern California rivers.

List of Acronyms

AFDM	Ash-Free Dry Mass
ATX	Anatoxins
CCHAB	California Cyanobacteria and Harmful Algal Bloom Network
CYN	Cylindrospermopsins
ELISA	Enzyme-Linked Immunosorbent Assay
FHAB	Freshwater Harmful Algal Bloom
HAB	Harmful Algal Bloom
LCMS	Liquid Chromatograph with Mass Spectrometry
MCY	Microcystins
MPSL	Marine Pollution Studies Laboratory
MQO	Measurement Quality Objective
NCRWQCB	North Coast Regional Water Quality Control Board
NOD	Nodularins
OEHHA	Office of Environmental Health Hazard Assessment
SOP	Standard Operating Procedure
SPATT	Solid Phase Adsorption Toxin Tracking
STX	Saxitoxins
SWAMP	Surface Water Ambient Monitoring Program
USEPA	United States Environmental Protection Agency

Glossary

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

Benthic – refers to organisms that attach to the bottom substrates of rivers or other waterbodies.

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

Cyanobacteria – historically referred to as “blue-green” algae, they are actually bacteria (i.e., prokaryotes) that contain chlorophyll-a and are capable of photosynthesis. Cyanobacteria co-occur with “true” algae (i.e., eukaryotes).

Cyanotoxins – toxic molecules produced by cyanobacteria that through contact can affect the skin (i.e., dermatoxins), or through ingestion can affect the liver (i.e., hepatotoxins) and central nervous system (i.e., neurotoxins).

Harmful algal blooms (HABs) – a “bloom” is a 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.

Measurement quality objective (MQO) – specific goals defined by data users that clearly describe the data quality that is sought for the project. The quality assurance program should focus on the definition, implementation and assessment of MQOs that are specified for the sampling.

Plankton – refers to organisms that are free-floating in the open water.

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

Reachwide – method for biotic assemblage sample collection that does not target a specific substrate type, but rather systemically selects sampling locations across the reach, allowing for any of a number of substrate types to be represented in the resulting composite sample.

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

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1 Introduction

1.1 Study Rationale and Objectives

Between 2001-2021, there have been 18 suspected or documented dog deaths in the California North Coast Region attributed to cyanobacterial harmful algal blooms (cyanoHABs). These deaths were a result of incidental ingestion of toxigenic benthic cyanobacterial mats. Animal deaths like these are significant since they often provide warnings of potential human health risks, particularly for sensitive groups like children (Hilborn and Beasley, 2015; Backer and Miller, 2016). In 2014 and 2021, human illnesses have also been attributed to cyanoHAB exposure in the Trinity River and South Fork Eel River in Northern California, respectively. In the State of California, different research or monitoring programs are measuring cyanobacteria and their cyanotoxins to better understand their occurrence and health impacts across the state.

The purpose of this study was to collect data to inform the development of a benthic cyanobacterial monitoring program for the protection of the recreating public and pets[1] in the California North Coast Region. To this end, monitoring sites were established in three rivers with a history of benthic cyanobacterial blooms: the Eel River, South Fork Eel River, and Russian River. Staff collected ambient water column grab samples, cyanobacterial mat samples, and deployed Solid Phase Adsorption Toxin Tracking (SPATT) samplers to characterize the occurrence and diversity of cyanobacteria and their cyanotoxins in these rivers. Although multiple sampling techniques were employed to evaluate the presence of cyanobacteria and cyanotoxins, this study was not designed to identify the environmental conditions and controllable factors that cause biostimulatory conditions and influence benthic bloom development. Specifically, sampling results from this study were used to answer the following questions:

1) What cyanobacterial genera are responsible for the formation of toxic benthic mats in the Eel, South Fork Eel, and Russian Rivers?
2) What cyanotoxins are being produced in the Eel, South Fork Eel, and Russian Rivers?
3) Which cyanotoxins are associated with the various mat-forming cyanobacterial genera?
4) Are there spatial and seasonal patterns to mat formation and cyanotoxin production in the Eel, South Fork Eel, and Russian Rivers?

Results from the study were used to provide sampling recommendations for future monitoring programs. Although a summary of these recommendations is provided in the latter sections of this report, a more detailed framework will be required for implementation.

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[1] This monitoring program addresses ambient water and benthic cyanobacteria populations, focusing on the protection of the recreating public and pets. The monitoring results, discussion, and recommendations do not address nor lend themselves to the evaluation of drinking water concerns.

1.2 Cyanobacteria Overview

Cyanobacteria are photosynthetic bacteria found throughout the world (Huisman et al., 2018), including the lakes, reservoirs, rivers, and streams of Northern California (Fetscher et al. 2015; Bouma-Gregson et al., 2018). Although they are natural components of healthy aquatic ecosystems, when environmental factors are favorable, cyanobacterial cells will grow rapidly causing nuisance planktonic blooms or extensive benthic mats, both commonly called cyanobacterial harmful algal blooms or cyanoHABs. CyanoHABs are considered harmful because some cyanobacterial genera can produce toxic compounds (i.e., cyanotoxins) that have serious health effects for humans and animals. These cyanotoxins can result in impacts to drinking water, recreation, aquatic life, domestic animals, and wildlife.

CyanoHABs can occur in various forms and in different habitats. Cyanobacteria can grow in the open water of lakes, reservoirs, and large rivers (e.g., Sacramento-San Joaquin Delta or Ohio River). In the open water, cyanobacteria are planktonic since cells grow suspended in the sunlit upper portions of the water column. Because they can float, many planktonic cyanobacterial species form surface scums that pose a heightened health risk due to the concentration of cyanotoxins at the water surface where they can be more easily ingested. Cyanobacteria can also form mats that are attached to benthic or bottom surfaces of a waterbody (e.g., rocks, sand, woody debris, aquatic vegetation) (Quiblier et al., 2013; Wood et al. 2020). Benthic cyanobacterial cells produce mucus which binds cells together and gives structure and strength to the mat. Mats are the most common form of cyanoHABs in wadeable streams and rivers but can also occur in lakes. Planktonic cyanoHABs have been documented for centuries (Kirkby, 1672; Francis, 1878) while benthic mats have only received research attention in the last couple decades (Quiblier et al., 2013; Fetscher et al., 2015; Wood et al., 2020).

Benthic mat-forming cyanobacteria are known to occupy many ecological niches within the riverine system, from slow-moving backwater locations to swift water riffle and cascade habitats. Mats may remain sporadic and patchy, or they may cover large areas which may dominate portions of the riverbed. In some instances, a river reach may contain numerous habitats containing dozens of cyanobacterial species with the potential to produce several cyanotoxins at the same time, however, not all mat forming cyanobacteria are toxigenic or produce cyanotoxins. Benthic cyanobacteria have been implicated in canine mortalities in California, Utah, Texas, New Zealand, France, and Canada (Wood et al., 2020).

Benthic cyanobacterial growth can be episodic and ephemeral. Mats begin to develop in the spring as days lengthen, water temperatures warm, and when flows decrease and water clarity increases after winter rains cease. The timing of mat growth varies from year to year and species to species, though mat growth and expansion generally occurs over weeks, and mats can persist throughout the summer growing season (Bouma-Gregson et al., 2018; McAllister et al., 2018; Thomson-Laing et al., 2021).

Eventually, mats age and detach from their substrates and float to the surface where they are then transported downstream. Detached mats can remain floating for several days and clumps of floating mats often accumulate in slow flowing portions of the river or may become stranded along the shore (Bouma-Gregson et al., 2017). Because of their mobility and accumulation at recreational beaches or swimming holes, detached floating mats pose a heightened risk to public health in comparison to those that are submerged and remain attached to substrates.

1.3 Cyanotoxins Overview

Both planktonic and benthic cyanobacteria produce dozens of different cyanotoxin molecules that are toxic to humans and animals (Chorus and Welker, 2021a). Although cyanotoxins have diverse chemical structures, they generally affect the nervous system (neurotoxins), liver (hepatotoxins), skin (dermatoxins), and sometimes kidneys (nephrotoxins). Not all cyanobacterial species or strains produce cyanotoxins, and the function of cyanotoxins within cyanobacterial cells is still not clearly understood (Huisman et al., 2018). The North Coast Regional Water Quality Control Board (hereafter referred to as Regional Water Board) analyzed samples for five common cyanotoxins; their mode of action and health effects are presented below (Table 1).

Table 1. The five cyanotoxins monitored by the Regional Water Board.

Toxin Class	Toxin Type	Acute Health Effects
Anatoxins (ATX)	Neurotoxin	Tingling, burning, numbness, drowsiness, incoherent speech, salivation, respiratory paralysis leading to death.
Cylindrospermopsins (CYN)	Hepatotoxin, Nephrotoxin	Fever, headache, vomiting, bloody diarrhea.
Microcystins (MCY)	Hepatotoxin	Abdominal pain, headache, sore throat, vomiting and nausea, dry cough, diarrhea, blistering around the mouth, and pneumonia.
Nodularins (NOD)		
Saxitoxins (STX)	Neurotoxin	Nausea, vomiting, a floating sensation, headache, muscle weakness, respiratory paralysis leading to death.

Cyanotoxins are grouped into classes that contain multiple congeners, or toxins with slight variations on the same general molecular structure. Anatoxins include the congeners anatoxin-a, homoanatoxin-a, dihydro-anatoxin, and dihydro-homoanatoxin. New research suggests that dihydro-anatoxin may be a more potent cyanotoxin than anatoxin-a when ingested (Puddick et al., 2021). Additionally, dihydro-anatoxin has been found to elicit a toxic affect in benthic macroinvertebrates when present in the water column (Anderson et al., 2018). Dihydro-anatoxin has been detected in extracts from a species of *Microcoleus* (*Phormidium*) collected in the Russian River in 2015 (Conklin et al., 2020).

Cylindrospermopsins include five potential congeners, two of which have been documented as naturally occurring (deoxy-cylindrospermopsin, epi-cylindrospermopsin); additional research is needed to determine whether the other three cylindrospermopsin analogs are actual congeners, precursory molecules, or degradation products (USEPA 2019). There are over 200 congeners of microcystins with microcystin-LR being the most common and having the most toxicological data. The most toxic microcystins include microcystin-LR, -LA, and -YR (USEPA 2019). Microcystins and nodularins have similar molecular structures and health effects and are often reported together since some analytical methods cannot differentiate the two molecules. There are 57 known congeners of saxitoxin. Saxitoxins are responsible for paralytic shellfish poisoning in humans and animals.

There are three common pathways through which humans or animals are exposed to cyanotoxins: ingestion, contact, or inhalation (Chorus and Welker, 2021b). Ingestion is the pathway of greatest concern since consumption of cyanobacterial cells can deliver a large dose of cyanotoxins to a human or animal. Through contact with the skin, some cyanotoxins (e.g., aplysiatoxin) can cause rashes or other irritation, however, all cyanobacterial cells contain molecules on their cell membranes that may cause irritation; these molecules are not generally considered cyanotoxins. Lastly, cyanobacterial cells and cyanotoxins can become aerosolized within small water droplets and then inhaled (Backer et al., 2010; Plaas and Paerl, 2020); the health implications of this exposure pathway are poorly understood.

Only recently have criteria or trigger levels been developed in the United States and in the State of California for the protection of public health based upon the exposure to planktonic cyanobacteria and their cyanotoxins (USEPA, 2015a; USEPA 2015b; CCHAB, 2016; USEPA 2019). The development of these criteria and trigger levels were based upon extensive research into planktonic cyanobacterial blooms, which proliferate in lakes, reservoirs, and large river systems. Unlike planktonic cyanobacteria, the routes of exposure and potential risks associated with benthic cyanotoxin producers are only now being questioned and investigated by researchers. Until criteria or guidance are developed to explicitly address benthic-produced cyanotoxins, resource managers must rely upon planktonic-derived criteria and trigger levels to determine any potential health risks from cyanotoxins produced in benthic mats (see *Comparing to Trigger Levels* for more information).

1.4 Watershed and Site Description

River flows in Northern California are strongly influenced by a Mediterranean climate, which is characterized by hot, dry summers and cool, wet winters. During the dry season, generally May through September, coastal areas experience marine layers defined by morning fog and overcast conditions, whereas inland areas are typically hot and dry. The precipitation dominated flows of the winter and spring give way to groundwater or reservoir-release dominated flows through the summer and fall.

These conditions set up an environment which may be conducive to the proliferation of benthic cyanobacterial mats by creating periods of stable flow, temperature, and light availability. Flow regimes and other watershed information are described below for the Eel, South Fork Eel, and Russian Rivers.

1.4.1 Eel River Watershed

The mainstem Eel River watershed (less the South Fork Eel River subwatershed) is a 3,283 mi^2 watershed in southern Humboldt and northern Mendocino Counties with elevation that ranges from sea level to 6,245 feet. The river flows for approximately 200 miles from headwaters in the coastal mountains of Lake and Mendocino Counties down to the mouth near Eureka, California. The Eel has four major tributaries: the North Fork, Middle Fork, South Fork, and Van Duzen Rivers. The river supports various types of recreation including whitewater kayaking, flatwater boating, fishing, and swimming.

The mainstem Eel River has two dams, Scott Dam and Van Arsdale Dam, located in the uppermost section of the river. Flows in the upper section of the river are controlled by releases from these dams, however, as the Eel River flows toward the ocean, the addition of waters from several major undammed tributaries transitions the managed upper reaches to a more natural flow regime in the middle and lower sections. In the managed upper section of the Eel River, median seasonal flows (June 1-October 8) in 2016, 2018, and 2019 were in the lower 25th percentile of the period of record (2007-2019) while 2017 was in the upper 25th percentile (Figure 1). There are no flow gages in the middle section of the river to compare the flow conditions in 2016-2019 to that of historical averages.

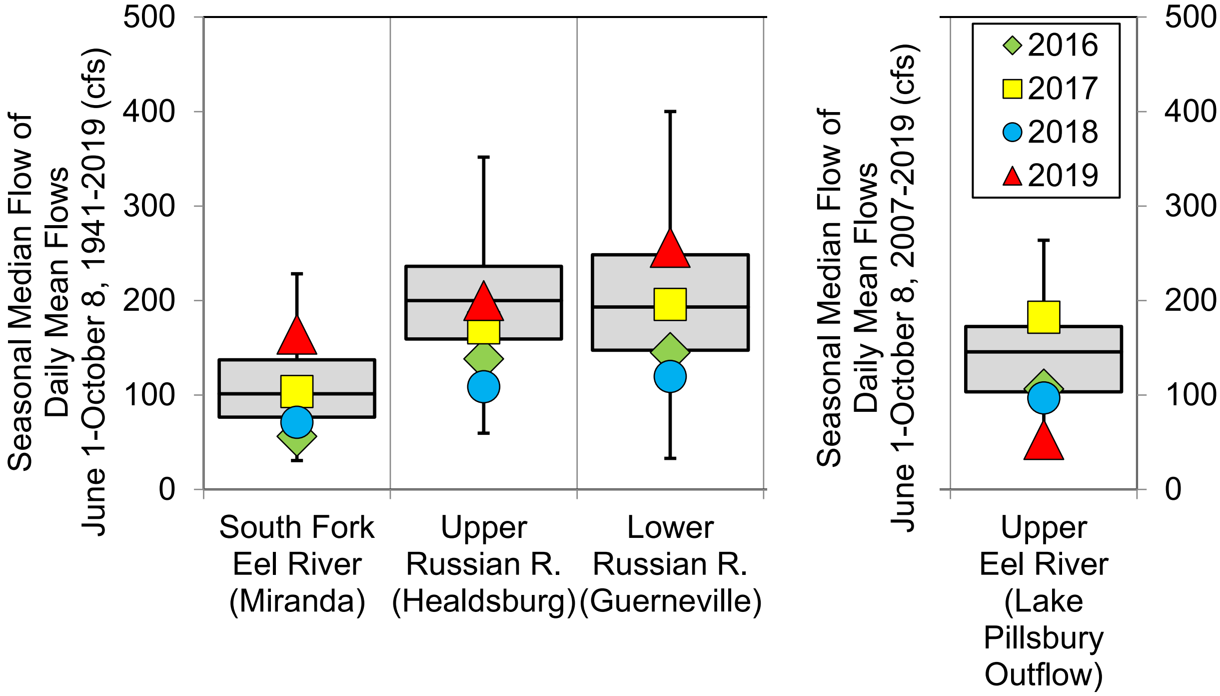

Figure 1. Flow in cubic feet per second (cfs) recorded at USGS gages in the Eel River, South Fork Eel River, and Russian River, from 2016 to 2019.

Approximately 95% of the annual rainfall in the Eel River occurs between October and April. Based on data recorded in Willits, CA, precipitation totals for the upper reach of the Eel River in 2017 and 2019 were in the upper 25th percentile for the period between 1989-2019, while 2016 was above the 50th percentile and 2018 was a drier year with total rainfall in the lower 25th percentile (Figure 2). In the middle section near Laytonville, the precipitation totals for 2016 and 2019 were similar to that of the upper section, while 2017 was wetter and 2018 was the driest year through that time period.

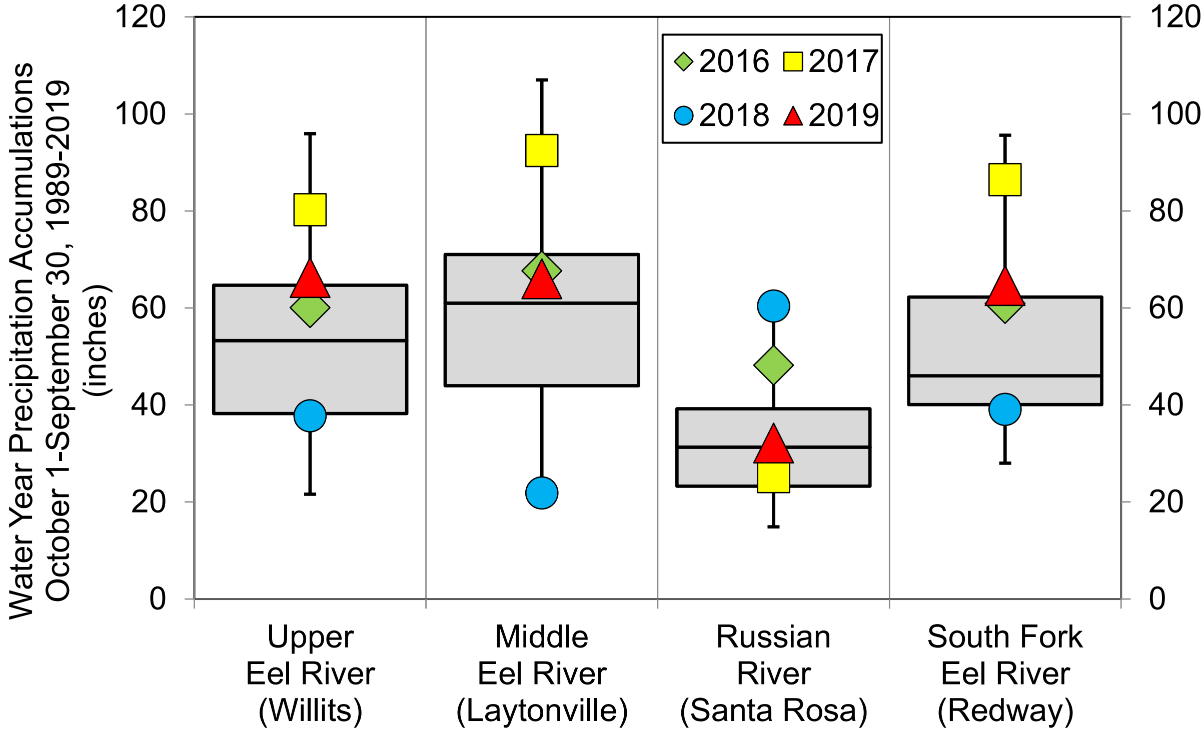

Figure 2. Precipitation in inches recorded at meteorological stations near the Eel River, South Fork Eel River, and Russian River, from 2016 to 2019.

Water temperatures varied in the upper reach of the Eel River. The upper reach site is located approximately 8 miles downstream of Lake Pillsbury and strongly influenced by the reservoir releases. The seasonal median of the daily maximum temperatures varied with 2016 and 2019 in the upper 25th percentile for the period between 2007-2021, while 2017 was above the 50th percentile and 2018 below the lower 25th percentile (Figure 3). There are no water temperature gages in the middle section in which to compare the water temperature conditions in 2016-2019 with that of historical averages.

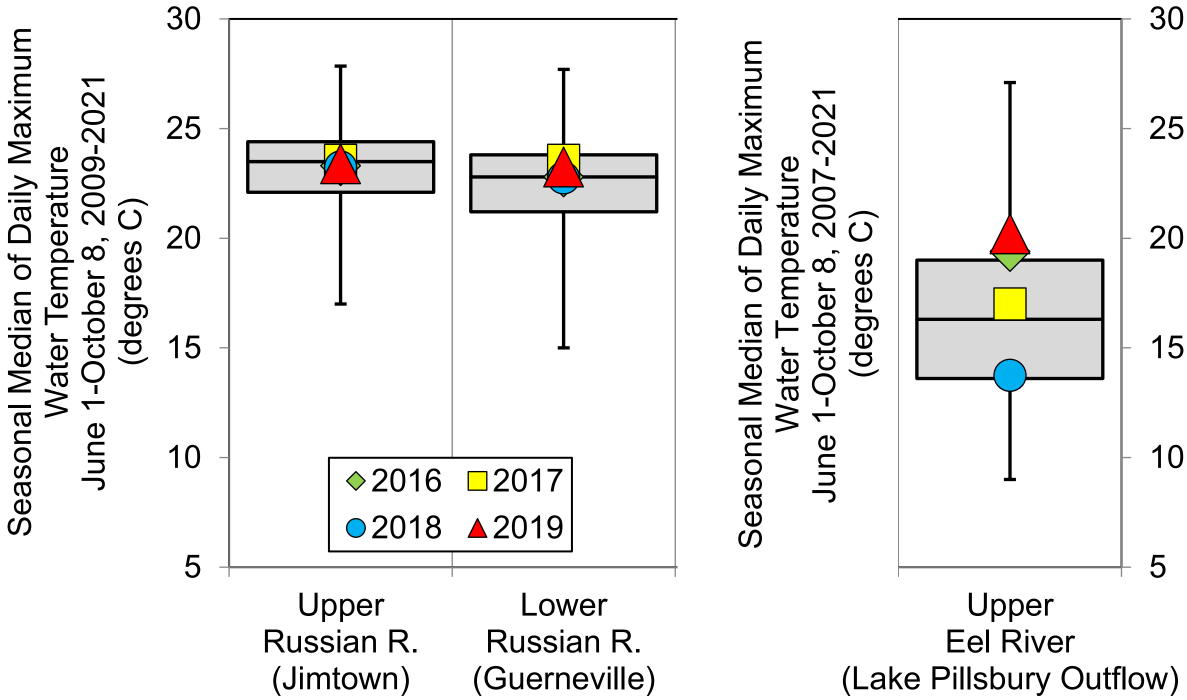

Figure 3. Water temperature in degrees Celsius (C) recorded at USGS gages in the Eel River and Russian River, from 2016 to 2019.

1.4.2 South Fork Eel River Watershed

The South Fork Eel River is a 688 mi^2 watershed located in northern Mendocino and southern Humboldt Counties, with elevations that range from 100 to 4,500 feet. The South Fork Eel River flows northward for approximately 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 joins the mainstem Eel River upstream of the town of Weott, approximately 40 river miles from the Pacific Ocean. Like the mainstem Eel River, the South Fork Eel River is heavily recreated with many access points along its length.

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. The median seasonal flows (June 1-October 8) in 2016 and 2018 were in the lower 25th percentile of the period of record, while 2017 was just above the 50th percentile and 2019 was in the upper 25th percentile (Figure 1).

The annual median rainfall as measured near Redway (CalFire Eel River Camp) is 47 inches. Approximately 93% of the annual rainfall occurs between October and April. Precipitation totals for 2016, 2017, and 2019 were all in the upper 25th percentile for the period between 2001-2021, while 2018 was a drier year with total rainfall in the lower 25th percentile (Figure 2).

There are no long-term water temperature data available for the South Fork Eel River.

1.4.3 Russian River Watershed

The Russian River is a 1,485 mi^2 watershed located in Sonoma and southern Mendocino Counties 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 is a highly regulated river with two large dam impoundments on two primary tributaries and several seasonal summer dams on the river's mainstem. The impoundments modify the natural flows of the river by decreasing the high flows of winter and increasing the low flows of summer. Except for large storm events, the flows in the upper Russian River are dominated by releases from Lake Mendocino and those of the lower Russian River are generally increased with the addition of outflow from Lake Sonoma. The median seasonal flows (June 1-October 8) in 2016 and 2018 were in the lower 25th percentile for the period of record between 1941-2019 (Figure 1). In 2017, median seasonal flow in the upper Russian River was between the 25th and 50th percentile, while flow in the lower Russian was at the 50th percentile. In 2019, upper Russian River flow was at the 50th percentile and the lower Russian River was at the 75th percentile.

The 23-year annual median rainfall as measured in Santa Rosa (1989-2019) is 31 inches. Approximately 95% of the annual rainfall occurs between October and April. Precipitation totals for 2016 and 2018 were in the upper 25th percentile while 2017 and 2019 were at or below the 50th percentile (Figure 2). Median of the daily maximum water temperatures varied very little for all study years and were around the 50th percentile (Figure 3).

The Russian River is heavily recreated with many access points along its length. The summertime reservoir releases provide sufficient flows for recreational activities and the distribution of drinking water within Mendocino, Sonoma, and Marin Counties. Several recreational summer dams and periodic closures of the river's mouth turn the lower sections of the Russian River into a series of shallow ponded sections connected by short free-flowing river segments. The summer seasonal flows remain relatively consistent throughout the summer season and year to year, providing a stable flow regime that allows for various ecological niches to develop within the river where benthic algae and cyanobacteria can establish and flourish.

2 Methods

2.1 Site Selection Criteria and Sampling Locations

Sampling sites in the Eel, South Fork Eel, and Russian Rivers were selected based on previously documented dog deaths, spatial representation, or recreational use (Table 2). For example, sampling was concentrated in the lower South Fork Eel between the towns of Redway and Myers Flat because a number of documented or suspected dog deaths have previously occurred in this region.

Table 2. Sampling sites in the Eel River, South Fork Eel River, and Russian River, from 2016 to 2019.

Site Code	Site Name	Site Rationale	Sample Year	Latitude	Longitude
111ER8102	Eel River at Trout Creek Campground	Dog Death	2016-2019	39.3750	-123.0628
111ER6381	Eel River above Outlet Creek	Spatial Representation	2016	39.6253	-123.3408
111ER6140	Eel River Upstream Dos Rios	Spatial Representation	2018-2019	39.6874	-123.3594
111SF6856	South Fork Eel River at Big Bend Lodge	Spatial Representation	2016-2019	38.8256	-123.6807
111SF4640	South Fork Eel River at Cooks Valley	Dog Death	2017-2019	40.0000	-123.7869
111SF2423	South Fork Eel River below Dean Creek	Dog Death	2016, 2019	40.1541	-123.7966
114RR7396	Russian River at Hopland USGS Gage	Spatial Representation	2016-2019	39.0263	-123.1303
114RR5407	Russian River at Cloverdale Airport	Spatial Representation	2016-2019	38.7738	-123.9898
114RR4234	Russian River at Alexander Valley Rd	Recreational Use	2016	38.6587	-122.8296

Site Code	Site Name	Site Rationale	Sample Year	Latitude	Longitude
114RR2655	Russian River Below Kabutts Rd	Dog Death	2016-2019	38.5599	-122.8543
114RR2079	Russian River Below Laguna de Santa Rosa	Spatial Representation	2017	38.4952	-122.8966
114RR1159	Russian River at Vacation Beach	Recreational Use	2016	38.4832	-123.0109

In the Eel River, site 111ER8102, the site of a dog death in 2015, is located within the managed section of the Eel River between the two dams where the flows remain consistent throughout the summer season. Sites 111ER6381 and 111ER6140 are located in the more natural flow regime of the middle section, upstream of the several major tributaries, and approximately 40 miles downstream of site 111ER8102 (Figure 4).

In the South Fork Eel River, sites 111SF4640 and 111SF2423 are located in the middle and lower sections, respectively, and are sites where dog deaths had previously been reported. Site 111SF6856 provides additional spatial context in the upper middle reach (Figure 4).

In the Russian River, site 114RR2655 was the site of one known and one suspected dog death in 2015. Sites 114RR1159 and 114RR4234 are heavily recreated sites in the lower and middle sections. Site 114RR2079 is located in a free-flowing region between two summer dams in the lower section, and sites 114RR5407 and 114RR7396 are located in the middle and upper sections, respectively (Figure 4).

Figure 4. Map of the sampling sites in the Eel River, South Fork Eel River, and Russian River, from 2016 to 2019.

2.2 Sampling Design and Rationale

2.2.1 Spatial Sampling

Sites, or sample reaches, were chosen using a targeted sampling design based on the history of cyanotoxin events, recreational use, or spatial representation, as well as accessibility of the site. Locations for each monitoring activity were selected within the river reach based upon individual reach conditions. Ambient water column grab samples were collected from the centroid of flow. Solid Phase Adsorption Toxin Tracking (SPATT) samplers were deployed to capture dissolved cyanotoxins over time in areas that provided flows across the sampler but were not high enough to damage it (see *2.3.4 Solid Phase Adsorption Toxin Tracking Passive Samplers* below for more information on SPATTs). Reachwide benthic mat samples were identified and collected from all habitats within a sample reach (e.g., riffles, pools, and along shoreline). The individual sample reaches varied in length from 50-150 meters.

2.2.2 Temporal Sampling

Each study component consisted of a number of visits per site during the sample period (May-October) from 2016 to 2019. Cyanobacteria and cyanotoxin samples were collected during the spring, summer, and fall to characterize cyanoHAB dynamics throughout the recreation season. Sample collection methods included both instantaneous (i.e., benthic mat samples, water grab samples) as well as integrative (i.e., SPATT samples) measurements.

2.2.3 Inventories of Monitoring Activities

The tables below show a summary of monitoring activities that were conducted in the mainstem Eel, South Fork Eel, and Russian Rivers during the study. Each of the field sampling type (i.e., characteristic group) are discussed in more detail in the following sections. The complete dataset associated with each monitoring activity can be found in Appendices 1-7.

Table 3. Summary of monitoring activities in the Eel River, from 2016 to 2019.

Characteristic Group	Medium	Activity Category	Field Activity	Laboratory Analysis	Season & Timing	Total Sites	Total Samples
Visual assessment	Benthic mat	Observation	Categorical observations	None	Spring, summer, fall	3	62
Benthic algae assemblages	Benthic mat	Collection	Benthic mat sampling	Taxonomic identification	Spring, summer, fall	3	58
Benthic algae biomass	Benthic mat	Collection	Benthic mat sampling	Ash-free dry mass	Summer, fall	2	30
Cyanotoxin concentration	Benthic mat & water	Collection	Benthic mat, water, and SPATT sampling	ELISA, LCMS	Spring, summer, fall	3	194

Table 4. Summary of monitoring activities in the South Fork Eel River, from 2016 to 2019.

Characteristic Group	Medium	Activity Category	Field Activity	Laboratory Analysis	Season & Timing	Total Sites	Total Samples
Visual assessment	Benthic mat	Observation	Categorical observations	None	Spring, summer, fall	3	102
Benthic algae assemblages	Benthic mat	Collection	Benthic mat sampling	Taxonomic identification	Spring, summer, fall	3	119
Benthic algae biomass	Benthic mat	Collection	Benthic mat sampling	Ash-free dry mass	Summer, fall	3	40

Characteristic Group	Medium	Activity Category	Field Activity	Laboratory Analysis	Season & Timing	Total Sites	Total Samples
Cyanotoxin concentration	Benthic mat & water	Collection	Benthic mat, water, and SPATT sampling	ELISA, LCMS	Spring, summer, fall	3	290

Table 5. Summary of monitoring activities in the Russian River, from 2016 to 2019.

Characteristic Group	Medium	Activity Category	Field Activity	Laboratory Analysis	Season & Timing	Total Sites	Total Samples
Visual assessment	Benthic mat	Observation	Categorical observations	None	Spring, summer, fall	6	112
Benthic algae assemblages	Benthic mat	Collection	Benthic mat sampling	Taxonomic identification	Spring, summer, fall	6	90
Benthic algae biomass	Benthic mat	Collection	Benthic mat sampling	Ash-free dry mass	Summer, fall	5	29
Cyanotoxin concentration	Benthic mat & water	Collection	Benthic mat, water, and SPATT sampling	ELISA, LCMS	Spring, summer, fall	6	300

2.3 Field Sampling

2.3.1 Visual Assessment

Visually identifying cyanotoxin-producing genera is an integral part of any benthic cyanoHAB monitoring program. To the untrained eye, benthic cyanoHABs are easily overlooked as they do not affect the appearance of the water, or they can be mistaken for harmless green algae and vice versa. Although a reachwide visual assessment of benthic mat conditions and cyanobacterial identification does not provide toxicity data for public health protection, it does provide information on timing, frequency, and magnitude of bloom development. Further, ongoing visual assessments of mat development and observations of cyanotoxin-producing genera can aid in establishing potential risk and appropriate response scenarios.

Qualitative visual assessments were performed at each sample site. Visual assessment included walking the length and breadth of the sample reach to coarsely estimate the percentage of benthic surfaces covered by green algae and cyanobacteria. Percentages were then binned into the categories listed in Table 6.

Table 6. Percent cover categories for benthic cyanobacteria.

Category	Percent Cover
Indeterminant	Flows or water clarity obscured the ability to assess conditions
Absent	No observable algae or cyanobacteria present
Minimal	< 5% cover
Present	5-24% cover
Common	25-49% cover
Abundant	50-99% cover
Complete	100% cover

2.3.2 Benthic Cyanobacterial Mat Samples

Benthic cyanobacterial mat samples were analyzed for concentrations of five common cyanotoxins (Table 1). Cyanotoxin testing of benthic mats capture the particulate component of cyanotoxin production, or what is present within the mat prior to extracellular release through natural cell death or cell death from incidental ingestion. Taxonomic identification of cyanobacteria was conducted under the microscope and identified cyanobacteria to at least the genus level.

Cyanobacterial mat samples were collected as one of two sample types: reachwide composites or single species dominant mat samples. Reachwide composite samples are qualitative and designed to document the presence of all cyanobacterial genera inhabiting a sample reach by proportionately collecting samples from each unique benthic mat. Cyanotoxin results from reachwide composites underreport public health risks since it integrates cyanotoxin concentrations across cyanotoxin producers and non-producers.

Single species dominant mat samples are composites from several mats that are dominated by a single genus or species. Results derived from testing multiple single species mats will also underreport public health risks since it averages cyanotoxin concentrations across mats that likely include areas of high and low cyanotoxin production.

Benthic mat samples were collected by gloved hand, scraper, or syringe. The appropriate collection method was chosen based on mat integrity and bottom substrate. Samples were collected and held in clear polystyrene or amber glass bottles. Taxonomic samples were stored in the dark at 4-6^{o} C and delivered to taxonomists for identification within 72 hours of sample collection. Cyanobacterial mat subsamples for cyanotoxin analysis were stored in the dark at 4-6^{o} C and delivered to the laboratory for analysis within 48 hours of sample collection. Any cyanotoxin samples exceeding a 48-hour hold time were stored at -20^{o} C and shipped frozen for overnight delivery.

2.3.3 Ambient Water Column Grab Samples

Ambient water column grab samples provide discrete measures of cyanotoxin concentrations at the time and location the sample is collected, measuring both the dissolved cyanotoxin fractions in the water column and any particulate (i.e., floating or suspended cyanobacterial cells) that may be present. Water column grab samples help characterize the potential exposure to the recreating public from wading, swimming, and other water contact activities. Although this type of sample collection is most applicable to documenting the risks associated with planktonic rather than benthic cyanobacteria, it is the only measure directly applicable to current public health criteria and guidelines (see *2.5.2 Comparing to Trigger Levels*).

Sample collection followed California's Surface Water Ambient Monitoring Program (SWAMP) standard operating procedures (SOPs) for harmful algal blooms (SWAMP 2017a). All water column samples were collected from well-mixed areas within the sampling reach. Samples were stored at 4-6^{o} C and delivered to the laboratory for analysis within 48 hours of sample collection. Any collected samples exceeding a 48-hour hold time were stored at -20^{o} C and shipped frozen for overnight delivery.

2.3.4 Solid Phase Adsorption Toxin Tracking (SPATT) Passive Samplers

Solid Phase Adsorbing Toxin Tracking (SPATT) samplers are “teabag-like” passive samplers constructed of an inert mesh and filled with a porous resin capable of adsorbing cyanotoxins (Kudela, 2017; Roue et al., 2018). SPATT results are reported as the mass of cyanotoxin per mass of resin (ng/g). Unlike surface water grab samples, which are a point-in-time measures, SPATT samplers are semi-integrative, adsorbing and desorbing dissolved cyanotoxins over time. Because adsorption and desorption rates vary as a function of environmental conditions and deployment length, SPATTS are considered to be semi-qualitative.

Cyanotoxin concentrations derived from SPATT samples are not applicable to health or water quality thresholds; however, SPATTs document the presence of various cyanotoxins over time, including those at low concentrations, which may otherwise be missed or undetectable when collecting a water grab sample alone.

SPATT samplers were deployed in accordance with SOPs for SPATT Assemblage and Extraction of HAB Toxins (Howard et al., 2018). SPATT samplers were attached to metal stakes and located in well-mixed zones within the sample reach. SPATTS were deployed for varying time periods ranging from 24 hours to 14 days in length. Upon retrieval, SPATTs were stored at 4-6^{o} C and delivered to the laboratory for analysis within 48 hours of sample collection. Any collected SPATTs exceeding a 48-hour hold time were stored at -20^{o} C and shipped frozen for overnight delivery.

2.4 Laboratory Analysis

2.4.1 Cyanobacteria Taxonomic Identification

Taxonomic identification of cyanobacteria in single species and reachwide benthic mat samples was conducted by California State University at San Marcos (CSUSM) and the Regional Water Board. Soft bodied algae or cyanobacteria were identified to at least the genus level, or the lowest taxonomic level possible, using a compound microscope. Identifications followed the Statewide Algae Bioassessment Program SOP for soft bodied algae (Stancheva et al., 2015); however, protocols used by the Regional Water Board may have been adjusted based on trainings and procedures provided by other entities (Rosen and Armand, 2015; Bend Genetics, 2018; My Water Quality: California HABs Portal, 2021).

2.4.2 Benthic Biomass Ash Free Dry Mass (AFDM)

Ash free dry mass (AFDM) analysis measures the amount of organic matter within a sample by drying and combusting a filtered benthic cyanobacterial mat sample. Mat samples include many forms of organic matter including multiple cyanobacterial species, green algae, bacteria, and organic debris. Although AFDM does not provide a quantitative measure of the biomass of the cyanobacterial mat sampled, it does provide a measurement of the organic material, which can be used to standardize cyanotoxin comparisons among samples.

AFDM was conducted by the Department of Fish and Wildlife's Water Pollution Control Laboratory in 2016 and Delta Environmental from 2017 to 2019. To determine the relative (normalized) toxicity of the various mats, the mat samples were first homogenized using a blender and subsequently subsampled. A 50 mL subsample was analyzed for cyanotoxins and a 5-25 mL sample (dependent upon mat texture and thickness) was filtered and frozen for AFDM analysis. The filter was then combusted and the AFDM on the filter calculated. The results provided a measure of cyanotoxin production per unit of cyanobacterial mat AFDM.

2.4.3 Cyanotoxin Enzyme-Linked Immunosorbent Assay (ELISA)

Enzyme-linked immunosorbent assay (ELISA) detects and quantifies cyanotoxins using reactive proteins or antibodies. ELISA measures multiple cyanotoxin congeners and cannot differentiate among congeners of a molecular structure. ELISA passively binds the cyanotoxins and their congeners to a membrane in a 96 well plate, then separates the non-bound material. A colorimetric measurement is then taken with the amount of toxin bound to the membrane being proportional to a color change in each well. ELISA provides a total concentration of several detectable cyanotoxin congeners that may be in the sample. The methodology has been tested to determine which congeners may cross-react with the target cyanotoxin, though not all congeners of each cyanotoxin have been tested (Table 7). Cross-reactivity is expressed as percentages which represents the assays relative response to specific congeners. All ELISA laboratory analyses were performed using Abraxis manufactured kits at the California Department of Fish and Wildlife's Water Pollution Control Laboratory, the University of California at Santa Cruz, or Bend Genetics.

Table 7. ELISA manufactured cyanotoxin kits and their cross-reactivity among congeners.

Cyanotoxin	ELISA Manufactured Kit	Documented Cross-Reactivity
ATX	ELISA Abraxis 520060	(+)Anatoxin-a 100.0%; Homoanatoxin-a 124.8%
CYL	ELISA Abraxis 522011	Cylindrospermopsin 100%; Deoxy-Cylindrospermopsin 112%; 7-Epi-Cylindrospermopsin 157%
MCY/NOD	ELISA Abraxis 520011ES	MC-YR, MC-LF, DM-MC-RR, MC-LR, MC-RR, MC-LW, DM-MC-LR, Nodularin
MCY/NOD	ELISA Abraxis 520011 (EPA Method 546)	MC-YR, MC-LF, DM-MC-RR, MC-LR, MC-RR, MC-LW, DM-MC-LR, Nodularin
STX	ELISA Abraxis 52255B	Saxitoxin (STX) 100%; Decarbamoyl STX 29%; GTX 2 & 3 23%; GTX-5B 23%; Lyngbyatoxin 13%

ATX, anatoxins; CYN, cylindrospermopsins; MCY, microcystins; NOD, nodularins; STX, saxitoxins

ELISA analysis of anatoxins has been tested and verified to cross-react with anatoxin-a and homoanatoxin-a but has not been tested against dihydro-anatoxin or dihydro-homoanatoxin. Recent research also suggests that dihydro-anatoxin may be a more potent cyanotoxin than anatoxin-a (Anderson et. al. 2018, Puddick et. al. 2021).

For these reasons, the anatoxin concentrations generated by the ELISA method may underreport the cyanotoxin concentrations and the potential risks to the public.

ELISA analysis of microcystins (EPA Method 546) is based upon the presence of a specific amino acid in the microcystin molecule called the ADDA group. The ADDA group is common to all known microcystins and nodularins and their congeners. ELISA analysis of microcystins has been tested and verified to cross-react with nine microcystin congeners and two nodularin congeners, therefore, ELISA microcystins results include the sum of multiple microcystin and nodularin congeners. With over 256 microcystin congeners and 10 NOD congeners, the concentration results generated by the ELISA method may underreport the true cyanotoxin concentration in any sample.

ELISA analysis of cylindrospermopsins has been tested and verified to cross-react with epi-cylindrospermopsin and deoxy-cylindrospermopsin, two of the five known congeners. ELISA analysis of saxitoxins has been tested and verified to cross-react with 10 of the 57 known saxitoxin congeners and analogs. As with anatoxins and microcystins, the concentration results generated by the ELISA method for cylindrospermopsins and saxitoxins may underreport the true cyanotoxin concentrations in the samples.

2.4.4 Cyanotoxin Liquid Chromatography with Mass Spectrometry (LCMS)

LCMS is a chemistry technique that separates a sample into various components and then creates and detects charged ions in the sample to identify the types of molecules in a sample. LCMS results provide information on the structure, identity, and quantity of each specific cyanotoxin when compared to a known standard. Presently, standards are only available for a few cyanotoxin congeners, which limits the ability of LCMS analysis to quantify the presence and concentration of other common cyanotoxin congeners. This limitation may underreport the total concentration of the target cyanotoxins and overall risk to the recreating public.

LCMS analysis of anatoxins, cylindrospermopsins, nodularins, and saxitoxins were performed by the California Department of Fish and Wildlife’s Water Pollution Control Laboratory and the University of California at Santa Cruz and did not identify the many congeners of these cyanotoxins, but only quantified the target cyanotoxins: anatoxin-a, cylindrospermopsin, nodularin-R, and saxitoxin. The LCMS analysis of microcystins performed by these labs was a summation of several congener concentrations. In 2016, the microcystins results included a summation of four congeners: microcystin-LA, -LR, -RR, and -YR. In 2017 through 2019, the microcystins results included a summation of the five congeners: microcystin-LF -LA, -LR, -RR, and -YR.

2.4.5 Laboratories and Reporting

During the study, the Regional Water Board used three laboratories and relied on ELISA and LCMS to determine the cyanotoxin concentrations in water grab, cyanobacterial mat, and SPATT samples. ELISA and LCMS methods do not include the same list of cyanotoxin congeners in the analysis matrix, and the analytical methods differ in the manner in which they derive the concentration values. Therefore, direct comparison of cyanotoxin concentrations between laboratory methods is not possible. However, for the purposes of this report, no distinction is made in the results between the two laboratory methods, nor are comparisons made between methods.

All cyanotoxin results, regardless of method, are reported by target cyanotoxin. LCMS analysis of anatoxin-a and ELISA analysis of combined anatoxin congeners both will be reported collectively as anatoxins (ATX). LCMS analysis of cylindrospermopsin and ELISA analysis of combined cylindrospermopsin congeners will both be reported collectively as cylindrospermopsins (CYN). Nodularin results through LCMS identify nodularin-R concentrations and will be reported as nodularin (NOD). ELISA results for microcystins are cross-reactive with nodularin, therefore the LCMS results for microcystins and nodularins are summed to present the LCMS results in a manner that is consistent with ELISA results; these data will be reported as microcystins/nodularins (MCY/NOD). LCMS analysis of saxitoxin and ELISA analysis of combined saxitoxin congeners will be reported collectively as saxitoxins (STX).

The Department of Fish and Wildlife's Water Pollution Control Laboratory performed ELISA and LCMS analysis of water and mat samples in 2016. The University of California at Santa Cruz performed LCMS analysis of SPATTs in 2016, and both ELISA and LCMS analysis of water, mat, and SPATT samples in 2018 and 2019. Bend Genetics, a private lab, performed ELISA analysis of water, mat, and SPATT samples in 2017, 2018, and 2019. For the purposes of this report, we do not make a distinction in the results between the three laboratories.

2.5 Data Processing and Interpretation

2.5.1 Statistical Analyses

The data for this study were analyzed using various summary statistics (e.g., percentages, medians) and are presented in this report using a series of bar graphs, boxplots, time series plots, and tables. Each analysis and figure are used to highlight significant findings in the study, but also to compare the different sampling approaches that were employed (i.e., benthic mats vs. water column vs. SPATT samplers).

2.5.2 Comparing to Trigger Levels

The toxic effects of the various cyanotoxins are well known and documented (Chorus and Welker, 2021c), but the critical concentrations and thresholds for exposure to each are less well known. Only recently has criteria or trigger levels based upon the exposure to toxigenic planktonic cyanobacteria for the protection of public health been developed in the State of California (CCHAB, 2016) and the United States (USEPA, 2019). Until criteria or guidance are developed to explicitly address benthic-produced cyanotoxins, we must rely upon the planktonic-derived criteria and trigger levels to determine any potential health risks to the public.

In May 2019, the United State Environmental Protection Agency (USEPA) released *Recommended Human Health Recreational Ambient Water Quality Criteria or Swimming Advisories for Microcystins and Cylindrospermopsin* (USEPA, 2019). USEPA's recommendations focus on protecting the public from the potential health risks related to the exposure of microcystins and cylindrospermopsins during primary contact recreation (i.e., swimming). Under the USEPA recommended guidelines, public health is considered to be protected when ambient concentrations of total microcystins are less than 8 µg/L and cylindrospermopsins are less than 15 µg/L. USEPA does not have similar criteria or recommendations for anatoxins, nodularins, or saxitoxins. These thresholds were derived from data on planktonic blooms and did not account for the potential health risks from cyanotoxins held within the benthic cyanobacteria mats.

The California Cyanobacteria and Harmful Algal Bloom (CCHAB) Network was established in 2006 to develop and maintain a coordinated program designed to address cyanobacteria and harmful algal blooms in California. The CCHAB Network became a formal workgroup under the California Water Quality Monitoring Council approximately eight years after forming. In 2016, in coordination with the State of California's Office of Environmental Health and Hazard Assessment (OEHHA), CCHAB released an update to a 2010 voluntary guidance document, incorporating a three-tiered system for posting signs at water bodies to protect the recreating public and animals from planktonic blooms during primary contact and non-contact recreation (Table 8) (CCHAB, 2016). The three-tiered system is based upon cyanotoxin concentration trigger levels, providing varying measures of safety based upon increasing cyanotoxin concentrations, as well as non-cyanotoxin trigger levels at the lowest tier.

Table 8. Planktonic cyanoHAB trigger levels for posting signs to protect human and animal health.

Cyanotoxin	No Advisory [a]	CAUTION (Tier 1)	WARNING (Tier 2)	DANGER (Tier 3)
Total Microcystins [b]	< **0.8** ug/L	**0.8** ug/L	**6** ug/L	**20** ug/L
Anatoxin-a	**Non-detect** [c]	**Detected** [c]	**20** ug/L	**90** ug/L
Cylindrospermopsin	< **1** ug/L	**1** ug/L	**4** ug/L	**17** ug/L
Cell density of potential toxin producers	< **4,000** cells/mL	**4,000** cells/mL	---	---
Site-specific indicator(s)	No site-specific indicators present	Discoloration, scum, algal mats, soupy or paint-like appearance Suspected illness	---	---

[a] For deposting. All criteria for No Advisory must be met for a minimum of 2 weeks. A general awareness sign may remain posted and healthy water habits are still recommended.

[b] Microcystins refers to the sum of all measured Microcystin congeners.

[c] Must use an analytical method that detects ≤ 1µg/L Anatoxin-a.

The posting of increasingly restrictive planktonic advisory signs is recommended when each successive trigger concentration level is reached. These levels and associated advisory signs are:

- **Caution (Tier 1)** – People should stay away from scum, and pets and livestock should be kept away from the water and scum. Fish can be consumed after rinsing with potable water and removing guts.
- **Warning (Tier 2)** - People should not swim in the water (no contact recreation), and pets and livestock should be kept away from the water. Fish can be consumed after rinsing with potable water and removing guts. Non-contact recreation such as fishing and boating is still allowed.
- **Danger (Tier 3)** - There is a present danger. People, pets and livestock should stay out of the water and away from water spray. Fish should not be consumed.

In 2020, the CCHAB Network, in collaboration with the North Coast Regional Water Quality Control Board, the State Water Resources Control Board, and OEHHA, developed signs and posting guidelines for benthic cyanobacteria or toxic algal mats (CCHAB, 2020). Posting guidelines follow a similar general framework as planktonic advisories but are not associated with any numeric trigger levels. The benthic advisory sign is posted when toxigenic mats have been identified at the location and advise that people and their animals should avoid areas where mats are attached, floating, or accumulating. Benthic advisory signs may be accompanied by planktonic advisory signs if water column values also exceed trigger levels; however, recreational health risks in a riverine system are associated with incidental ingestion of mats since this material contains most of the cyanotoxin load (My Water Quality: California HABs Portal, 2021). As such, children and dogs are especially at risk given their water recreating behavior. The State and Regional Water Resources Control Boards implement the voluntary guidance adopted by the CCHAB Network through the Freshwater and Estuarine HAB Program’s incident response and monitoring framework.

In this report, cyanotoxin results are presented for cyanobacterial mat, water column, and SPATT samples that were collected to characterize benthic cyanoHABs in three North Coast rivers. Although river water column concentrations of cyanotoxins are commonly compared to the planktonic trigger levels, they are not directly comparable. Planktonic trigger levels were derived to characterize health risks from planktonic cyanoHABs in lakes and reservoirs where the health risk from planktonic cyanoHABs is derived from the incidental ingestion of ambient water during swimming that contain intact cyanobacterial cells and dissolved cyanotoxins.

Thereby, the incidental ingestion of benthic mat material during recreation is unique and has not been characterized to derive criteria for the protection of human health.

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 the Results section 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 from Regional Water Board staff. However, these data are considered 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; SWAMP 2017b), and the SWAMP Quality Assurance Project Plan for bioassessments (SCCWRP 2009).

3 Results

3.1 Cyanobacteria Presence and Distribution

Through visual assessment and taxonomic identification of benthic mat samples, multiple toxigenic cyanobacterial genera were documented in the Eel, South Fork Eel, and Russian Rivers. Only a subset of six cyanobacterial genera were observed to form large benthic mats. Cyanobacterial results for each sampling method are presented in the following sections.

3.1.1 Cyanobacteria Visual Assessment Results

Field observations identified six cyanobacterial genera that frequently form macroscopic mats (i.e., mats greater than 1,000 cm^2) in various niches of the Eel, South Fork Eel, and Russian Rivers: *Anabaena*, *Cylindrospermum, Microcoleus* (*Phormidium*)[2], *Nostoc, Oscillatoria*, and *Scytonema* (Table 9). All these genera are documented to produce at least one cyanotoxin (Table 10).

Table 9. Cyanobacteria that form macroscopic mats in the Eel River, South Fork Eel River, and Russian River, from 2016 to 2019.

Genera	Habitat description
Anabaena	Occupy shallow, warmer backwater/side channel sections or along shallow river margins with little or no direct flow. Can be found growing in and amongst filamentous green algae which provide areas of limited flow. Easily detached from the substrate through recreational disturbance.
Cylindrospermum	Found amongst the larger sands or smaller gravels as well as along the margins or mid-channel where flows are slow but steady. Easily detached from the substrate through recreational disturbance.
Microcoleus (Phormidium)*	Commonly found in swift, riffled sections adhered to cobbles and boulders or growing on mats of filamentous green algae. Initial growth stages are not easily detached from the substrate. As the mat thickens, it can detach more easily from substrates by recreational disturbance and will eventually self-detach under the right environmental conditions.
Nostoc	Cosmopolitan genus occupying many habitats. Found attached to boulders and cobbles in swift-moving riffles or in backwater/side channel areas, or even unattached in areas experiencing slow or no flow.
Oscillatoria	Predominantly found in the sandy/silty sections of the river reach, in medium to heavy shade and in areas of slower flow. Easily detached from the substrate through recreational disturbance and will eventually self-detach under the right environmental conditions.

[2] *Microcoleus* includes taxa formerly identified as *Phormidium* (see Strunecky et al., 2013). *Microcoleus* and *Phormidium* genera are similar in appearance, both micro- and macroscopically, and occupy the same habitats. The bulk of sample collection occurred prior to taxonomic differentiation; therefore this report treats both genera as one.

Genera	Habitat description
Scytonema	Most often grows on cobbles/boulders located in swift water sections. Tightly attached to the substrate and does not detach from the substrate through recreational disturbance.

**Microcoleus* includes taxa formerly identified as *Phormidium* (Strunecky et al., 2013). See My Water Quality: California HABs Portal, 2021, for pictures of macroscopic mats.

Cyanobacterial cover remained below 5% at most Russian River sites, except for site 114RR5407 which ranged between 25-50% in 2016 and 2018. The Eel River demonstrated low cover (<5%) in the middle reach sites of 111ER6381 and 111ER6140, while site 111ER8102 in the upper reach demonstrated up to 100% cover in each year that cover could be evaluated. The South Fork Eel River sites consistently experienced cover percentages greater than 50%. Additional details on the percent cover of cyanobacteria at each sampling site can be found in Appendix 1.

Across the three rivers and throughout the study, cyanobacterial growth followed a general pattern of increasing biomass through most of the sample season from June through September, followed by decreasing populations when sample collection ended in mid-October. Early in the sample season, benthic cyanobacterial cover is generally low with greater genera diversity, but as the season progresses, diversity begins to wane as mat-forming genera begin to bloom and dominate the benthos.

3.1.2 Cyanobacteria Taxonomic Identification Results

Although individual macroscopic mats in the three rivers are generally dominated by one of the six cyanobacterial genera found to form these mats, other genera of cyanobacteria, algae, bacteria, and micro-organisms can colonize the mat structure. Microscopic analysis of reachwide samples collected in 2016 (N = 44) identified 20 additional sub-dominant cyanobacterial genera inhabiting cyanobacterial or other algal mats in the Eel, South Fork Eel, and Russian Rivers. Of these additional genera, 11 are potentially toxigenic, though none of these have been observed to form macroscopic mats and thus pose a lessened health risk to the recreating public (Table 10).

Table 10. Cyanobacterial genera detected in reachwide mat samples in 2016 and their potential cyanotoxins. Cyanobacterial genera that produce macroscopic mats are shaded in grey. ATX, anatoxins; CYN, cylindrospermopsins; MCY, microcystins; NOD, nodularins; STX, saxitoxins.

Genera	Detections by River			Potential Cyanotoxins				
	Eel	SF Eel	Russian	ATX	CYN	MCY	NOD	STX
Anabaena	X	X	X		X	X		X
Aphanocapsa	X					X		
Aphanothece	X	X	X					
Calothrix	X	X	X					

Genera	Detections by River			Potential Cyanotoxins				
	Eel	SF Eel	Russian	ATX	CYN	MCY	NOD	STX
Chroococcus	X	X						
Coelomoron		X						
Cylindrospermum	X	X	X	X				X
Dolichospermum	X	X		X	X	X		X
Geitlerinema	X	X	X	X		X		X
Gleocapsa		X						
Gloeothece			X					
Gloeotrichia	X	X				X		
Leptolyngbya	X	X	X			X		
Lyngbya			X		X			X
Merismopedia			X			X		
Microchaete	X							
Microcoleus *	X	X	X	X	X	X		X
Nodularia		X					X	
Nostoc	X	X	X	X		X	X	
Oscillatoria	X	X	X	X	X	X		
Pseudanabaena	X					X		
Rhabdoderma			X					
Rivularia	X	X	X			X		
Scytonema		X				X		X
Spirulina			X					
Trichormus	X	X	X			X		
Total	17	18	16	6	5	14	2	7

**Microcoleus* includes taxa formerly identified as *Phormidium* (Strunecky et al., 2013). See [My Water Quality: California HABs Portal](), 2021, for cyanotoxins produced by cyanobacteria.

The presence of cyanobacterial genera in reachwide composite mat samples was similar across the Eel, South Fork Eel, and Russian Rivers, and mat-forming genera were identified at all sampling sites. Additionally, microscopy detected the most diverse genera in the South Fork Eel River (N = 18). Eleven genera were detected in all three rivers which included nine known cyanotoxin producers. The total number of genera known to produce toxins in each river were 13 in the Eel River, 13 in the South Fork Eel River, and 11 in the Russian River. Additional details on the cyanobacteria identified at each sampling site and river can be found in Appendix 2 and 3.

3.2 Cyanotoxin Presence and Distribution

Employing multiple cyanotoxin monitoring methods, all five cyanotoxins evaluated in this study were detected in the Eel, South Fork Eel, and Russian Rivers from 2016 to 2019. Anatoxins and microcystins/nodularins were the most frequently detected cyanotoxins in all three rivers.

Cyanotoxin results for each sampling method are presented in the following sections.

3.2.1 Cyanotoxin Benthic Mat Results

Although occurring broadly across all three rivers, cyanotoxin detections in single species and reachwide composite mat samples varied per site (Table 11). From 2016 to 2019, anatoxins and microcystins/nodularins were detected in each river and at every sampling site. Cylindrospermopsins were detected at six of the 12 sample sites but were not detected in the Eel River. Nodularins were detected in each river but only at four of the 12 sample sites. Saxitoxins were detected in each river at seven of the 12 sites sampled. It is important to note that although detections for a particular cyanotoxin may have occurred at a site, not every sample collected at the site was positive for that cyanotoxin.

Table 11. Cyanotoxin detections in all cyanobacterial mat samples by sampling site, from 2016 to 2019. ATX, anatoxins; CYN, cylindrospermopsins; MCY, microcystins; NOD, nodularins; STX, saxitoxins.

River	Site	Site Name	Cyanotoxins Detected in Benthic Mats				
			ATX	CYL	MCY/NOD	NOD	STX
Eel River	111ER8102	Trout Creek Campground	X		X	X	X
	111ER6381	Above Outlet Creek	X		X		X
	111ER6140	Above Dos Rios	X		X		
South Fork Eel River	111SF6856	Big Bend Lodge	X	X	X	X	X
	111SF4640	At Cooks Valley	X	X	X	X	
	111SF2423	Below Dean Creek	X		X		X
Russian River	114RR7396	Hopland USGS Gage	X	X	X	X	
	114RR5407	Cloverdale Airport	X	X	X		X
	114RR4234	Alexander Valley Rd	X		X		
	114RR2655	Below Kabutts Rd	X	X	X		X

River	Site	Site Name	Cyanotoxins Detected in Benthic Mats				
			ATX	CYL	MCY/NOD	NOD	STX
	114RR2079	Below Laguna de Santa Rosa	X	X	X		X
	114RR1159	Vacation Beach	X		X		

For each of the three rivers, anatoxins and microcystins/nodularins were detected more frequently in single species and reachwide mat samples than cylindrospermopsins, nodularins, and saxitoxins (Table 12). Across all rivers, annual detection rates ranged between 77.0-91.2% for anatoxins and 53.8-76.3% for microcystins/nodularins, while cylindrospermopsins, nodularins, and saxitoxins detections ranged from 0-14.8%, 4.2-16.7%, and 10.3-50.0%, respectively. Saxitoxins detection rates were notably higher (50%) in the mainstem Eel River than in the South Fork Eel River and Russian River (<12%).

Table 12. Detection rates of cyanotoxins in all cyanobacterial mat samples across all sites, from 2016 to 2019. ATX, anatoxins; CYN, cylindrospermopsins; MCY, microcystins; NOD, nodularins; STX, saxitoxins.

Benthic Mat Samples		ATX	CYN	MCY/NOD	NOD	SXT
Eel River	Detections	41	0	21	1	8
	Total Samples	49	23	39	24	16
	Detection Rate	83.7%	0.0%	53.8%	4.2%	50.0%
Russian River	Detections	47	4	28	1	3
	Total Samples	61	27	43	6	29
	Detection Rate	77.0%	14.8%	65.1%	16.7%	10.3%
South Fork Eel River	Detections	83	6	58	4	4
	Total Samples	91	44	76	35	36
	Detection Rate	91.2%	13.6%	76.3%	11.4%	11.1%
Total	Detections	171	10	107	6	15
	Total Samples	201	94	158	65	81
	Detection Rate	85.1%	10.6%	67.7%	9.2%	18.5%

The cyanotoxin concentrations in most mat samples were not standardized by mat biomass or surface area, therefore, they are considered semi-quantitative results. To illustrate general trends in cyanotoxin concentrations, the figures and tables below utilize bins ranging from non-detect to greater than 10,000 ug/L to summarize count data and maximum concentrations.

Unless otherwise indicated, the terms “high” and “low” are relative to bins and are used to make general comparisons among cyanotoxin classes, cyanobacterial genera, and the three rivers. Specific cyanotoxin measurements for single species and reachwide benthic mat samples can be found in Appendices 3 and 4, respectively.

In addition to being frequently detected, anatoxins were also measured at higher concentrations in single species and reachwide mat samples than the other cyanotoxins (Figure 5). Anatoxins were most frequently measured at the highest concentrations across all three rivers, while most detections of the other cyanotoxins are at concentrations below 1 µg/L.

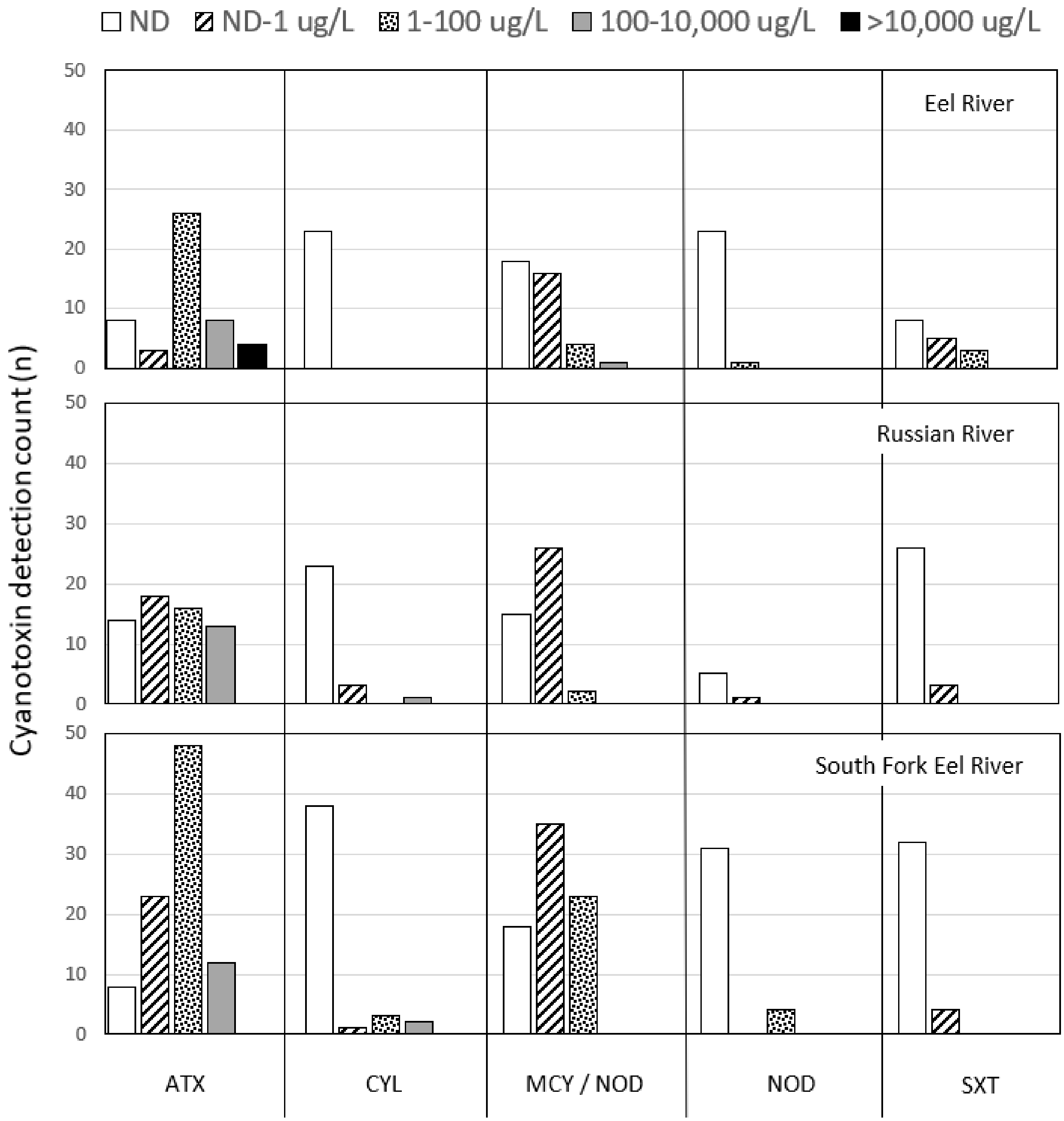

Figure 5. Cyanotoxin concentrations in all cyanobacterial mat samples by river, from 2016 to 2019. Concentrations are binned into five categories from non-detect (ND) to greater than 10,000 ug/L. ATX, anatoxins; CYN, cylindrospermopsins; MCY, microcystins; NOD, nodularins; STX, saxitoxins.

From 2016 to 2019, cyanotoxin concentrations measured in single species dominated mats varied by cyanobacterial genera and river (Table 13). In the Eel River, higher concentrations of anatoxins (46,040 ug/L), microcystins/nodularins (166.8 ug/L), and saxitoxins (5.76 ug/L) were detected in *Microcoleus* (*Phormidium*) dominated mats while cylindrospermopsin concentrations were low. In the South Fork Eel River, anatoxins (585.3 ug/L) were highest in *Anabaena* dominated mats while microcystins/nodularins (< 25 ug/L) were lower and consistent among mat-forming genera. The highest cylindrospermopsin concentrations (1,366 ug/L) were measured in *Nostoc* mats in the South Fork Eel River and saxitoxins were either not detected or measured at very low concentrations in all mats. In the Russian River, the highest anatoxins (8,115 ug/L), cylindrospermopsins (137.2 ug/L), microcystins/nodularins (6.02 ug/L), and saxitoxins (0.06 ug/L) concentrations were detected in *Microcoleus* (*Phormidium*) dominated mats. High concentrations of anatoxins (7,709 ug/L) and microcystins/nodularins (5.80 ug/L) were also observed in *Oscillatoria* and *Anabaena* dominated mats in the Russian River, respectively. The complete dataset can be found in Appendix 3.

Table 13. Binned maximum cyanotoxin concentrations for single species dominant mat samples in the Eel River, South Fork Eel River, and Russian River, from 2016 to 2019. Maximum concentrations are binned into five categories from non-detect (ND) to greater than 10,000 ug/L. Bins with the highest cyanotoxin concentrations for each river are shaded in grey. ATX, anatoxins; CYN, cylindrospermopsins; MCY, microcystins; NOD, nodularins; STX, saxitoxin; ---, no sample collected.

River	Genera	ATX (ug/L)	CYN (ug/L)	MCY/NOD (ug/L)	STX (ug/L)
Eel River	*Anabaena*	1-100	ND	1-100	ND-1
	Cylindrospermum	1-100	ND	ND-1	ND-1
	*Microcoleus**	>10,000	ND	10-1,000	1-100
	Oscillatoria	1-10	ND	ND-1	ND
South Fork Eel River	*Anabaena*	100-10,000	1-100	1-100	ND
	Cylindrospermum	100-10,000	ND	1-100	ND-1
	*Microcoleus**	100-10,000	1-100	1-100	ND-1
	Nostoc	100-10,000	100-10,000	1-100	ND
	Oscillatoria	ND-1	ND	ND-1	ND
	Scytonema	100-10,000	ND	1-100	ND-1
Russian River	*Anabaena*	1-100	ND-1	1-100	ND
	Cylindrospermum	100-10,000	ND-1	ND	---
	*Microcoleus**	100-10,000	100-10,000	1-100	ND-1
	Nostoc	100-10,000	ND	ND-1	ND
	Oscillatoria	100-10,000	ND-1	ND-1	ND

**Microcoleus* includes taxa formerly identified as *Phormidium* (Strunecky et al., 2013).

Across all three rivers and years, higher concentrations of anatoxins were found in mats dominated by one or more of the six macroscopic mat-forming cyanobacterial genera (Figure 6).

Cylindrospermopsin concentrations were highest in mats dominated by *Anabaena, Nostoc,* and *Microcoleus (Phormidium)*, while microcystins/nodularins were elevated in mats dominated by *Anabaena, Cylindrospermum, Nostoc, Microcoleus (Phormidium),* and *Scytonema*. Saxitoxins never exceeded 10 ug/L and only exceeded 1 ug/L in mats dominated by *Microcoleus (Phormidium)*.

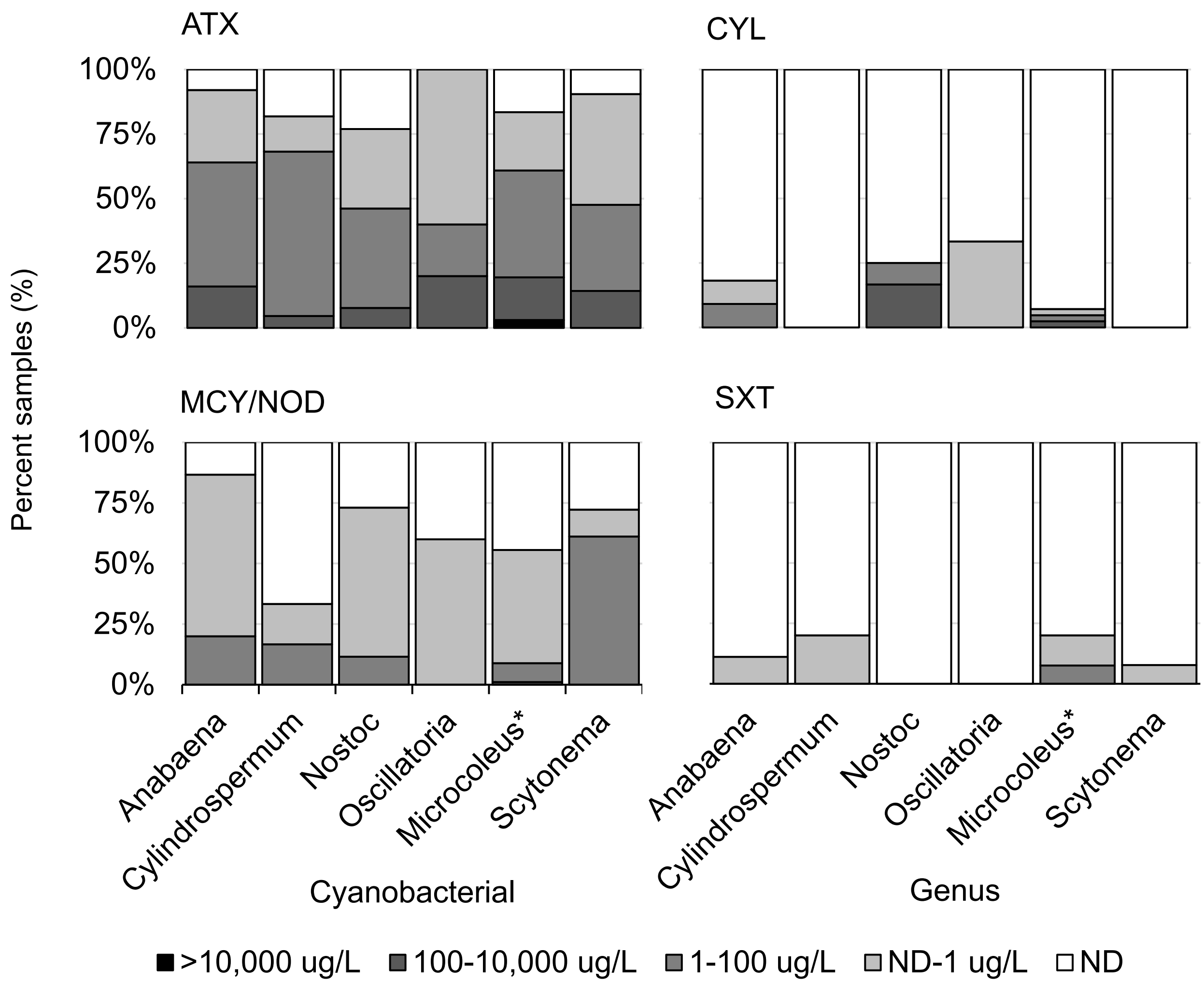

Figure 6. Cyanotoxin concentrations in single species dominant mats across all rivers, from 2016 to 2019. ATX, anatoxins; CYN, cylindrospermopsins; MCY, microcystins; NOD, nodularins; STX, saxitoxins. (*) *Microcoleus* includes taxa formerly identified as *Phormidium* (Strunecky et al., 2013).

To better understand the potential toxicity of various mat-forming cyanobacteria genera, cyanotoxin concentrations in mats were normalized using ash free dry mass analysis (AFDM) to estimate cyanotoxin concentration per unit of cyanobacterial mat biomass (Figure 7). AFDM samples were collected from single species dominated mats formed by mat-forming genera.

The maximum concentration of anatoxins approached 100 mg/kg AFDM in the Eel River while they exceeded 1,000 mg/kg AFDM in the South Fork Eel and Russian Rivers; these elevated concentrations were found in *Anabaena* and *Microcoleus* (*Phormidium*) dominated mats. In the South Fork Eel River, *Nostoc* and *Cylindrospermum* samples had the highest concentrations of cylindrospermopsins, 629 and 41 mg per kg of AFDM, respectively; however as shown in Figure 7, these high values and the low sample size (N = 4) lead to the large range of cylindrospermopsins concentrations. Maximum concentrations of all other cyanotoxins were < 20 mg/kg AFDM in all three rivers, a 50-fold lower concentration. Additional data on benthic mat AFDM results can be found in Appendix 5.

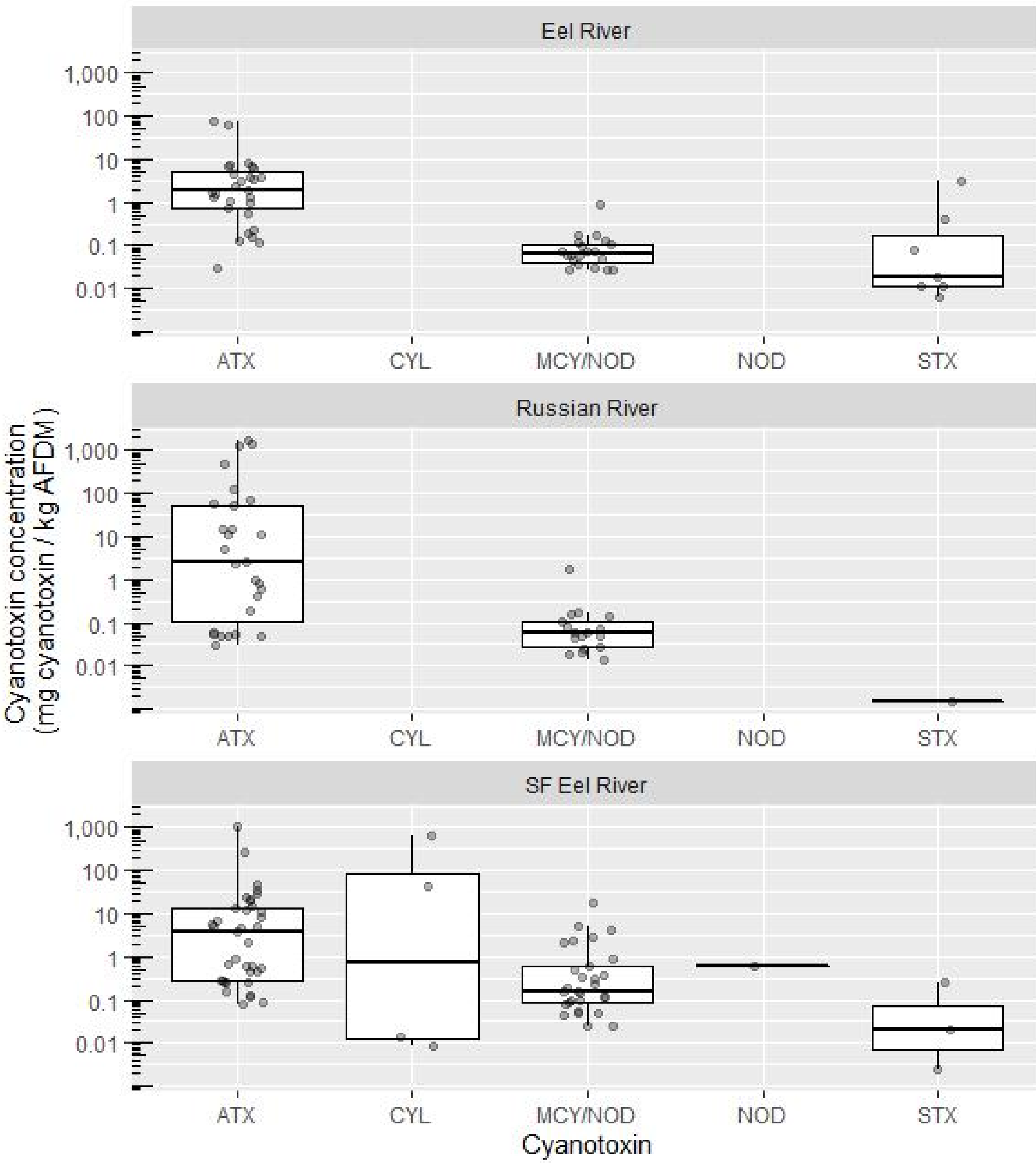

Figure 7. Cyanotoxin concentrations normalized by ash free dry mass (AFDM) of single species dominant mats, from 2016 to 2019. Only samples where cyanotoxins were detected are included. ATX, anatoxins; CYN, cylindrospermopsins; MCY, microcystins; NOD, nodularins; STX, saxitoxins.

Cyanotoxin measurements of reachwide and single species benthic mats documented the presence of all five cyanotoxins in every year from 2016 to 2019. To discern any temporal trends throughout the sample season, cyanotoxin results for reachwide and single species mats were pooled across all rivers, sites, and years, and results were binned based on concentrations that ranged from ND to >10,000 ug/L (Figure 8). Anatoxins within mats increased in concentrations through the early season, peaked in late August, remained elevated through October, then gradually decreased the remainder of the season. Microcystins/nodularins were detected throughout the season with highest concentrations early in the season. Saxitoxins that were detected within mats were present in low levels starting in mid-July and persisted for the season. Cylindrospermopsins were relatively high at the beginning of the season, then peaked in mid-August, but were interspersed with many non-detects. Nodularins were not detected except at low concentrations from August to September.

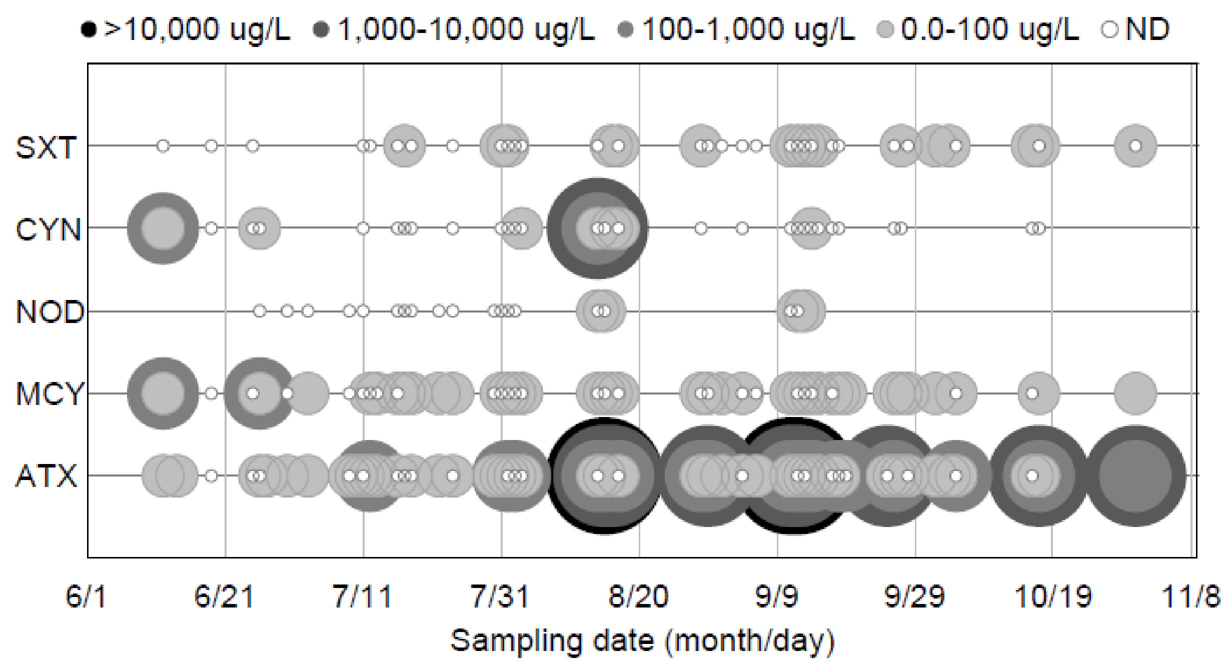

Figure 8. Cyanotoxin concentrations in all cyanobacterial mat samples across all rivers, sites, and years during the sampling season. ATX, anatoxins; CYN, cylindrospermopsins; MCY, microcystins; NOD, nodularins; STX, saxitoxins.

Across all rivers, anatoxins in reachwide and single species mats were highest in 2016 and 2018, cylindrospermopsins were highest in 2019, microcystins/nodularins were similar in most years, and saxitoxins were low and mostly non-detects in all years. Additional details on the cyanotoxin detections in benthic mats can be found in Appendix 3 and 4.

3.2.2 Cyanotoxin Water Column Results

In contrast to benthic mat samples, ambient water column grab samples rarely detected cyanotoxins. A total of 244 water grab samples were collected from the 12 sample sites during the four-year sample period. While anatoxins were the most frequently detected cyanotoxin in mats, they were only detected in 3.5% of water grab samples across all rivers and years (Table 14). Microcystins/nodularins were the most frequently detected cyanotoxin in water samples (21.9%) yet were the second most frequently detected cyanotoxin in mats. Saxitoxins and cylindrospermopsins were detected in < 5% of water samples.

Table 14. Cyanotoxin detection rates for ambient water column grab samples in the Eel River, South Fork Eel River, and Russian River, from 2016 to 2019. ATX, anatoxins; CYN, cylindrospermopsins; MCY, microcystins; NOD, nodularins; STX, saxitoxins.

Water Grab Samples		ATX	CYN	MCY/NOD	NOD	SXT
Eel River	Detections	1	1	9	2	0
	Total Samples	50	48	49	32	33
	Detection Rate	2.0%	2.1%	18.4%	6.3%	0.0%
Russian River	Detections	5	3	17	2	3
	Total Samples	104	97	102	50	90
	Detection Rate	4.8%	3.1%	16.7%	4.0%	3.3%
South Fork Eel River	Detections	2	0	23	0	0
	Total Samples	76	68	73	43	68
	Detection Rate	2.6%	0.0%	31.5%	0.0%	0.0%
Total	Detections	8	4	49	4	3
	Total Samples	230	213	224	125	191
	Detection Rate	3.5%	1.9%	21.9%	3.2%	1.6%

When comparing cyanotoxin concentrations in ambient water column grab samples to California's CCHAB Network trigger levels (Table 8), the Caution level was exceeded by anatoxins in 8 samples (ATX caution level = detection[3]) and microcystins in 4 samples (MCY caution level = 0.8 ug/L) during the study. These exceedances occurred in all three rivers at the samples sites and dates identified in Table 15. The higher Warning and Danger levels were never exceeded by a water grab sample. All cylindrospermopsins detections (N = 4) were below the CCHAB trigger level (1.0 ug/L). There are no current trigger levels to compare nodularins (N = 4) or saxitoxins (N = 3) results.

[3] The detection determination for anatoxins must use an analytical method that detects ≤1 ug/L anatoxin-a.

Table 15. Cyanotoxin concentrations in ambient water column grab samples that exceeded CCHAB caution levels, from 2016 to 2019. ATX, anatoxins; MCY, microcystins; NOD, nodularins; ---, no exceedances.

River	Site Code	Site Name	Date	ATX (ug/L)	MCY/NOD (ug/L)
Eel River	111ER6381	Above Outlet Creek	9/15/2016	---	1.58
	111ER8102	Trout Campground	8/14/2019	0.26	---
South Fork Eel River	111SF4640	At Cooks Valley	9/12/2018	---	2.27
	111SF4640	At Cooks Valley	8/14/2019	0.55	---
	111SF4640	At Cooks Valley	9/11/2019	2.19	---
Russian River	114RR5407	Cloverdale Airport	8/18/2016	---	0.81
	114RR7396	Hopland USGS Gage	8/18/2016	---	0.83
	114RR2655	Below Kabutts Road	9/29/2016	0.18	---
	114RR1159	At Vacation Beach	9/30/2016	0.15	---
	114RR7396	Hopland USGS Gage	9/30/2016	0.15	---
	114RR2655	Below Kabutts Road	9/11/2019	1.79	---
	114RR5407	At Cloverdale Airport	9/11/2019	1.75	---

Similar to benthic mat results, temporal trends for the sampling season were evaluated by combining cyanotoxin results for ambient water column grab samples across all rivers, sites, and years, and binning these results by concentrations that ranged from ND to >1.0 ug/L (Figure 9). The few detections of saxitoxins, nodularins, cylindrospermopsins, and anatoxins in ambient water were clustered within about a 4-6-week period, however, these clusters occurred at different times of the season. Saxitoxins were only detected in September, nodularins in July and August, anatoxins in August and September, and cylindrospermopsins only had two low detections in June. Microcystins were detected most frequently in ambient water and occurred across the entire sampling season. The highest concentrations of water grab samples mostly occurred after August, with the exception of nodularins, which is similar in timing to when the highest within-mat concentrations were also measured.

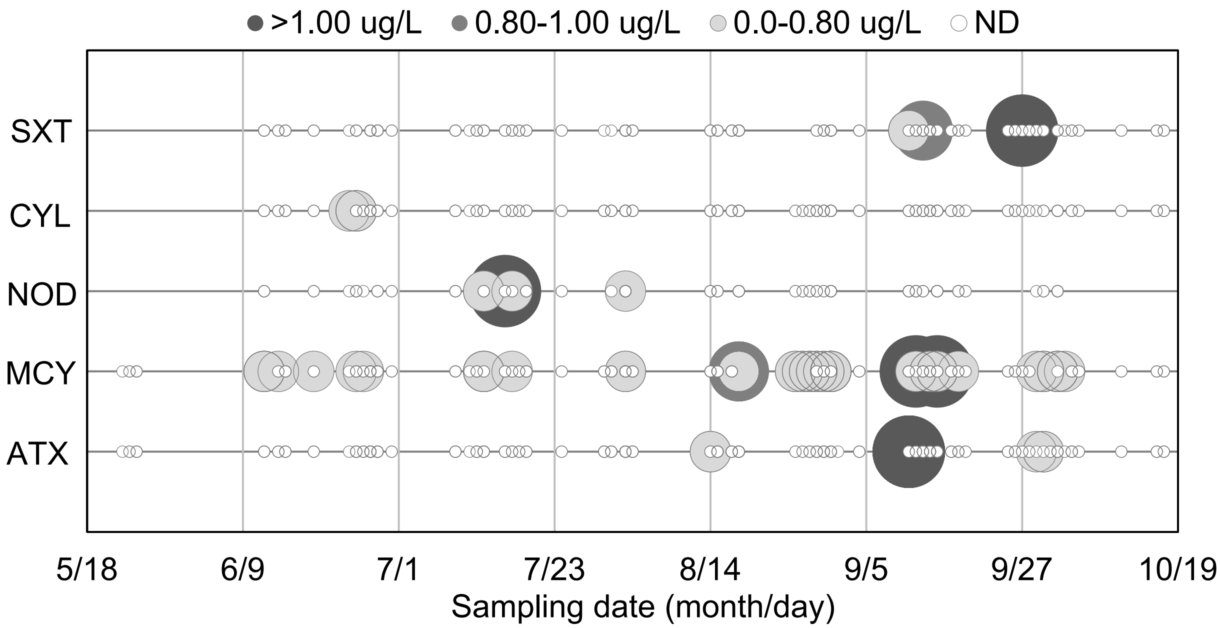

Figure 9. Cyanotoxin concentrations in ambient water column grab samples across all rivers, sites, and years during the sampling season. ATX, anatoxins; CYN, cylindrospermopsins; MCY, microcystins; NOD, nodularins; STX, saxitoxins.

Detection of all five cyanotoxins in water column samples varied per year from 2016 to 2019. Across all rivers, ambient anatoxins were highest in 2019 but were not detected in 2017 and 2018. Ambient cylindrospermopsins were only detected in 2019, and saxitoxins were detected in 2017 and 2019 but were not detected in 2016 and 2018. Microcystins/nodularins were detected every year in all three rivers with highest ambient water concentrations occurring in 2018. Additional details for ambient water column concentrations for each sampling site and year can be found in Appendix 6.

3.2.3 Cyanotoxin SPATT Results

A total of 319 SPATT samplers were deployed at the 12 sample sites during the 2016 to 2019 timeframe. Across all years, all five cyanotoxins were detected in the Eel and Russian Rivers, while all but saxitoxins were detected in the South Fork Eel River (Table 16).

Table 16. Cyanotoxin detections in SPATT samples by sampling site in the Eel River, South Fork Eel River, and Russian River, from 2016 to 2019. ATX, anatoxins; CYN, cylindrospermopsins; MCY, microcystins; NOD, nodularins; STX, saxitoxins.

River	Site Code	Site Name	Cyanotoxins Detected in SPATTs					
			ATX	CYL	MCY	MCY/NOD	NOD	STX
Eel River	111ER8102	Trout Creek Campground	X	X	X	X	X	X
	111ER6381	Above Outlet Creek			X	X	X	
	111ER6140	Above Dos Rios	X	X	X	X	X	
South Fork Eel River	111SF6856	Big Bend Lodge	X	X	X	X	X	
	111SF4640	At Cooks Valley	X	X	X	X	X	
	111SF2423	Below Dean Creek	X		X	X	X	
Russian River	114RR7396	Hopland USGS Gage	X	X	X	X	X	X
	114RR5407	Cloverdale Airport	X	X	X	X	X	X
	114RR4234	Alexander Valley Rd			X	X	X	
	114RR2655	Below Kabutts Rd	X	X	X	X	X	
	114RR2079	Below Laguna de Santa Rosa	X	X		X		X
	114RR1159	Vacation Beach			X	X	X	

The detection rate for individual cyanotoxins varied by river. The minimum and maximum detection rates both occurred in the South Fork Eel River, with no saxitoxin detections, and a microcystins/nodularins detection rate of 81.1% (Table 17). Across all rivers, microcystins/nodularins were detected most frequently (73.7%) and saxitoxins least frequently (2.4%).

Table 17. Cyanotoxin detection rates for SPATT samples in the Eel River, South Fork Eel River, and Russian River, from 2016 to 2019. ATX, anatoxins; CYN, cylindrospermopsins; MCY, microcystins; NOD, nodularins; STX, saxitoxins.

SPATT Samples		ATX	CYN	MCY/NOD	NOD	SXT
Eel River	Detections	16	9	35	24	1
	Total Samples	52	43	50	43	39
	Detection Rate	30.8%	20.9%	70.0%	55.8%	2.6%
Russian River	Detections	69	17	91	67	3
	Total Samples	134	130	134	112	81
	Detection Rate	51.5%	13.1%	67.9%	59.8%	3.7%
South Fork Eel River	Detections	99	11	107	57	0
	Total Samples	133	125	132	117	48
	Detection Rate	74.4%	8.8%	81.1%	48.7%	0.0%
Total	Detections	184	37	233	148	4
	Total Samples	319	298	316	272	168
	Detection Rate	57.7%	12.4%	73.7%	54.4%	2.4%

Across all years, cyanotoxin concentrations in SPATTs spanned several orders of magnitude, however, the distribution of concentrations for each cyanotoxin was similar across all three rivers (Figure 10). In addition to being most frequently detected by SPATT samplers, microcystins/nodularins and nodularins also had the highest median SPATT concentrations. The Russian River had lower maximum SPATT values for microcystins/nodularins and nodularins, yet it had a higher median nodularins concentration than the Eel or South Fork Eel Rivers. For all rivers, anatoxins had median SPATT values around 10 ng/g, however, the South Fork Eel River had many outliers with anatoxin concentrations approaching 1,000 ng/g. The Russian River had the highest anatoxins outlier at 1,717 ng/g. The median SPATT values for cylindrospermopsins and saxitoxins were below 10 ng/g and no values exceeded 100 ng/g.

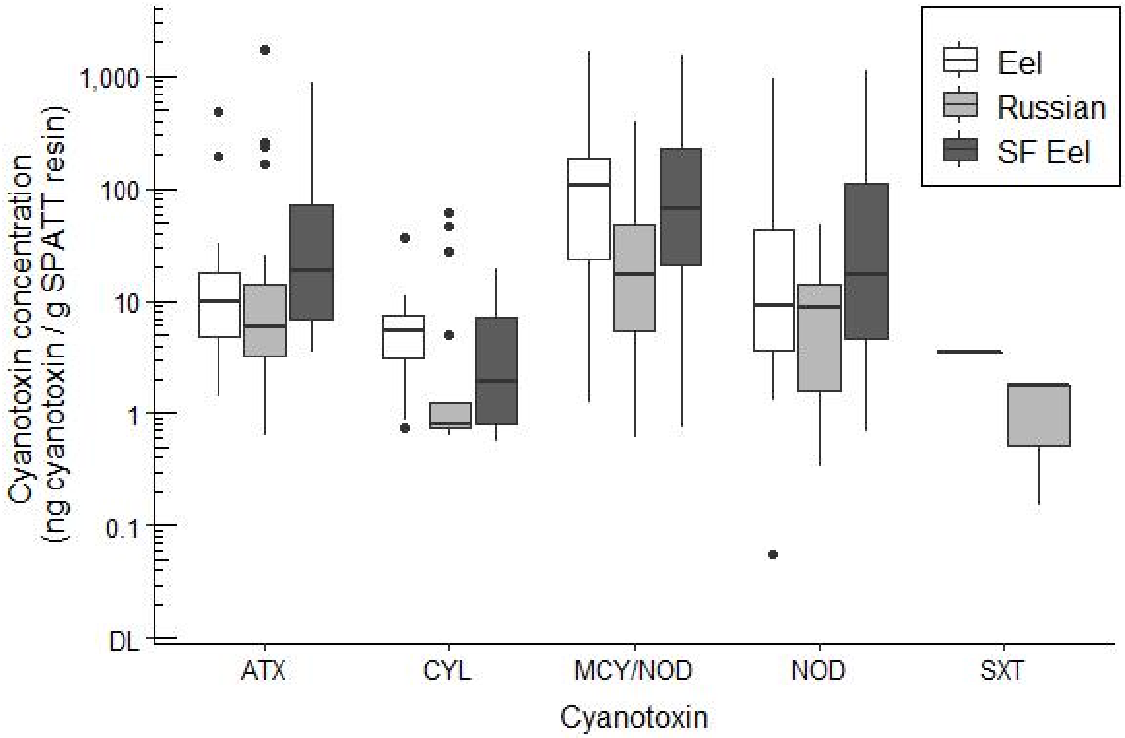

Figure 10. SPATT cyanotoxin concentrations in the Eel River, South Fork Eel River, and Russian River, from 2016 to 2019. Only SPATT samples where concentrations were above the detection limit (DL) are included. ATX, anatoxins; CYN, cylindrospermopsins; MCY, microcystins; NOD, nodularins; STX, saxitoxins.

To discern any temporal trends throughout the sample season, cyanotoxin results for SPATTs across all rivers, sites, and years were combined and binned based on concentrations that ranged from ND to >1,000 ng/g (Figure 11). Anatoxins in SPATTs were detected throughout the sample season with concentrations increasing in the early season, peaking in September, then decreasing through the remainder of the season. Microcystins/nodularins and nodularins were detected throughout the season, though highest concentrations were in June and July. Although cylindrospermopsins were detected in SPATTs in concentrations lower than the other cyanotoxins, concentrations were highest through July, followed by mostly non-detects in August and September. Saxitoxins were rarely detected with only a single low-level detection in June, August, and September.

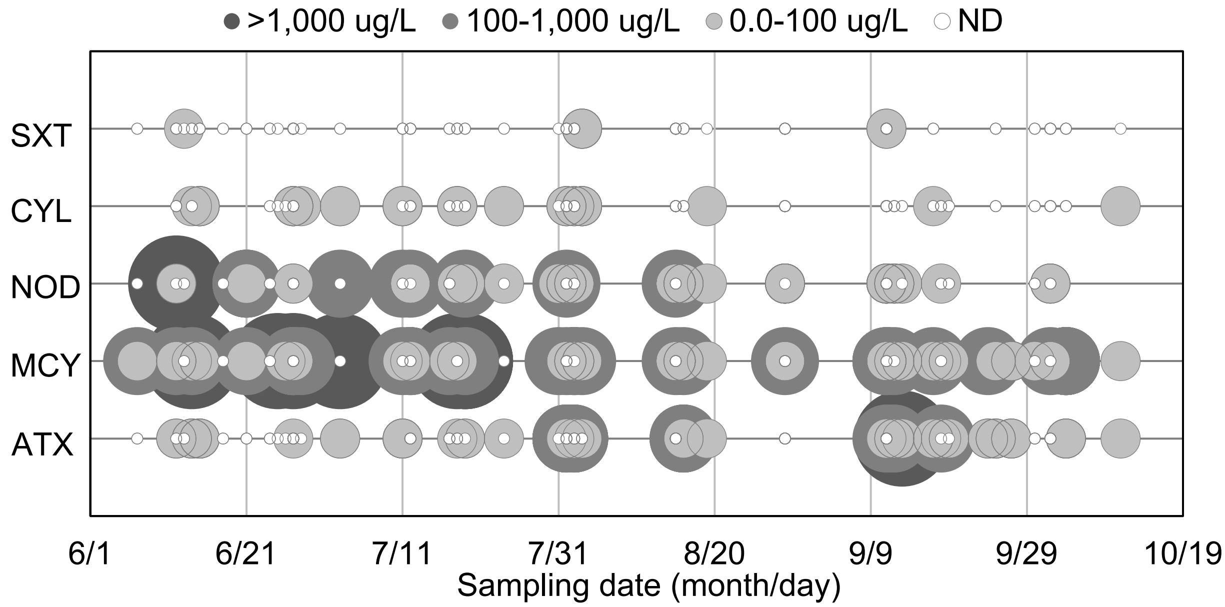

Figure 11. Cyanotoxin concentrations in SPATT samples across all rivers, sites, and years during the sampling season. ATX, anatoxins; CYN, cylindrospermopsins; MCY, microcystins; NOD, nodularins; STX, saxitoxins.

Detection of all five cyanotoxins in SPATT samples varied per year. Across all rivers, anatoxins were highest in 2018 but were not detected in 2016. Cylindrospermopsins and saxitoxins had low level concentrations in 2017 and 2019 but were not detected in 2016 and 2018. Microcystins/nodularins were detected every year in all three rivers. Additional details for SPATT concentrations for each sampling site and year can be found in Appendix 7.

4 Discussion

4.1 Study Summary

This study utilized several monitoring and analytical techniques that allowed the Regional Water Board to characterize the presence of benthic cyanobacteria and cyanotoxins in the Eel, South Fork Eel, and Russian Rivers. Additionally, this study compared the efficacy of different sampling techniques and provides monitoring recommendations for successful cyanoHAB programs.

This study did not investigate the environmental conditions or controllable factors that may lead to biostimulatory conditions and cyanobacterial bloom development. Additional data and studies are needed to address these knowledge gaps and are discussed in more detail in the *Future Studies* section below.

Results from this study answered the four questions presented at the beginning of the report; these questions and general responses are provided below. All report findings are discussed in more detail in the following sections.

1 What cyanobacterial genera are responsible for the formation of toxic benthic mats in the Eel, South Fork Eel, and Russian Rivers?

   Six benthic cyanobacterial genera were found to form toxic macroscopic mats in the three rivers: *Anabaena*, *Cylindrospermum*, *Microcoleus* (*Phormidium*), *Nostoc*, *Oscillatoria*, and *Scytonema*. Other toxic cyanobacterial genera may be present in lower densities within macroscopic mats.

2 What cyanotoxins are being produced in the Eel, South Fork Eel, and Russian Rivers?

   All five cyanotoxin classes were detected in the three rivers but detection rates and cyanotoxin concentrations varied by site and sample type (i.e., benthic mat, ambient water column, or SPATT samples). Anatoxins and microcystins/nodularins were the most frequently and widely detected cyanotoxins, occurring in each river and at every sampling site from 2016 to 2019.

3 Which cyanotoxins are associated with the various mat-forming cyanobacterial genera?

   The six mat-forming cyanobacterial genera collectively produced all five cyanotoxin classes. Mats dominated by *Anabaena*, *Microcoleus* (*Phormidium*), and *Oscillatoria* frequently produced the highest concentrations of cyanotoxins. Concentrations of anatoxins were highest in benthic mat samples, while microcystins/nodularins were highest in water column samples.

4 Are there spatial and seasonal patterns to mat formation and cyanotoxin production in the Eel, South Fork Eel, and Russian Rivers?

   Mat-forming benthic cyanobacteria were identified at all sampling sites in the three rivers. In general, benthic cyanobacterial biomass increases from June through September, followed by a decrease in October.

4.2 Cyanobacteria and Cyanotoxins

Results from this study contribute to the growing awareness of benthic toxigenic cyanobacteria occurring in streams and rivers across the world. The first documented report of anatoxin-a dog poisoning in North America occurred in the South Fork Eel River (Puschner et al., 2008), and additional research since that death has confirmed the presence of toxigenic cyanobacteria in the South Fork Eel River (Bouma-Gregson et al., 2018) and Russian River (Conklin et al., 2020).

Animal deaths are often sentinels for potential human health risks, particularly for sensitive groups like children (Hilborn and Beasley, 2015; Backer and Miller, 2016). Beyond the North Coast Region, wadeable streams across the State of California have been shown to harbor potentially toxigenic cyanobacteria that produce cyanotoxins within mats and biofilms (Fetscher et al., 2015). Outside California, benthic cyanotoxins have been reported in New Zealand, Canada, France, and elsewhere (Wood et al., 2020). Notably, Spain, which shares a similar Mediterranean climate with California, has many reports of toxic benthic cyanobacteria (Sabater et al., 2003; Loza et al., 2013; Cantoral Uriza et al., 2017). A growing body of research suggests that wadeable streams in Mediterranean climates are likely to harbor potentially toxigenic cyanobacterial species, which may proliferate into large macroscopic mats and, therefore, pose a public health risk.

Six toxigenic cyanobacterial genera that form macroscopic mats were documented in the Eel, South Fork Eel, and Russian Rivers: *Anabaena, Cylindrospermum, Microcoleus (Phormidium), Nostoc, Oscillatoria,* and *Scytonema* (Table 9). Anatoxins and microcystins/nodularins were the most frequently detected and widely distributed within macroscopic mats, with anatoxins consistently having the highest within-mat concentrations. Of the six mat-forming genera, only *Cylindrospermum*, *Microcoleus* (*Phormidium*), *Nostoc,* and *Oscillatoria* have been documented to produce anatoxins (Table 10) (Wood et al., 2020). Anatoxins were frequently detected in mats dominated by *Anabaena*, however, no anatoxin-producing *Anabaena* strain has been isolated to date (Kust et al., 2018). Therefore, it appears sub-dominant anatoxin-producing cyanobacteria may inhabit mats formed by non-anatoxin producing *Anabaena*. Previous research proposed that *Microcoleus* (*Phormidium*) living within *Anabaena*-dominated mats are the potential source of anatoxins in the South Fork Eel River (Kelly et al., 2019).

The variation of cyanotoxin detections in cyanobacterial mat samples shows frequent production of anatoxins and microcystins/nodularins with sporadic cylindrospermopsins and saxitoxins production. Anatoxins are also the primary cyanotoxin associated with benthic cyanobacterial mats in other countries (e.g., New Zealand and France) (Wood et al., 2020), and previous research in the South Fork Eel also frequently detected anatoxins and microcystins in cyanobacterial mats (Bouma-Gregson et al., 2018). The infrequent detection of cylindrospermopsin and saxitoxin in these rivers matches patterns across all of California, i.e., cyanotoxin data collected by the Water Boards Freshwater and Estuarine Harmful Algal Bloom Program infrequently detects cylindrospermopsins and saxitoxins in California water bodies (California Open Data Portal, 2021). Because anatoxins and microcystins/nodularins were detected at all sites and in all years and have also been detected in mats at other locations throughout the North Coast Region, evidence is mounting that these two cyanotoxins are consistently produced each summer in the Eel, South Fork Eel, and Russian Rivers.

While cyanotoxin concentrations within mats are thought to be high enough to cause canine mortalities, cyanotoxins in ambient water grab samples never triggered recreational advisories above the Caution level.

Anatoxins in water samples were detected less frequently than microcystins/nodularins and also at much lower rates and concentrations than in benthic mat samples. Previous research has shown that it is common to find undetectable or very low cyanotoxin concentrations in the water column when cyanotoxins are produced in mats (Wood and Puddick 2017; Bouma-Gregson et al., 2018; Wood et al., 2018). The discrepancy between cyanotoxin detections in mats and the water column is likely due to the physiology of toxin production and the chemistry of toxin molecules. When cyanobacterial cells synthesize most toxin molecules, the toxins remain within the cells and only escape the mats when individual cells are liberated from a mat and become suspended in the water column, or when a cell membrane ruptures and releases dissolved cyanotoxins into the water column. However, the exception to this is cylindrospermopsins, which has been shown to leak or be released from viable cells at high rates (Chorus and Welker 2021c). Once toxins are released from cells and dissolve into the water column, they eventually degrade into non-toxic molecules. The degradation rates vary among cyanotoxins, with microcystins being more stable than anatoxins (Chorus and Welker 2021c). Thus, the higher detection of microcystins in ambient water samples (Table 14) may be due to faster degradation rates of anatoxins. These findings suggest that dissolved water column cyanotoxins are less of a recreational risk through incidental ingestion of ambient water than is the incidental ingestion of benthic mat material.

SPATT samplers showed widespread production and release of anatoxins and microcystins/nodularins in the Eel, South Fork Eel, and Russian Rivers. SPATT results affirmed that microcystins/nodularins are found in higher concentrations in the water column, and that other cyanotoxins can also be present at relatively high frequencies. According to detection data, SPATTs were able to detect a greater number of cyanotoxins at more sites and at higher rates than ambient water grab or benthic mat samples (Tables 12, 14, and 17). It is important to note, however, that SPATT deployment times varied during the study (i.e., range from 2-14 days), therefore, each sampler was subject to various adsorption and desorption rates as well as different environmental factors. These results demonstrate the unique ability of SPATTs to integrate low concentrations of dissolved cyanotoxins that may not be captured or measurable in instantaneous ambient water grab samples. The sensitivity of SPATTs allows them to be used as sentinel samplers to determine what cyanotoxins are moving through the river system, providing for a more robust approach to understanding the temporal changes in cyanobacterial production.

4.3 Monitoring Recommendations

4.3.1 Cyanotoxin Laboratory Analysis

As a qualitative tool in determining cyanotoxin concentrations, the cross-reactivity of ELISA to multiple cyanotoxin congeners provides a more complete analysis of cyanotoxin concentrations in a given sample than does LCMS.

To derive cyanotoxin concentration via LCMS, multiple sample runs are necessary to measure and quantify the results against various standards should they exist. LCMS analysis is therefore a more costly alternative to ELISA and may underreport concentrations and, as a consequence, underestimate risk to the recreating public. In summary, the North Coast Region recommends ELISA for cyanotoxin analysis since it detects more congeners and therefore provides a more cumulative measurement at a lower cost.

4.3.2 Cyanotoxin Monitoring

The development of a cyanotoxin monitoring program in riverine systems dominated by benthic cyanobacterial mats should focus on the detection and quantification of anatoxins in cyanobacterial mats. Anatoxins were the most frequently detected cyanotoxin in macroscopic benthic mats (82% of samples) and were detected in the highest concentrations. Additionally, anatoxins have been implicated in 18 cyanobacteria-related dog deaths in the North Coast Region. Although microcystins/nodularins were detected in over 50% of benthic mat samples, the concentrations were much lower than anatoxins by more than 100-fold in most cases. Saxitoxins and cylindrospermopsins were rarely detected and concentrations were generally low, except for one high cylindrospermopsin concentration measured in a single *Nostoc* mat sample. While the focus of a developed monitoring program should be anatoxins, screening methodologies could be implemented to conduct less frequent analyses for other cyanotoxins to provide confirmation that they are not present in elevated concentrations. Riverine systems that are influenced by large planktonic cyanoHABs in upstream lakes and reservoirs may need to prioritize additional cyanotoxins, however, recommendations for planktonic dominated systems are beyond the scope of this report.

This study documents increasing cyanobacterial biomass from June through October with a corresponding increase in cyanotoxin concentrations within benthic mats and in the water column. These findings are based on results from three monitoring methods: benthic mat, ambient water grab, and SPATT samplers. Each method provides a unique perspective that when employed synergistically can be effective in identifying risk and direct the appropriate response. The major health risk associated with benthic cyanoHABs in riverine systems is the incidental ingestion of toxic mat material from detached mats. As such, benthic mat samples should be prioritized over ambient water grab samples, yet both sample types are limited in that they only identify cyanotoxin concentrations present at that specific time and location. SPATT samplers integrate cyanotoxins over time wherever they are deployed, capturing the dissolved fraction of cyanotoxins in the water column from the local point of deployment to all points upstream. The ability to integrate and document increases in water column cyanotoxin concentrations makes SPATTs a valuable riverine monitoring method for inferring increases in benthic cyanobacterial mat formation.

4.3.3 Cyanobacteria Monitoring

Not all cyanobacteria produce cyanotoxins, and although monitoring from 2016 to 2019 identified over twenty cyanobacterial taxa in the Eel, South Fork Eel, and Russian Rivers, this study found that only a few genera need to be monitored consistently when present. Cyanotoxin analysis of cyanobacterial mats dominated by different genera found that *Anabaena, Microcoleus* (*Phormidium*)*,* and *Oscillatoria* dominated mats most frequently contained cyanotoxins in high concentrations. These genera were also relatively abundant across the three rivers. These genera are not known to produce all of the toxins detected in monitoring samples, but the mats may contain microscopic sub-dominant cyanobacterial species that produce the various cyanotoxins within the mats (Kelly et al., 2019). Overall, *Anabaena, Microcoleus* (*Phormidium*), and *Oscillatoria* are considered to be the cyanobacterial genera of concern in the Eel, South Fork Eel, and Russian Rivers and should be considered compulsory for a benthic cyanoHAB program.

The three genera of concern often grow in different habitats which can occur in many locations throughout the length of a river (Table 9). This knowledge should help guide the visual assessment component of a monitoring program. *Anabaena* grows predominantly in low- or no-flow habitats, often in backwater areas or along streambanks. Frequently, *Anabaena* can be found growing on filamentous green algae or within the slack-water areas created by filamentous green algae, eventually replacing the green algae late in the summer season. *Microcoleus* (*Phormidium*) grows predominantly in faster moving waters on cobble and gravel dominated river bottoms and can be opportunistic, growing on green algae or aquatic vegetation. *Oscillatoria* typically grows in the slow-moving locations dominated by sands and silts and situated in shady locations. *Oscillatoria* mats are less cohesive than *Microcoleus* (*Phormidium*) dominated mats; they are also weakly attached to substrate and will dislodge easily from the riverbed. Because benthic mats commonly dislodge and float when disturbed, cyanobacterial monitoring in riverine systems should also focus on any accumulations that occur downstream or that become stranded on recreational beaches.

Cyanobacteria monitoring should focus on conducting visual assessments to identify toxigenic genera, document increasing biomass and mat development, and verify the potential public health risks when cyanobacterial mat detachment from the substrate is occurring. Visual assessment coupled with SPATT samplers, as well as periodic cyanotoxin testing of the benthic mats, should be employed to confirm health risks and appropriate response scenarios.

To use resources efficiently, a successful program should employ the three monitoring methods in a stepwise manner, documenting the development and proliferation of cyanobacterial mats and appropriately identifying risk. SPATTs positioned throughout a river early in the season can be used as sentinel samplers to document when dissolved cyanotoxins are present and moving through the system in increasing concentrations. This approach offers a low-cost alternative to repeated benthic mat or ambient water grab samples at numerous sampling locations.

As cyanotoxin concentrations in the SPATTs increase, visual observations of cyanobacterial mat development and eventual detachment should be instituted. As visual observation documents the development of mat forming toxigenic benthic cyanobacteria are beginning to proliferate, cyanotoxin testing of the mats should be employed to determine the potential health risks associated with river recreation, guiding the appropriate response scenario.

4.3.4 Monitoring Timeframe

As in many aquatic ecosystems, cyanobacterial growth and abundance in the Eel, South Fork Eel, and Russian Rivers was greatest in the summer. The initiation of seasonal growth is strongly influenced by the extent, timing, and intensity of winter and spring rains. For example, increased flows from large late-season storms in April or May can delay algal colonization and growth by several weeks. Growth in biomass generally continues through the summer season and starts to slow by September or October. Although growth may slow in the fall, environmental conditions can remain favorable for mats to persist until the first large winter storms raise river levels and slough away the remaining summer biomass.

SPATT time series data and observed cyanotoxin mat concentrations support the visual observations of increasing summer cyanobacterial biomass throughout the sample season, with corresponding cyanotoxin concentrations generally increasing through the summer season, peaking in September, and decreasing through the remainder of the season. These results are similar to SPATT results from Bouma-Gregson et al. (2018) that also found decreasing SPATT cyanotoxins concentrations in September and October. The temporal trends in cyanotoxin production are toxin specific with microcystins/nodularins detections greatest in the late spring and early summer, while anatoxins peak in the mid- to late summer season. Nonetheless, due to their ability to harbor elevated cyanotoxin concentrations, macroscopic mats of *Anabaena*, *Microcoleus* (*Phormidium*), and *Oscillatoria* should be considered potentially toxigenic no matter the time of year. Riverine systems that are influenced by large planktonic cyanoHABs in upstream lakes and reservoirs may need to adjust the seasonal component to coincide with bloom development in those waterbodies, however, those recommendations are beyond the scope of this report.

Overall, a benthic cyanobacterial monitoring program in riverine systems should occur between May and October, which typically coincides with increased recreational activity. SPATT deployments should begin in May, followed by the implementation of needs-based visual assessment, especially in years with dry winters, or until more robust relationships on the initial timing of mat formations are developed for the Eel, South Fork Eel, and Russian Rivers. Ongoing data analysis of SPATT concentrations and visual assessments can help determine the timing and need for toxin analysis of cyanobacterial mats.

Riverine systems are dynamic, and cyanobacteria are opportunistic. A robust visual assessment program would help identify if cyanobacterial community shifts are occurring over time, and continued analysis of SPATT concentration data would provide ongoing verification of cyanotoxin production that could lead to changes in identifying genera and cyanotoxins of concern. This recommendation is of greater significance as rivers experience ongoing droughts due to climate change.

4.4 Recommendations for Future Studies

This study documents the cyanotoxin production of benthic mat-forming cyanobacterial genera in three Northern California rivers. Toxigenic benthic cyanobacteria pose a health risk to the recreating public and domestic animals through the incidental ingestion of mat material rather than water. Additional studies and research are needed to develop benthic criteria to protect the public and animals.

Cyanotoxin analysis in benthic mat samples used the same approach as for water samples, i.e., mat material and ambient water were homogenized and tested for the amount of cyanotoxins present in a known volume. This approach provides important information for documenting cyanotoxin trends but does not specifically target mat material and does not allow for direct comparison of toxin concentrations among mat samples. Future studies should investigate the best approach to standardizing data collection and lab assessment to determine cyanotoxin concentrations in benthic mats for the evaluation of human health, domestic animal, and wildlife protection.

AFDM analysis was used as a way of standardizing some cyanotoxin results, normalizing cyanotoxin concentrations by the mass of mat material sampled. AFDM confirmed the trends observed in mat samples evaluated through other lab methods and provided a sound approach to making comparisons among cyanobacterial genera and rivers. However, AFDM results cannot be used to assess potential public health threats since human health criteria are expressed as ug/L cyanotoxin in the water column. Thus, the Regional Water Board encourages future studies to focus on determining the cyanotoxin levels in benthic mats that result in threats to public health, domestic animals, and wildlife. This work should include partnering with the Office of Environmental Health Hazard Assessment (OEHHA) to develop thresholds for the ingestion of mat material.

Future studies should also consider focusing on the development of percent cover thresholds for the benthic mat forming genera of concern: *Anabaena*, *Microcoleus* (*Phormidium*), and *Oscillatoria*. Benthic trigger levels for public health alerts could be developed that associate percent cover or toxigenic cyanobacterial biomass and cyanotoxin concentrations that would pose a threat to the public, domestic animals, and wildlife.

Additional studies should refine sampling protocols for SPATT samplers. As discussed in this report, SPATT samplers are subject to differing adsorption and desorption rates as a function of environmental factors and deployment time. For example, environmental conditions such as water clarity or hardness may affect a SPATT's ability to adsorb cyanotoxins, and variable flow regimes may impact adsorption and desorption rates in general, and each of these factors vary with time. Because environmental factors are largely uncontrollable in a natural setting, it is important to understand the site-specific factors which may dictate the amount of time a SPATT should be deployed.

Although a substantial amount of research has defined what factors contribute to planktonic cyanoHABs (e.g., nutrients, temperature), it is less clear what factors influence benthic cyanobacterial growth, especially since they occur in all habitats under a wide range of environmental conditions. Future studies should focus on the long-term (seasonal) environmental conditions that are supportive of toxigenic cyanobacterial growth and how they are influenced by biostimulatory conditions and other potentially controllable factors.

Future research should include the effects of climate change and how altered precipitation patterns or drought influence benthic biomass and cyanotoxin production. Results from these studies and others could be used to answer the question of whether benthic cyanoHABs are increasing in frequency, duration, and magnitude, or whether increases in postings and reports are an artifact of increased awareness and monitoring, or both.

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6 Appendices

Appendix 1. Benthic cyanobacteria percent cover and associated categories by sampling site and date in the Eel River, South Fork Eel River, and Russian River, from 2016 to 2019.

River	Site	Date	Percent Cover	Category
Eel River	111ER6140	6/7/2018	0	ABSENT
Eel River	111ER6140	6/26/2018	<5%	MINIMAL
Eel River	111ER6140	7/19/2018	<5%	MINIMAL
Eel River	111ER6140	8/14/2018	<5%	MINIMAL
Eel River	111ER6140	9/12/2018	0	ABSENT
Eel River	111ER6140	9/18/2018	0	ABSENT
Eel River	111ER6140	10/4/2018	0	ABSENT
Eel River	111ER6140	6/30/2019	<5%	MINIMAL
Eel River	111ER6140	7/3/2019	<5%	MINIMAL
Eel River	111ER6140	7/16/2019	<5%	MINIMAL
Eel River	111ER6140	7/18/2019	<5%	MINIMAL
Eel River	111ER6140	7/31/2019	0	ABSENT
Eel River	111ER6140	8/2/2019	0	ABSENT
Eel River	111ER6140	9/17/2019	0	ABSENT
Eel River	111ER6140	9/24/2019	0	ABSENT
Eel River	111ER6381	8/1/2016	<5%	MINIMAL
Eel River	111ER6381	8/18/2016	<5%	MINIMAL
Eel River	111ER6381	9/1/2016	<5%	MINIMAL
Eel River	111ER6381	9/14/2016	<5%	MINIMAL
Eel River	111ER6381	10/1/2016	<5%	MINIMAL
Eel River	111ER8102	8/1/2016	50-99%	ABUNDANT
Eel River	111ER8102	8/15/2016	50-99%	ABUNDANT
Eel River	111ER8102	9/6/2016	50-99%	ABUNDANT
Eel River	111ER8102	9/15/2016	100%	COMPLETE
Eel River	111ER8102	9/30/2016	50-99%	ABUNDANT
Eel River	111ER8102	6/14/2017	<5%	MINIMAL
Eel River	111ER8102	6/27/2017	5-24%	PRESENT
Eel River	111ER8102	8/17/2017	50-99%	ABUNDANT
Eel River	111ER8102	8/29/2017	50-99%	ABUNDANT
Eel River	111ER8102	9/13/2017	<5%	MINIMAL
Eel River	111ER8102	9/27/2017	<5%	MINIMAL
Eel River	111ER8102	10/31/2017	50-99%	ABUNDANT
Eel River	111ER8102	6/6/2018	5-24%	PRESENT
Eel River	111ER8102	6/12/2018	5-24%	PRESENT
Eel River	111ER8102	6/25/2018	25-49%	COMMON
Eel River	111ER8102	7/12/2018	50-99%	ABUNDANT

River	Site	Date	Percent Cover	Category
Eel River	111ER8102	7/17/2018	25-49%	COMMON
Eel River	111ER8102	8/15/2018	100%	COMPLETE
Eel River	111ER8102	9/12/2018	100%	COMPLETE
Eel River	111ER8102	9/18/2018	50-99%	ABUNDANT
Eel River	111ER8102	10/4/2018	5-24%	PRESENT
Eel River	111ER8102	6/10/2019	UNKNOWN	INDETERMINANT
Eel River	111ER8102	6/13/2019	UNKNOWN	INDETERMINANT
Eel River	111ER8102	6/18/2019	UNKNOWN	INDETERMINANT
Eel River	111ER8102	6/20/2019	UNKNOWN	INDETERMINANT
Eel River	111ER8102	6/24/2019	UNKNOWN	INDETERMINANT
Eel River	111ER8102	6/27/2019	UNKNOWN	INDETERMINANT
Eel River	111ER8102	6/30/2019	UNKNOWN	INDETERMINANT
Eel River	111ER8102	7/3/2019	UNKNOWN	INDETERMINANT
Eel River	111ER8102	7/9/2019	UNKNOWN	INDETERMINANT
Eel River	111ER8102	7/11/2019	UNKNOWN	INDETERMINANT
Eel River	111ER8102	7/16/2019	UNKNOWN	INDETERMINANT
Eel River	111ER8102	7/18/2019	UNKNOWN	INDETERMINANT
Eel River	111ER8102	7/22/2019	UNKNOWN	INDETERMINANT
Eel River	111ER8102	7/24/2019	UNKNOWN	INDETERMINANT
Eel River	111ER8102	7/30/2019	UNKNOWN	INDETERMINANT
Eel River	111ER8102	8/1/2019	UNKNOWN	INDETERMINANT
Eel River	111ER8102	8/14/2019	UNKNOWN	INDETERMINANT
Eel River	111ER8102	8/16/2019	UNKNOWN	INDETERMINANT
Eel River	111ER8102	9/4/2019	5-24%	PRESENT
Eel River	111ER8102	9/6/2019	5-24%	PRESENT
Eel River	111ER8102	9/18/2019	<5%	MINIMAL
SF Eel River	111SF2423	8/1/2016	5-24%	PRESENT
SF Eel River	111SF2423	8/18/2016	50-99%	ABUNDANT
SF Eel River	111SF2423	9/1/2016	<5%	MINIMAL
SF Eel River	111SF2423	9/14/2016	<5%	MINIMAL
SF Eel River	111SF2423	10/1/2016	<5%	MINIMAL
SF Eel River	111SF2423	6/12/2019	<5%	MINIMAL
SF Eel River	111SF2423	6/19/2019	<5%	MINIMAL
SF Eel River	111SF2423	7/31/2019	<5%	MINIMAL
SF Eel River	111SF2423	8/2/2019	<5%	MINIMAL
SF Eel River	111SF2423	8/14/2019	<5%	MINIMAL
SF Eel River	111SF2423	8/16/2019	<5%	MINIMAL
SF Eel River	111SF2423	8/26/2019	25-49%	COMMON
SF Eel River	111SF2423	8/27/2019	25-49%	COMMON
SF Eel River	111SF2423	8/28/2019	25-49%	COMMON
SF Eel River	111SF2423	8/29/2019	25-49%	COMMON
SF Eel River	111SF2423	8/30/2019	25-49%	COMMON

River	Site	Date	Percent Cover	Category
SF Eel River	111SF2423	9/6/2019	NOT REPORTED	NOT REPORTED
SF Eel River	111SF2423	9/11/2019	NOT REPORTED	NOT REPORTED
SF Eel River	111SF2423	9/17/2019	5-24%	PRESENT
SF Eel River	111SF2423	9/27/2019	5-24%	PRESENT
SF Eel River	111SF2423	10/5/2019	NOT REPORTED	NOT REPORTED
SF Eel River	111SF4640	5/25/2017	0	ABSENT
SF Eel River	111SF4640	6/14/2017	<5%	MINIMAL
SF Eel River	111SF4640	6/27/2017	<5%	MINIMAL
SF Eel River	111SF4640	7/12/2017	<5%	MINIMAL
SF Eel River	111SF4640	8/17/2017	50-99%	ABUNDANT
SF Eel River	111SF4640	8/29/2017	50-99%	ABUNDANT
SF Eel River	111SF4640	9/13/2017	25-49%	COMMON
SF Eel River	111SF4640	9/26/2017	50-99%	ABUNDANT
SF Eel River	111SF4640	10/16/2017	50-99%	ABUNDANT
SF Eel River	111SF4640	6/7/2018	<5%	MINIMAL
SF Eel River	111SF4640	6/12/2018	<5%	MINIMAL
SF Eel River	111SF4640	6/26/2018	50-99%	ABUNDANT
SF Eel River	111SF4640	7/19/2018	50-99%	ABUNDANT
SF Eel River	111SF4640	8/14/2018	50-99%	ABUNDANT
SF Eel River	111SF4640	9/12/2018	25-49%	COMMON
SF Eel River	111SF4640	9/18/2018	50-99%	ABUNDANT
SF Eel River	111SF4640	10/4/2018	5-24%	PRESENT
SF Eel River	111SF4640	6/5/2019	0	ABSENT
SF Eel River	111SF4640	6/7/2019	<5%	MINIMAL
SF Eel River	111SF4640	6/19/2019	<5%	MINIMAL
SF Eel River	111SF4640	6/21/2019	<5%	MINIMAL
SF Eel River	111SF4640	7/9/2019	25-49%	COMMON
SF Eel River	111SF4640	7/11/2019	25-49%	COMMON
SF Eel River	111SF4640	7/16/2019	<5%	MINIMAL
SF Eel River	111SF4640	7/18/2019	50-99%	ABUNDANT
SF Eel River	111SF4640	7/31/2019	50-99%	ABUNDANT
SF Eel River	111SF4640	8/14/2019	50-99%	ABUNDANT
SF Eel River	111SF4640	8/16/2019	50-99%	ABUNDANT
SF Eel River	111SF4640	8/26/2019	25-49%	COMMON
SF Eel River	111SF4640	8/27/2019	25-49%	COMMON
SF Eel River	111SF4640	8/28/2019	25-49%	COMMON
SF Eel River	111SF4640	8/29/2019	25-49%	COMMON
SF Eel River	111SF4640	8/30/2019	25-49%	COMMON
SF Eel River	111SF4640	9/6/2019	25-49%	COMMON
SF Eel River	111SF4640	9/11/2019	25-49%	COMMON
SF Eel River	111SF4640	9/17/2019	5-24%	PRESENT
SF Eel River	111SF4640	9/27/2019	5-24%	PRESENT

River	Site	Date	Percent Cover	Category
SF Eel River	111SF4640	10/1/2019	50-99%	ABUNDANT
SF Eel River	111SF4640	10/3/2019	25-49%	COMMON
SF Eel River	111SF4640	10/5/2019	25-49%	COMMON
SF Eel River	111SF4640	10/7/2019	25-49%	COMMON
SF Eel River	111SF4640	10/9/2019	25-49%	COMMON
SF Eel River	111SF4640	10/11/2019	25-49%	COMMON
SF Eel River	111SF6856	8/1/2016	<5%	MINIMAL
SF Eel River	111SF6856	8/18/2016	5-24%	PRESENT
SF Eel River	111SF6856	9/1/2016	<5%	MINIMAL
SF Eel River	111SF6856	9/14/2016	<5%	MINIMAL
SF Eel River	111SF6856	10/1/2016	<5%	MINIMAL
SF Eel River	111SF6856	5/25/2017	<5%	MINIMAL
SF Eel River	111SF6856	6/14/2017	<5%	MINIMAL
SF Eel River	111SF6856	6/27/2017	<5%	MINIMAL
SF Eel River	111SF6856	7/12/2017	<5%	MINIMAL
SF Eel River	111SF6856	8/17/2017	25-49%	COMMON
SF Eel River	111SF6856	8/29/2017	25-49%	COMMON
SF Eel River	111SF6856	9/13/2017	5-24%	PRESENT
SF Eel River	111SF6856	9/26/2017	<5%	MINIMAL
SF Eel River	111SF6856	10/16/2017	<5%	MINIMAL
SF Eel River	111SF6856	6/7/2018	<5%	MINIMAL
SF Eel River	111SF6856	6/12/2018	5-24%	PRESENT
SF Eel River	111SF6856	6/26/2018	5-24%	PRESENT
SF Eel River	111SF6856	7/19/2018	5-24%	PRESENT
SF Eel River	111SF6856	8/14/2018	50-99%	ABUNDANT
SF Eel River	111SF6856	9/12/2018	50-99%	ABUNDANT
SF Eel River	111SF6856	9/18/2018	25-49%	COMMON
SF Eel River	111SF6856	10/4/2018	50-99%	ABUNDANT
SF Eel River	111SF6856	6/5/2019	<5%	MINIMAL
SF Eel River	111SF6856	6/7/2019	<5%	MINIMAL
SF Eel River	111SF6856	6/19/2019	<5%	MINIMAL
SF Eel River	111SF6856	6/21/2019	50-99%	ABUNDANT
SF Eel River	111SF6856	7/16/2019	50-99%	ABUNDANT
SF Eel River	111SF6856	7/18/2019	50-99%	ABUNDANT
SF Eel River	111SF6856	7/30/2019	50-99%	ABUNDANT
SF Eel River	111SF6856	7/31/2019	50-99%	ABUNDANT
SF Eel River	111SF6856	8/2/2019	50-99%	ABUNDANT
SF Eel River	111SF6856	8/14/2019	50-99%	ABUNDANT
SF Eel River	111SF6856	8/16/2019	50-99%	ABUNDANT
SF Eel River	111SF6856	8/26/2019	50-99%	ABUNDANT
SF Eel River	111SF6856	8/27/2019	50-99%	ABUNDANT
SF Eel River	111SF6856	8/28/2019	50-99%	ABUNDANT

River	Site	Date	Percent Cover	Category
SF Eel River	111SF6856	8/30/2019	50-99%	ABUNDANT
SF Eel River	111SF6856	9/6/2019	5-24%	PRESENT
SF Eel River	111SF6856	9/11/2019	5-24%	PRESENT
SF Eel River	111SF6856	9/17/2019	5-24%	PRESENT
SF Eel River	111SF6856	9/27/2019	5-24%	PRESENT
SF Eel River	111SF6856	10/5/2019	NOT REPORTED	NOT REPORTED
Russian River	114RR1159	7/20/2016	<5%	MINIMAL
Russian River	114RR1159	8/2/2016	<5%	MINIMAL
Russian River	114RR1159	8/15/2016	<5%	MINIMAL
Russian River	114RR1159	8/30/2016	<5%	MINIMAL
Russian River	114RR1159	9/12/2016	<5%	MINIMAL
Russian River	114RR1159	9/30/2016	0	ABSENT
Russian River	114RR2079	5/26/2017	0	ABSENT
Russian River	114RR2079	6/15/2017	0	ABSENT
Russian River	114RR2079	6/28/2017	<5%	MINIMAL
Russian River	114RR2079	7/18/2017	0	ABSENT
Russian River	114RR2079	8/3/2017	<5%	MINIMAL
Russian River	114RR2079	8/15/2017	<5%	MINIMAL
Russian River	114RR2079	8/30/2017	5-24%	PRESENT
Russian River	114RR2079	9/14/2017	<5%	MINIMAL
Russian River	114RR2079	9/28/2017	5-24%	PRESENT
Russian River	114RR2079	10/17/2017	50-99%	ABUNDANT
Russian River	114RR2655	8/15/2016	<5%	MINIMAL
Russian River	114RR2655	8/30/2016	5-24%	PRESENT
Russian River	114RR2655	9/12/2016	<5%	MINIMAL
Russian River	114RR2655	9/29/2016	25-49%	COMMON
Russian River	114RR2655	5/26/2017	0	ABSENT
Russian River	114RR2655	6/15/2017	0	ABSENT
Russian River	114RR2655	6/28/2017	<5%	MINIMAL
Russian River	114RR2655	7/18/2017	0	ABSENT
Russian River	114RR2655	8/3/2017	0	ABSENT
Russian River	114RR2655	8/15/2017	<5%	MINIMAL
Russian River	114RR2655	8/30/2017	<5%	MINIMAL
Russian River	114RR2655	9/14/2017	<5%	MINIMAL
Russian River	114RR2655	9/28/2017	5-24%	PRESENT
Russian River	114RR2655	10/17/2017	NOT REPORTED	NOT REPORTED
Russian River	114RR2655	10/31/2017	5-24%	PRESENT
Russian River	114RR2655	6/6/2018	0	ABSENT
Russian River	114RR2655	6/27/2018	0	ABSENT
Russian River	114RR2655	7/17/2018	0	ABSENT
Russian River	114RR2655	8/2/2018	<5%	MINIMAL
Russian River	114RR2655	9/13/2018	<5%	MINIMAL

River	Site	Date	Percent Cover	Category
Russian River	114RR2655	9/19/2018	<5%	MINIMAL
Russian River	114RR2655	9/25/2018	5-24%	PRESENT
Russian River	114RR4234	8/2/2016	<5%	MINIMAL
Russian River	114RR4234	8/15/2016	5-24%	PRESENT
Russian River	114RR4234	8/30/2016	<5%	MINIMAL
Russian River	114RR4234	9/12/2016	<5%	MINIMAL
Russian River	114RR4234	9/30/2016	<5%	MINIMAL
Russian River	114RR5407	7/27/2016	5-24%	PRESENT
Russian River	114RR5407	8/2/2016	5-24%	PRESENT
Russian River	114RR5407	8/15/2016	25-49%	COMMON
Russian River	114RR5407	8/30/2016	25-49%	COMMON
Russian River	114RR5407	9/12/2016	25-49%	COMMON
Russian River	114RR5407	10/3/2016	<5%	MINIMAL
Russian River	114RR5407	5/24/2017	0	ABSENT
Russian River	114RR5407	6/15/2017	0	ABSENT
Russian River	114RR5407	6/27/2017	<5%	MINIMAL
Russian River	114RR5407	7/18/2017	5-24%	PRESENT
Russian River	114RR5407	8/3/2017	5-24%	PRESENT
Russian River	114RR5407	8/17/2017	<5%	MINIMAL
Russian River	114RR5407	8/30/2017	5-24%	PRESENT
Russian River	114RR5407	9/14/2017	NOT REPORTED	NOT REPORTED
Russian River	114RR5407	9/27/2017	5-24%	PRESENT
Russian River	114RR5407	10/17/2017	UNKNOWN	INDETERMINANT
Russian River	114RR5407	6/6/2018	<5%	MINIMAL
Russian River	114RR5407	6/25/2018	<5%	MINIMAL
Russian River	114RR5407	7/17/2018	<5%	MINIMAL
Russian River	114RR5407	7/31/2018	25-49%	COMMON
Russian River	114RR5407	9/13/2018	<5%	MINIMAL
Russian River	114RR5407	9/19/2018	<5%	MINIMAL
Russian River	114RR5407	9/25/2018	<5%	MINIMAL
Russian River	114RR5407	6/7/2019	<5%	MINIMAL
Russian River	114RR5407	6/10/2019	<5%	MINIMAL
Russian River	114RR5407	6/13/2019	<5%	MINIMAL
Russian River	114RR5407	6/18/2019	<5%	MINIMAL
Russian River	114RR5407	6/19/2019	<5%	MINIMAL
Russian River	114RR5407	6/25/2019	<5%	MINIMAL
Russian River	114RR5407	6/27/2019	<5%	MINIMAL
Russian River	114RR5407	7/9/2019	<5%	MINIMAL
Russian River	114RR5407	7/11/2019	<5%	MINIMAL
Russian River	114RR5407	7/22/2019	<5%	MINIMAL
Russian River	114RR5407	7/24/2019	<5%	MINIMAL
Russian River	114RR5407	7/30/2019	<5%	MINIMAL

River	Site	Date	Percent Cover	Category
Russian River	114RR5407	8/1/2019	<5%	MINIMAL
Russian River	114RR5407	8/16/2019	<5%	MINIMAL
Russian River	114RR5407	8/19/2019	<5%	MINIMAL
Russian River	114RR5407	9/4/2019	<5%	MINIMAL
Russian River	114RR5407	9/6/2019	<5%	MINIMAL
Russian River	114RR5407	9/12/2019	<5%	MINIMAL
Russian River	114RR5407	9/27/2019	<5%	MINIMAL
Russian River	114RR5407	10/1/2019	UNKNOWN	INDETERMINANT
Russian River	114RR5407	10/3/2019	UNKNOWN	INDETERMINANT
Russian River	114RR5407	10/5/2019	UNKNOWN	INDETERMINANT
Russian River	114RR5407	10/7/2019	UNKNOWN	INDETERMINANT
Russian River	114RR5407	10/9/2019	UNKNOWN	INDETERMINANT
Russian River	114RR5407	10/11/2019	UNKNOWN	INDETERMINANT
Russian River	114RR7396	8/2/2016	UNKNOWN	INDETERMINANT
Russian River	114RR7396	8/15/2016	UNKNOWN	INDETERMINANT
Russian River	114RR7396	8/30/2016	UNKNOWN	INDETERMINANT
Russian River	114RR7396	9/15/2016	UNKNOWN	INDETERMINANT
Russian River	114RR7396	9/30/2016	UNKNOWN	INDETERMINANT
Russian River	114RR7396	5/24/2017	0	ABSENT
Russian River	114RR7396	6/15/2017	<5%	MINIMAL
Russian River	114RR7396	6/27/2017	<5%	MINIMAL
Russian River	114RR7396	7/12/2017	UNKNOWN	INDETERMINANT
Russian River	114RR7396	8/3/2017	UNKNOWN	INDETERMINANT
Russian River	114RR7396	8/17/2017	UNKNOWN	INDETERMINANT
Russian River	114RR7396	8/30/2017	UNKNOWN	INDETERMINANT
Russian River	114RR7396	9/14/2017	UNKNOWN	INDETERMINANT
Russian River	114RR7396	9/26/2017	UNKNOWN	INDETERMINANT
Russian River	114RR7396	10/16/2017	UNKNOWN	INDETERMINANT
Russian River	114RR7396	6/6/2018	5-24%	PRESENT
Russian River	114RR7396	6/17/2018	5-24%	PRESENT
Russian River	114RR7396	6/25/2018	<5%	MINIMAL
Russian River	114RR7396	7/18/2018	<5%	MINIMAL
Russian River	114RR7396	8/2/2018	0	ABSENT
Russian River	114RR7396	8/15/2018	0	ABSENT
Russian River	114RR7396	9/13/2018	UNKNOWN	INDETERMINANT
Russian River	114RR7396	9/25/2018	UNKNOWN	INDETERMINANT

Appendix 2. Taxonomic identification of cyanobacterial reachwide mat samples by sampling site and date in the Eel River, South Fork Eel River, and Russian River in 2016.

River	Site Code	Date	Genera	Species Identification
EEL RIVER	111ER6381	8/1/2016	*Gloeotrichia*	*Gloeotrichia natans*
EEL RIVER	111ER6381	8/1/2016	*Leptolyngbya*	*Leptolyngbya notata*
EEL RIVER	111ER6381	8/1/2016	*Nostoc*	*Nostoc cf commune*
EEL RIVER	111ER6381	8/18/2016	*Anabaena*	*Anabaena sp 2*
EEL RIVER	111ER6381	8/18/2016	*Anabaena*	*Anabaena sphaerica*
EEL RIVER	111ER6381	8/18/2016	*Calothrix*	*Calothrix fusca*
EEL RIVER	111ER6381	8/18/2016	*Chroococcus*	*Chroococcus vacuolatus*
EEL RIVER	111ER6381	8/18/2016	*Geitlerinema*	*Geitlerinema splendidum*
EEL RIVER	111ER6381	8/18/2016	*Gloeotrichia*	*Gloeotrichia natans*
EEL RIVER	111ER6381	8/18/2016	*Microchaete*	*Microchaete tenera*
EEL RIVER	111ER6381	8/18/2016	*Microcoleus (Phormidium)*	*Phormidium autumnale*
EEL RIVER	111ER6381	8/18/2016	*Microcoleus (Phormidium)*	*Phormidium irriguum*
EEL RIVER	111ER6381	8/18/2016	*Microcoleus (Phormidium)*	*Phormidium nigroviride*
EEL RIVER	111ER6381	8/18/2016	*Oscillatoria*	*Oscillatoria princeps*
EEL RIVER	111ER6381	9/1/2016	*Anabaena*	*Anabaena californica*
EEL RIVER	111ER6381	9/1/2016	*Anabaena*	*Anabaena sphaerica*
EEL RIVER	111ER6381	9/1/2016	*Aphanocapsa*	*Aphanocapsa spp*
EEL RIVER	111ER6381	9/1/2016	*Aphanothece*	*Aphanothece spp*
EEL RIVER	111ER6381	9/1/2016	*Aphanothece*	*Aphanothece stagnina*
EEL RIVER	111ER6381	9/1/2016	*Chroococcus*	*Chroococcus minimus*
EEL RIVER	111ER6381	9/1/2016	*Chroococcus*	*Chroococcus turgidus*
EEL RIVER	111ER6381	9/1/2016	*Chroococcus*	*Chroococcus vacuolatus*
EEL RIVER	111ER6381	9/1/2016	*Cladophora*	*Cladophora glomerata*
EEL RIVER	111ER6381	9/1/2016	*Dolichospermum*	*Dolichospermum sp. 4*
EEL RIVER	111ER6381	9/1/2016	*Geitlerinema*	*Geitlerinema acutissimum*
EEL RIVER	111ER6381	9/1/2016	*Geitlerinema*	*Geitlerinema splendidum*

River	Site Code	Date	Genera	Species Identification
EEL RIVER	111ER6381	9/1/2016	*Gloeotrichia*	*Gloeotrichia natans*
EEL RIVER	111ER6381	9/1/2016	*Microchaete*	*Microchaete tenera*
EEL RIVER	111ER6381	9/1/2016	*Microcoleus (Phormidium)*	*Phormidium autumnale*
EEL RIVER	111ER6381	9/1/2016	*Microcoleus (Phormidium)*	*Phormidium irriguum*
EEL RIVER	111ER6381	9/1/2016	*Microcoleus (Phormidium)*	*Phormidium nigroviride*
EEL RIVER	111ER6381	9/1/2016	*Nostoc*	*Nostoc carneum*
EEL RIVER	111ER6381	9/1/2016	*Nostoc*	*Nostoc muscorum*
EEL RIVER	111ER6381	9/1/2016	*Oscillatoria*	*Oscillatoria limosa*
EEL RIVER	111ER6381	9/1/2016	*Oscillatoria*	*Oscillatoria princeps*
EEL RIVER	111ER6381	9/1/2016	*Pseudanabaena*	*Pseudanabaena mucicola*
EEL RIVER	111ER6381	9/1/2016	*Trichormus*	*Trichormus fertilissimus*
EEL RIVER	111ER6381	9/1/2016	*Trichormus*	*Trichormus rotundosporus*
EEL RIVER	111ER6381	9/14/2016	*Anabaena*	*Anabaena oscillatorioides*
EEL RIVER	111ER6381	9/14/2016	*Anabaena*	*Anabaena sp 1*
EEL RIVER	111ER6381	9/14/2016	*Aphanocapsa*	*Aphanocapsa spp*
EEL RIVER	111ER6381	9/14/2016	*Aphanothece*	*Aphanothece spp*
EEL RIVER	111ER6381	9/14/2016	*Chroococcus*	*Chroococcus minimus*
EEL RIVER	111ER6381	9/14/2016	*Chroococcus*	*Chroococcus turgidus*
EEL RIVER	111ER6381	9/14/2016	*Chroococcus*	*Chroococcus vacuolatus*
EEL RIVER	111ER6381	9/14/2016	*Dolichospermum*	*Dolichospermum sp. 4*
EEL RIVER	111ER6381	9/14/2016	*Geitlerinema*	*Geitlerinema acutissimum*
EEL RIVER	111ER6381	9/14/2016	*Geitlerinema*	*Geitlerinema splendidum*
EEL RIVER	111ER6381	9/14/2016	*Gloeotrichia*	*Gloeotrichia natans*
EEL RIVER	111ER6381	9/14/2016	*Microcoleus (Phormidium)*	*Phormidium chalybeum*
EEL RIVER	111ER6381	9/14/2016	*Microcoleus (Phormidium)*	*Phormidium irriguum*
EEL RIVER	111ER6381	9/14/2016	*Nostoc*	*Nostoc carneum*
EEL RIVER	111ER6381	9/14/2016	*Oscillatoria*	*Oscillatoria limosa*
EEL RIVER	111ER6381	9/14/2016	*Oscillatoria*	*Oscillatoria tenuis*
EEL RIVER	111ER8102	8/1/2016	*Anabaena*	*Anabaena cf felisii*

River	Site Code	Date	Genera	Species Identification
EEL RIVER	111ER8102	8/1/2016	*Anabaena*	*Anabaena cf saaremaaensis*
EEL RIVER	111ER8102	8/1/2016	*Anabaena*	*Anabaena cf sphaerica*
EEL RIVER	111ER8102	8/1/2016	*Anabaena*	*Anabaena oscillatorioides*
EEL RIVER	111ER8102	8/1/2016	*Aphanothece*	*Aphanothece stagnina*
EEL RIVER	111ER8102	8/1/2016	*Cylindrospermum*	*Cylindrospermum licheniforme*
EEL RIVER	111ER8102	8/1/2016	*Geitlerinema*	*Geitlerinema amphibium*
EEL RIVER	111ER8102	8/1/2016	*Leptolyngbya*	*Leptolyngbya notata*
EEL RIVER	111ER8102	8/1/2016	*Microcoleus (Phormidium)*	*Phormidium autumnale*
EEL RIVER	111ER8102	8/15/2016	*Aphanothece*	*Aphanothece stagnina*
EEL RIVER	111ER8102	8/15/2016	*Cylindrospermum*	*Cylindrospermum licheniforme*
EEL RIVER	111ER8102	8/15/2016	*Microcoleus (Phormidium)*	*Phormidium autumnale*
EEL RIVER	111ER8102	8/15/2016	*Microcoleus (Phormidium)*	*Phormidium breve*
EEL RIVER	111ER8102	8/15/2016	*Microcoleus (Phormidium)*	*Phormidium formosum*
EEL RIVER	111ER8102	8/15/2016	*Microcoleus (Phormidium)*	*Phormidium irriguum*
EEL RIVER	111ER8102	8/15/2016	*Nostoc*	*Nostoc cf verrucosum*
EEL RIVER	111ER8102	9/6/2016	*Anabaena*	*Anabaena sp 2*
EEL RIVER	111ER8102	9/6/2016	*Anabaena*	*Anabaena sphaerica*
EEL RIVER	111ER8102	9/6/2016	*Aphanothece*	*Aphanothece stagnina*
EEL RIVER	111ER8102	9/6/2016	*Cylindrospermum*	*Cylindrospermum stagnale*
EEL RIVER	111ER8102	9/6/2016	*Geitlerinema*	*Geitlerinema amphibium*
EEL RIVER	111ER8102	9/6/2016	*Microcoleus (Phormidium)*	*Phormidium cf irriguum*
EEL RIVER	111ER8102	9/6/2016	*Microcoleus (Phormidium)*	*Phormidium retzii*
EEL RIVER	111ER8102	9/6/2016	*Microcoleus (Phormidium)*	*Phormidium subfuscum*
EEL RIVER	111ER8102	9/6/2016	*Oscillatoria*	*Oscillatoria tenuis*
EEL RIVER	111ER8102	9/15/2016	*Anabaena*	*Anabaena sp 2*
EEL RIVER	111ER8102	9/15/2016	*Anabaena*	*Anabaena subcylindrica*
EEL RIVER	111ER8102	9/15/2016	*Cylindrospermum*	*Cylindrospermum stagnale*
EEL RIVER	111ER8102	9/15/2016	*Geitlerinema*	*Geitlerinema splendidum*
EEL RIVER	111ER8102	9/15/2016	*Microcoleus (Phormidium)*	*Phormidium autumnale*

River	Site Code	Date	Genera	Species Identification
EEL RIVER	111ER8102	9/15/2016	*Microcoleus (Phormidium)*	*Phormidium irriguum*
EEL RIVER	111ER8102	9/15/2016	*Microcoleus (Phormidium)*	*Phormidium retzii*
EEL RIVER	111ER8102	9/15/2016	*Trichormus*	*Trichormus fertilissimus*
SF EEL RIVER	111SF2423	8/1/2016	*Microcoleus (Phormidium)*	*Phormidium autumnale*
SF EEL RIVER	111SF2423	8/1/2016	*Microcoleus (Phormidium)*	*Phormidium irriguum*
SF EEL RIVER	111SF2423	8/1/2016	*Nodularia*	*Nodularia spumigena*
SF EEL RIVER	111SF2423	8/1/2016	*Nostoc*	*Nostoc cf verrucosum*
SF EEL RIVER	111SF2423	8/18/2016	*Anabaena*	*Anabaena oscillatorioides*
SF EEL RIVER	111SF2423	8/18/2016	*Anabaena*	*Anabaena sphaerica*
SF EEL RIVER	111SF2423	8/18/2016	*Aphanothece*	*Aphanothece stagnina*
SF EEL RIVER	111SF2423	8/18/2016	*Calothrix*	*Calothrix fusca*
SF EEL RIVER	111SF2423	8/18/2016	*Cladophora*	*Cladophora glomerata*
SF EEL RIVER	111SF2423	8/18/2016	*Gloeotrichia*	*Gloeotrichia natans*
SF EEL RIVER	111SF2423	8/18/2016	*Microcoleus (Phormidium)*	*Phormidium autumnale*
SF EEL RIVER	111SF2423	8/18/2016	*Microcoleus (Phormidium)*	*Phormidium chalybeum*
SF EEL RIVER	111SF2423	8/18/2016	*Microcoleus (Phormidium)*	*Phormidium irriguum*
SF EEL RIVER	111SF2423	8/18/2016	*Microcoleus (Phormidium)*	*Phormidium nigroviride*
SF EEL RIVER	111SF2423	8/18/2016	*Nodularia*	*Nodularia spumigena*
SF EEL RIVER	111SF2423	8/18/2016	*Nostoc*	*Nostoc verrucosum*
SF EEL RIVER	111SF2423	8/18/2016	*Oscillatoria*	*Oscillatoria limosa*
SF EEL RIVER	111SF2423	8/18/2016	*Scytonema*	*Scytonema crispum*
SF EEL RIVER	111SF2423	9/1/2016	*Anabaena*	*Anabaena sp 1*
SF EEL RIVER	111SF2423	9/1/2016	*Aphanothece*	*Aphanothece stagnina*
SF EEL RIVER	111SF2423	9/1/2016	*Calothrix*	*Calothrix fusca*
SF EEL RIVER	111SF2423	9/1/2016	*Geitlerinema*	*Geitlerinema acutissimum*
SF EEL RIVER	111SF2423	9/1/2016	*Gloeotrichia*	*Gloeotrichia natans*
SF EEL RIVER	111SF2423	9/1/2016	*Microcoleus (Phormidium)*	*Phormidium autumnale*
SF EEL RIVER	111SF2423	9/1/2016	*Nostoc*	*Nostoc verrucosum*
SF EEL RIVER	111SF2423	9/1/2016	*Trichormus*	*Trichormus*

River	Site Code	Date	Genera	Species Identification
SF EEL RIVER	111SF2423	9/14/2016	*Aphanothece*	*Aphanothece stagnina*
SF EEL RIVER	111SF2423	9/14/2016	*Calothrix*	*Calothrix fusca*
SF EEL RIVER	111SF2423	9/14/2016	*Calothrix*	*Calothrix parietina*
SF EEL RIVER	111SF2423	9/14/2016	*Geitlerinema*	*Geitlerinema cf acutissimum*
SF EEL RIVER	111SF2423	9/14/2016	*Gloeotrichia*	*Gloeotrichia natans*
SF EEL RIVER	111SF2423	9/14/2016	*Leptolyngbya*	*Leptolyngbya granulifera*
SF EEL RIVER	111SF2423	9/14/2016	*Leptolyngbya*	*Leptolyngbya notata*
SF EEL RIVER	111SF2423	9/14/2016	*Microcoleus (Phormidium)*	*Phormidium autumnale*
SF EEL RIVER	111SF2423	9/14/2016	*Nostoc*	*Nostoc verrucosum*
SF EEL RIVER	111SF2423	9/14/2016	*Scytonema*	*Scytonema crispum*
SF EEL RIVER	111SF2423	10/1/2016	*Geitlerinema*	*Geitlerinema amphibium*
SF EEL RIVER	111SF2423	10/1/2016	*Geitlerinema*	*Geitlerinema cf acutissimum*
SF EEL RIVER	111SF2423	10/1/2016	*Gloeotrichia*	*Gloeotrichia natans*
SF EEL RIVER	111SF2423	10/1/2016	*Leptolyngbya*	*Leptolyngbya notata*
SF EEL RIVER	111SF2423	10/1/2016	*Microcoleus (Phormidium)*	*Phormidium autumnale*
SF EEL RIVER	111SF2423	10/1/2016	*Microcoleus (Phormidium)*	*Phormidium irriguum*
SF EEL RIVER	111SF2423	10/1/2016	*Nostoc*	*Nostoc verrucosum*
SF EEL RIVER	111SF6856	8/1/2016	*Anabaena*	*Anabaena sp 2*
SF EEL RIVER	111SF6856	8/1/2016	*Anabaena*	*Anabaena sphaerica*
SF EEL RIVER	111SF6856	8/1/2016	*Aphanothece*	*Aphanothece cf clathrata*
SF EEL RIVER	111SF6856	8/1/2016	*Aphanothece*	*Aphanothece stagnina*
SF EEL RIVER	111SF6856	8/1/2016	*Coelomoron*	*Coelomoron pusillum*
SF EEL RIVER	111SF6856	8/1/2016	*Cylindrospermum*	*Cylindrospermum stagnale*
SF EEL RIVER	111SF6856	8/1/2016	*Geitlerinema*	*Geitlerinema amphibium*
SF EEL RIVER	111SF6856	8/1/2016	*Gloeotrichia*	*Gloeotrichia natans*
SF EEL RIVER	111SF6856	8/1/2016	*Microcoleus (Phormidium)*	*Phormidium autumnale*
SF EEL RIVER	111SF6856	8/18/2016	*Anabaena*	*Anabaena sp 2*
SF EEL RIVER	111SF6856	8/18/2016	*Anabaena*	*Anabaena sphaerica*
SF EEL RIVER	111SF6856	8/18/2016	*Aphanothece*	*Aphanothece clathrata*

River	Site Code	Date	Genera	Species Identification
SF EEL RIVER	111SF6856	8/18/2016	*Aphanothece*	*Aphanothece stagnina*
SF EEL RIVER	111SF6856	8/18/2016	*Gloeotrichia*	*Gloeotrichia natans*
SF EEL RIVER	111SF6856	8/18/2016	*Microcoleus (Phormidium)*	*Phormidium autumnale*
SF EEL RIVER	111SF6856	8/18/2016	*Microcoleus (Phormidium)*	*Phormidium nigroviride*
SF EEL RIVER	111SF6856	8/18/2016	*Nodularia*	*Nodularia spumigena*
SF EEL RIVER	111SF6856	8/18/2016	*Oscillatoria*	*Oscillatoria jenensis*
SF EEL RIVER	111SF6856	8/18/2016	*Oscillatoria*	*Oscillatoria tenuis*
SF EEL RIVER	111SF6856	9/1/2016	*Anabaena*	*Anabaena sp 1*
SF EEL RIVER	111SF6856	9/1/2016	*Aphanothece*	*Aphanothece clathrata*
SF EEL RIVER	111SF6856	9/1/2016	*Aphanothece*	*Aphanothece sp*
SF EEL RIVER	111SF6856	9/1/2016	*Aphanothece*	*Aphanothece stagnina*
SF EEL RIVER	111SF6856	9/1/2016	*Chroococcus*	*Chroococcus turgidus*
SF EEL RIVER	111SF6856	9/1/2016	*Cylindrospermum*	*Cylindrospermum stagnale*
SF EEL RIVER	111SF6856	9/1/2016	*Geitlerinema*	*Geitlerinema amphibium*
SF EEL RIVER	111SF6856	9/1/2016	*Geitlerinema*	*Geitlerinema splendidum*
SF EEL RIVER	111SF6856	9/1/2016	*Gloeotrichia*	*Gloeotrichia natans*
SF EEL RIVER	111SF6856	9/1/2016	*Microcoleus (Phormidium)*	*Phormidium irriguum*
SF EEL RIVER	111SF6856	9/1/2016	*Oscillatoria*	*Oscillatoria tenuis*
SF EEL RIVER	111SF6856	9/1/2016	*Scytonema*	*Scytonema crispum*
SF EEL RIVER	111SF6856	9/14/2016	*Aphanothece*	*Aphanothece stagnina*
SF EEL RIVER	111SF6856	9/14/2016	*Calothrix*	*Calothrix fusca*
SF EEL RIVER	111SF6856	9/14/2016	*Cylindrospermum*	*Cylindrospermum licheniforme*
SF EEL RIVER	111SF6856	9/14/2016	*Cylindrospermum*	*Cylindrospermum stagnale*
SF EEL RIVER	111SF6856	9/14/2016	*Dolichospermum*	*Dolichospermum sp 2*
SF EEL RIVER	111SF6856	9/14/2016	*Gloeotrichia*	*Gloeotrichia natans*
SF EEL RIVER	111SF6856	9/14/2016	*Microcoleus (Phormidium)*	*Phormidium autumnale*
SF EEL RIVER	111SF6856	9/14/2016	*Microcoleus (Phormidium)*	*Phormidium cf chalybeum*
SF EEL RIVER	111SF6856	9/14/2016	*Microcoleus (Phormidium)*	*Phormidium cf lucidum*
SF EEL RIVER	111SF6856	9/14/2016	*Nostoc*	*Nostoc parmelioides*

River	Site Code	Date	Genera	Species Identification
SF EEL RIVER	111SF6856	9/14/2016	*Oscillatoria*	*Oscillatoria limosa*
SF EEL RIVER	111SF6856	9/14/2016	*Scytonema*	*Scytonema crispum*
RUSSIAN RIVER	114RR1159	8/2/2016	*Anabaena*	*Anabaena saaremaaensis*
RUSSIAN RIVER	114RR1159	8/2/2016	*Anabaena*	*Anabaena sphaerica*
RUSSIAN RIVER	114RR1159	8/2/2016	*Cylindrospermum*	*Cylindrospermum stagnale*
RUSSIAN RIVER	114RR1159	8/2/2016	*Geitlerinema*	*Geitlerinema amphibium*
RUSSIAN RIVER	114RR1159	8/2/2016	*Leptolyngbya*	*Leptolyngbya notata*
RUSSIAN RIVER	114RR1159	8/15/2016	*Anabaena*	*Anabaena oscillatorioides*
RUSSIAN RIVER	114RR1159	8/15/2016	*Anabaena*	*Anabaena sp 2*
RUSSIAN RIVER	114RR1159	8/15/2016	*Aphanothece*	*Aphanothece stagnina*
RUSSIAN RIVER	114RR1159	8/15/2016	*Calothrix*	*Calothrix linearis*
RUSSIAN RIVER	114RR1159	8/15/2016	*Cylindrospermum*	*Cylindrospermum stagnale*
RUSSIAN RIVER	114RR1159	8/15/2016	*Geitlerinema*	*Geitlerinema amphibium*
RUSSIAN RIVER	114RR1159	8/15/2016	*Leptolyngbya*	*Leptolyngbya notata*
RUSSIAN RIVER	114RR1159	8/15/2016	*Nostoc*	*Nostoc cf verrucosum*
RUSSIAN RIVER	114RR1159	8/15/2016	*Trichormus*	*Trichormus*
RUSSIAN RIVER	114RR1159	8/30/2016	*Anabaena*	*Anabaena sp 1*
RUSSIAN RIVER	114RR1159	8/30/2016	*Geitlerinema*	*Geitlerinema amphibium*
RUSSIAN RIVER	114RR1159	8/30/2016	*Leptolyngbya*	*Leptolyngbya notata*
RUSSIAN RIVER	114RR1159	8/30/2016	*Microcoleus (Phormidium)*	*Phormidium retzii*
RUSSIAN RIVER	114RR1159	9/12/2016	*Anabaena*	*Anabaena sp 1*
RUSSIAN RIVER	114RR1159	9/12/2016	*Cylindrospermum*	*Cylindrospermum sp 1*
RUSSIAN RIVER	114RR1644	8/15/2016	*Cylindrospermum*	*Cylindrospermum stagnale*
RUSSIAN RIVER	114RR1644	8/15/2016	*Lyngbya*	*Lyngbya martensiana*
RUSSIAN RIVER	114RR1644	8/15/2016	*Microcoleus (Phormidium)*	*Phormidium breve*
RUSSIAN RIVER	114RR2401	8/1/2016	*Anabaena*	*Anabaena sp 2*
RUSSIAN RIVER	114RR2401	8/1/2016	*Leptolyngbya*	*Leptolyngbya cf lagerheimii*
RUSSIAN RIVER	114RR2401	8/1/2016	*Leptolyngbya*	*Leptolyngbya notata*
RUSSIAN RIVER	114RR2401	8/1/2016	*Lyngbya*	*Lyngbya martensiana*

River	Site Code	Date	Genera	Species Identification
RUSSIAN RIVER	114RR2401	8/1/2016	*Microcoleus (Phormidium)*	*Phormidium cf crassior*
RUSSIAN RIVER	114RR2401	8/1/2016	*Microcoleus (Phormidium)*	*Phormidium formosum*
RUSSIAN RIVER	114RR2401	8/1/2016	*Microcoleus (Phormidium)*	*Phormidium irriguum*
RUSSIAN RIVER	114RR2655	8/15/2016	*Microcoleus (Phormidium)*	*Phormidium autumnale*
RUSSIAN RIVER	114RR2655	8/15/2016	*Microcoleus (Phormidium)*	*Phormidium irriguum*
RUSSIAN RIVER	114RR2655	8/15/2016	*Oscillatoria*	*Oscillatoria limosa*
RUSSIAN RIVER	114RR2655	8/30/2016	*Microcoleus (Phormidium)*	*Phormidium irriguum*
RUSSIAN RIVER	114RR2655	8/30/2016	*Oscillatoria*	*Oscillatoria limosa*
RUSSIAN RIVER	114RR2655	9/12/2016	*Microcoleus (Phormidium)*	*Phormidium autumnale*
RUSSIAN RIVER	114RR2655	9/12/2016	*Microcoleus (Phormidium)*	*Phormidium irriguum*
RUSSIAN RIVER	114RR2655	9/12/2016	*Oscillatoria*	*Oscillatoria limosa*
RUSSIAN RIVER	114RR2655	9/29/2016	*Microcoleus (Phormidium)*	*Phormidium autumnale*
RUSSIAN RIVER	114RR2655	9/29/2016	*Microcoleus (Phormidium)*	*Phormidium irriguum*
RUSSIAN RIVER	114RR2655	9/29/2016	*Oscillatoria*	*Oscillatoria limosa*
RUSSIAN RIVER	114RR2655	9/29/2016	*Oscillatoria*	*Oscillatoria princeps*
RUSSIAN RIVER	114RR4234	8/2/2016	*Microcoleus (Phormidium)*	*Phormidium irriguum*
RUSSIAN RIVER	114RR4234	8/2/2016	*Nostoc*	*Nostoc muscorum*
RUSSIAN RIVER	114RR4234	8/2/2016	*Oscillatoria*	*Oscillatoria jenensis*
RUSSIAN RIVER	114RR4234	8/2/2016	*Oscillatoria*	*Oscillatoria limosa*
RUSSIAN RIVER	114RR4234	8/15/2016	*Aphanothece*	*Aphanothece stagnina*
RUSSIAN RIVER	114RR4234	8/15/2016	*Leptolyngbya*	*Leptolyngbya nostocorum*
RUSSIAN RIVER	114RR4234	8/15/2016	*Leptolyngbya*	*Leptolyngbya notata*
RUSSIAN RIVER	114RR4234	8/15/2016	*Microcoleus (Phormidium)*	*Phormidium autumnale*
RUSSIAN RIVER	114RR4234	8/15/2016	*Microcoleus (Phormidium)*	*Phormidium cf irriguum*
RUSSIAN RIVER	114RR4234	8/15/2016	*Nostoc*	*Nostoc cf ellipsosporum*
RUSSIAN RIVER	114RR4234	8/15/2016	*Nostoc*	*Nostoc muscorum*
RUSSIAN RIVER	114RR4234	8/15/2016	*Nostoc*	*Nostoc sp 3*
RUSSIAN RIVER	114RR4234	8/15/2016	*Oscillatoria*	*Oscillatoria limosa*
RUSSIAN RIVER	114RR4234	8/30/2016	*Oscillatoria*	*Oscillatoria limosa*

River	Site Code	Date	Genera	Species Identification
RUSSIAN RIVER	114RR4234	8/30/2016	*Spirulina*	*Spirulina corakiana*
RUSSIAN RIVER	114RR4234	9/12/2016	*Anabaena*	*Anabaena cf cylindrica*
RUSSIAN RIVER	114RR4234	9/12/2016	*Anabaena*	*Anabaena sp 1*
RUSSIAN RIVER	114RR4234	9/12/2016	*Aphanothece*	*Aphanothece stagnina*
RUSSIAN RIVER	114RR4234	9/12/2016	*Geitlerinema*	*Geitlerinema amphibium*
RUSSIAN RIVER	114RR4234	9/12/2016	*Microcoleus (Phormidium)*	*Phormidium autumnale*
RUSSIAN RIVER	114RR4234	9/12/2016	*Microcoleus (Phormidium)*	*Phormidium irriguum*
RUSSIAN RIVER	114RR4234	9/12/2016	*Nostoc*	*Nostoc cf verrucosum*
RUSSIAN RIVER	114RR4234	9/12/2016	*Nostoc*	*Nostoc muscorum*
RUSSIAN RIVER	114RR4234	9/12/2016	*Nostoc*	*Nostoc sp 3*
RUSSIAN RIVER	114RR4234	9/12/2016	*Oscillatoria*	*Oscillatoria limosa*
RUSSIAN RIVER	114RR4234	9/30/2016	*Geitlerinema*	*Geitlerinema amphibium*
RUSSIAN RIVER	114RR4234	9/30/2016	*Leptolyngbya*	*Leptolyngbya notata*
RUSSIAN RIVER	114RR4234	9/30/2016	*Oscillatoria*	*Oscillatoria limosa*
RUSSIAN RIVER	114RR4234	9/30/2016	*Oscillatoria*	*Oscillatoria princeps*
RUSSIAN RIVER	114RR5407	8/2/2016	*Anabaena*	*Anabaena oscillatorioides*
RUSSIAN RIVER	114RR5407	8/2/2016	*Geitlerinema*	*Geitlerinema amphibium*
RUSSIAN RIVER	114RR5407	8/2/2016	*Leptolyngbya*	*Leptolyngbya granulifera*
RUSSIAN RIVER	114RR5407	8/2/2016	*Microcoleus (Phormidium)*	*Phormidium irriguum*
RUSSIAN RIVER	114RR5407	8/2/2016	*Nostoc*	*Nostoc muscorum*
RUSSIAN RIVER	114RR5407	8/2/2016	*Oscillatoria*	*Oscillatoria princeps*
RUSSIAN RIVER	114RR5407	8/15/2016	*Aphanothece*	*Aphanothece stagnina*
RUSSIAN RIVER	114RR5407	8/15/2016	*Cladophora*	*Cladophora glomerata*
RUSSIAN RIVER	114RR5407	8/15/2016	*Gloeothece*	*Gloeothece palea*
RUSSIAN RIVER	114RR5407	8/15/2016	*Microcoleus (Phormidium)*	*Phormidium autumnale*
RUSSIAN RIVER	114RR5407	8/15/2016	*Microcoleus (Phormidium)*	*Phormidium irriguum*
RUSSIAN RIVER	114RR5407	8/15/2016	*Microcoleus (Phormidium)*	*Phormidium sp 1*
RUSSIAN RIVER	114RR5407	8/15/2016	*Nostoc*	*Nostoc muscorum*
RUSSIAN RIVER	114RR5407	8/15/2016	*Nostoc*	*Nostoc paludosum*

River	Site Code	Date	Genera	Species Identification
RUSSIAN RIVER	114RR5407	8/15/2016	*Oscillatoria*	*Oscillatoria princeps*
RUSSIAN RIVER	114RR5407	8/30/2016	*Aphanothece*	*Aphanothece stagnina*
RUSSIAN RIVER	114RR5407	8/30/2016	*Cladophora*	*Cladophora glomerata*
RUSSIAN RIVER	114RR5407	8/30/2016	*Geitlerinema*	*Geitlerinema amphibium*
RUSSIAN RIVER	114RR5407	8/30/2016	*Gloeothece*	*Gloeothece palea*
RUSSIAN RIVER	114RR5407	8/30/2016	*Microcoleus (Phormidium)*	*Phormidium autumnale*
RUSSIAN RIVER	114RR5407	8/30/2016	*Microcoleus (Phormidium)*	*Phormidium irriguum*
RUSSIAN RIVER	114RR5407	8/30/2016	*Nostoc*	*Nostoc muscorum*
RUSSIAN RIVER	114RR5407	9/12/2016	*Anabaena*	*Anabaena sp 2*
RUSSIAN RIVER	114RR5407	9/12/2016	*Aphanothece*	*Aphanothece stagnina*
RUSSIAN RIVER	114RR5407	9/12/2016	*Geitlerinema*	*Geitlerinema amphibium*
RUSSIAN RIVER	114RR5407	9/12/2016	*Microcoleus (Phormidium)*	*Phormidium autumnale*
RUSSIAN RIVER	114RR5407	9/12/2016	*Microcoleus (Phormidium)*	*Phormidium irriguum*
RUSSIAN RIVER	114RR5407	9/12/2016	*Nostoc*	*Nostoc muscorum*
RUSSIAN RIVER	114RR5407	9/12/2016	*Nostoc*	*Nostoc paludosum*
RUSSIAN RIVER	114RR5407	10/3/2016	*Aphanothece*	*Aphanothece stagnina*
RUSSIAN RIVER	114RR5407	10/3/2016	*Geitlerinema*	*Geitlerinema amphibium*
RUSSIAN RIVER	114RR5407	10/3/2016	*Microcoleus (Phormidium)*	*Phormidium irriguum*
RUSSIAN RIVER	114RR5407	10/3/2016	*Microcoleus (Phormidium)*	*Phormidium retzii*
RUSSIAN RIVER	114RR5407	10/3/2016	*Nostoc*	*Nostoc muscorum*
RUSSIAN RIVER	114RR5407	10/3/2016	*Oscillatoria*	*Oscillatoria princeps*
RUSSIAN RIVER	114RR7396	8/2/2016	*Leptolyngbya*	*Leptolyngbya notata*
RUSSIAN RIVER	114RR7396	8/2/2016	*Microcoleus (Phormidium)*	*Phormidium nigroviride*
RUSSIAN RIVER	114RR7396	8/2/2016	*Nostoc*	*Nostoc carneum*
RUSSIAN RIVER	114RR7396	8/2/2016	*Nostoc*	*Nostoc cf muscorum*
RUSSIAN RIVER	114RR7396	8/2/2016	*Rhabdoderma*	*Rhabdoderma vermiculare*
RUSSIAN RIVER	114RR7396	8/15/2016	*Microcoleus (Phormidium)*	*Phormidium breve*
RUSSIAN RIVER	114RR7396	8/15/2016	*Nostoc*	*Nostoc carneum*
RUSSIAN RIVER	114RR7396	8/15/2016	*Nostoc*	*Nostoc muscorum*

River	Site Code	Date	Genera	Species Identification
RUSSIAN RIVER	114RR7396	8/15/2016	*Nostoc*	*Nostoc paludosum*
RUSSIAN RIVER	114RR7396	9/15/2016	*Leptolyngbya*	*Leptolyngbya notata*
RUSSIAN RIVER	114RR7396	9/15/2016	*Microcoleus (Phormidium)*	*Phormidium irriguum*
RUSSIAN RIVER	114RR7396	9/30/2016	*Geitlerinema*	*Geitlerinema splendidum*

Appendix 3. Taxonomic identification and cyanotoxin concentrations for cyanobacterial single species dominant mat samples by sampling site and date in the Eel River, South Fork Eel River, and Russian River, from 2016 to 2019. ATX, anatoxins; CYN, cylindrospermopsins; MCY, microcystins; NOD, nodularins; STX, saxitoxins; ND, non-detect; ---, no analysis was performed.

River	Site Code	Date	Genera	ATX (ug/L)	CYL (ug/L)	MCY/NOD (ug/L)	NOD (ug/L)	SXT (ug/L)
EEL RIVER	111ER6140	6/26/2018	*Microcoleus (Phormidium)*	ND	---	166.76	---	---
EEL RIVER	111ER6140	6/26/2018	*Microcoleus (Phormidium)*	ND	ND	66.84	---	---
EEL RIVER	111ER6140	8/15/2018	*Microcoleus (Phormidium)*	46,040.23	ND	ND	ND	---
EEL RIVER	111ER6140	9/12/2018	*Microcoleus (Phormidium)*	14,051.71	ND	ND	ND	---
EEL RIVER	111ER6381	9/14/2016	*Oscillatoria*	38.01	ND	0.85	---	ND
EEL RIVER	111ER8102	9/15/2016	*Cylindrospermum*	15.60	ND	0.49	---	0.14
EEL RIVER	111ER8102	9/15/2016	*Geitlerinema*	11.48	ND	0.18	---	0.86
EEL RIVER	111ER8102	9/15/2016	*Microcoleus (Phormidium)*	12.45	ND	0.86	---	0.08
EEL RIVER	111ER8102	6/14/2017	*Anabaena*	1.58	---	---	---	---
EEL RIVER	111ER8102	6/14/2017	*Microcoleus (Phormidium)*	4.78	---	---	---	---
EEL RIVER	111ER8102	6/27/2017	*Anabaena*	1.90	---	---	---	---
EEL RIVER	111ER8102	6/27/2017	*Microcoleus (Phormidium)*	2.95	---	---	---	---

River	Site Code	Date	Genera	ATX (ug/L)	CYL (ug/L)	MCY/NOD (ug/L)	NOD (ug/L)	SXT (ug/L)
EEL RIVER	111ER8102	7/12/2017	*Anabaena*	1.26	---	---	---	---
EEL RIVER	111ER8102	7/12/2017	*Microcoleus (Phormidium)*	0.44	---	0.22	---	ND
EEL RIVER	111ER8102	8/17/2017	*Microcoleus (Phormidium)*	616.40	ND	0.54	---	0.03
EEL RIVER	111ER8102	8/29/2017	*Microcoleus (Phormidium)*	819.40	---	0.72	---	0.07
EEL RIVER	111ER8102	9/13/2017	*Microcoleus (Phormidium)*	637.20	---	0.78	---	2.56
EEL RIVER	111ER8102	9/27/2017	*Microcoleus (Phormidium)*	54.80	ND	0.23	---	5.76
EEL RIVER	111ER8102	10/31/2017	*Microcoleus (Phormidium)*	206.10	---	0.71	---	1.33
EEL RIVER	111ER8102	7/17/2018	*Anabaena*	ND	ND	75.00	ND	0.41
EEL RIVER	111ER8102	8/15/2018	*Cylindrospermum*	83.70	ND	ND	ND	---
EEL RIVER	111ER8102	8/15/2018	*Microcoleus (Phormidium)*	202.80	ND	9.15	ND	---
EEL RIVER	111ER8102	8/15/2018	*Microcoleus (Phormidium)*	7,679.72	ND	0.16	0.16	---
EEL RIVER	111ER8102	8/15/2018	*Microcoleus (Phormidium)*	12,689.10	ND	ND	ND	---
EEL RIVER	111ER8102	9/12/2018	*Cylindrospermum*	42.48	ND	ND	ND	---
EEL RIVER	111ER8102	9/12/2018	*Cylindrospermum*	ND	ND	ND	ND	---

River	Site Code	Date	Genera	ATX (ug/L)	CYL (ug/L)	MCY/NOD (ug/L)	NOD (ug/L)	SXT (ug/L)
EEL RIVER	111ER8102	9/12/2018	*Cylindrospermum*	30.24	ND	ND	ND	---
EEL RIVER	111ER8102	9/12/2018	*Cylindrospermum*	7.25	---	---	---	---
EEL RIVER	111ER8102	9/12/2018	*Microcoleus (Phormidium)*	15,045.34	ND	ND	ND	---
EEL RIVER	111ER8102	9/12/2018	*Microcoleus (Phormidium)*	ND	ND	ND	ND	---
EEL RIVER	111ER8102	9/12/2018	*Microcoleus (Phormidium)*	ND	ND	ND	ND	---
EEL RIVER	111ER8102	9/12/2018	*Microcoleus (Phormidium)*	258.60	---	---	---	---
EEL RIVER	111ER8102	9/18/2018	*Microcoleus (Phormidium)*	455.80	ND	0.58	---	ND
EEL RIVER	111ER8102	10/4/2018	*Microcoleus (Phormidium)*	4.94	---	---	---	---
EEL RIVER	111ER8102	6/30/2019	*Microcoleus (Phormidium)*	3.15	---	ND	ND	---
EEL RIVER	111ER8102	7/3/2019	*Microcoleus (Phormidium)*	1.78	---	1.99	ND	---
EEL RIVER	111ER8102	7/9/2019	*Microcoleus (Phormidium)*	12.66	---	ND	ND	---
EEL RIVER	111ER8102	7/10/2019	*Microcoleus (Phormidium)*	0.38	---	---	---	---
EEL RIVER	111ER8102	7/11/2019	*Microcoleus (Phormidium)*	12.52	---	ND	ND	---
EEL RIVER	111ER8102	7/16/2019	*Microcoleus (Phormidium)*	14.08	---	ND	ND	---

River	Site Code	Date	Genera	ATX (ug/L)	CYL (ug/L)	MCY/NOD (ug/L)	NOD (ug/L)	SXT (ug/L)
EEL RIVER	111ER8102	7/18/2019	*Microcoleus (Phormidium)*	17.05	---	0.56	ND	---
EEL RIVER	111ER8102	7/22/2019	*Microcoleus (Phormidium)*	4.51	---	0.52	ND	---
EEL RIVER	111ER8102	7/24/2019	*Microcoleus (Phormidium)*	6.86	---	0.26	ND	ND
EEL RIVER	111ER8102	7/30/2019	*Microcoleus (Phormidium)*	4.38	---	ND	ND	---
EEL RIVER	111ER8102	8/1/2019	*Microcoleus (Phormidium)*	ND	---	ND	ND	ND
EEL RIVER	111ER8102	8/1/2019	*Microcoleus (Phormidium)*	4.92	---	ND	ND	---
EEL RIVER	111ER8102	8/14/2019	*Microcoleus (Phormidium)*	ND	ND	ND	---	ND
EEL RIVER	111ER8102	8/14/2019	*Microcoleus (Phormidium)*	4.83	---	---	---	---
EEL RIVER	111ER8102	9/4/2019	*Microcoleus (Phormidium)*	0.95	ND	0.20	---	ND
EEL RIVER	111ER8102	9/4/2019	*Microcoleus (Phormidium)*	9.92	ND	0.19	---	ND
SF EEL RIVER	111SF2423	9/14/2016	*Microcoleus (Phormidium)*	2.80	ND	0.54	---	ND
SF EEL RIVER	111SF2423	9/14/2016	*Scytonema*	2.48	ND	4.91	---	0.05
SF EEL RIVER	111SF2423	6/25/2019	*Rivularia*	ND	ND	ND	---	ND
SF EEL RIVER	111SF2423	7/31/2019	*Anabaena*	8.30	---	0.26	ND	---

River	Site Code	Date	Genera	ATX (ug/L)	CYL (ug/L)	MCY/NOD (ug/L)	NOD (ug/L)	SXT (ug/L)
SF EEL RIVER	111SF2423	7/31/2019	*Microcoleus (Phormidium)*	2.78	---	ND	ND	---
SF EEL RIVER	111SF2423	8/14/2019	*Anabaena*	585.34	ND	0.31	ND	ND
SF EEL RIVER	111SF2423	9/17/2019	*Nostoc*	ND	ND	20.38	---	ND
SF EEL RIVER	111SF2423	10/5/2019	*Nostoc*	0.27	---	0.31	---	---
SF EEL RIVER	111SF2423	10/5/2019	*Microcoleus (Phormidium)*	167.30	---	0.13	---	---
SF EEL RIVER	111SF4640	8/17/2017	*Nostoc*	1.42	ND	ND	---	ND
SF EEL RIVER	111SF4640	8/29/2017	*Anabaena*	175.30	---	1.17	---	---
SF EEL RIVER	111SF4640	8/29/2017	*Nostoc*	11.97	---	0.28	---	---
SF EEL RIVER	111SF4640	8/29/2017	*Nostoc*	0.39	---	0.27	---	---
SF EEL RIVER	111SF4640	8/29/2017	*Nostoc*	1.74	---	ND	---	---
SF EEL RIVER	111SF4640	8/29/2017	*Microcoleus (Phormidium)*	41.25	---	0.22	---	---
SF EEL RIVER	111SF4640	8/29/2017	*Scytonema*	3.22	ND	3.25	---	ND
SF EEL RIVER	111SF4640	9/13/2017	*Anabaena*	3.06	---	0.58	---	---
SF EEL RIVER	111SF4640	9/13/2017	*Nostoc*	0.32	---	0.36	---	---

River	Site Code	Date	Genera	ATX (ug/L)	CYL (ug/L)	MCY/NOD (ug/L)	NOD (ug/L)	SXT (ug/L)
SF EEL RIVER	111SF4640	9/13/2017	*Nostoc*	0.14	---	ND	---	---
SF EEL RIVER	111SF4640	9/13/2017	*Microcoleus (Phormidium)*	30.00	---	ND	---	---
SF EEL RIVER	111SF4640	9/13/2017	*Scytonema*	0.73	---	2.25	---	---
SF EEL RIVER	111SF4640	9/26/2017	*Anabaena*	26.10	ND	0.77	---	ND
SF EEL RIVER	111SF4640	9/26/2017	*Anabaena*	0.42	ND	0.54	---	ND
SF EEL RIVER	111SF4640	9/26/2017	*Nostoc*	0.74	---	0.27	---	---
SF EEL RIVER	111SF4640	9/26/2017	*Microcoleus (Phormidium)*	123.20	---	0.45	---	---
SF EEL RIVER	111SF4640	9/26/2017	*Scytonema*	0.27	---	4.30	---	ND
SF EEL RIVER	111SF4640	10/16/2017	*Microcoleus (Phormidium)*	0.80	---	---	---	---
SF EEL RIVER	111SF4640	6/12/2018	*Hapalosiphon*	2.44	3.57	150.00	---	---
SF EEL RIVER	111SF4640	6/26/2018	*Cylindrospermum*	2.71	ND	24.34	---	---
SF EEL RIVER	111SF4640	6/26/2018	*Microcoleus (Phormidium)*	ND	---	7.97	---	---
SF EEL RIVER	111SF4640	6/26/2018	*Microcoleus (Phormidium)*	ND	9.55	1.13	ND	---
SF EEL RIVER	111SF4640	8/15/2018	*Cylindrospermum*	9.83	ND	3.96	3.96	---

River	Site Code	Date	Genera	ATX (ug/L)	CYL (ug/L)	MCY/NOD (ug/L)	NOD (ug/L)	SXT (ug/L)
SF EEL RIVER	111SF4640	8/15/2018	*Microcoleus (Phormidium)*	55.99	ND	ND	ND	---
SF EEL RIVER	111SF4640	8/15/2018	*Scytonema*	126.24	ND	ND	ND	---
SF EEL RIVER	111SF4640	9/12/2018	*Scytonema*	114.24	ND	ND	ND	---
SF EEL RIVER	111SF4640	9/12/2018	*Tolypothrix*	0.35	---	---	---	---
SF EEL RIVER	111SF4640	9/18/2018	*Rivularia*	ND	---	---	---	ND
SF EEL RIVER	111SF4640	10/4/2018	*Cylindrospermum*	0.34	---	---	---	---
SF EEL RIVER	111SF4640	10/4/2018	*Microcoleus (Phormidium)*	3.52	---	---	---	---
SF EEL RIVER	111SF4640	7/9/2019	*Microcoleus (Phormidium)*	ND	---	ND	ND	---
SF EEL RIVER	111SF4640	7/16/2019	*Hapalosiphon*	ND	ND	ND	ND	ND
SF EEL RIVER	111SF4640	7/16/2019	*Nostoc*	16.10	---	1.02	ND	---
SF EEL RIVER	111SF4640	7/18/2019	*Microcoleus (Phormidium)*	6.05	---	0.12	ND	---
SF EEL RIVER	111SF4640	7/31/2019	*Nostoc*	8.57	---	3.46	ND	---
SF EEL RIVER	111SF4640	7/31/2019	*Microcoleus (Phormidium)*	5.04	---	0.19	ND	---
SF EEL RIVER	111SF4640	7/31/2019	*Rivularia*	0.15	ND	7.86	---	ND

River	Site Code	Date	Genera	ATX (ug/L)	CYL (ug/L)	MCY/NOD (ug/L)	NOD (ug/L)	SXT (ug/L)
SF EEL RIVER	111SF4640	7/31/2019	*Scytonema*	9.58	ND	0.46	ND	ND
SF EEL RIVER	111SF4640	8/14/2019	*Anabaena*	67.20	ND	0.16	ND	ND
SF EEL RIVER	111SF4640	8/14/2019	*Nostoc*	46.10	34.88	0.29	ND	ND
SF EEL RIVER	111SF4640	8/14/2019	*Nostoc*	124.52	268.12	0.28	ND	ND
SF EEL RIVER	111SF4640	8/14/2019	*Microcoleus (Phormidium)*	12.82	---	---	---	---
SF EEL RIVER	111SF4640	9/11/2019	*Nostoc*	0.67	ND	0.22	---	ND
SF EEL RIVER	111SF4640	9/17/2019	*Rivularia*	0.19	ND	3.92	---	ND
SF EEL RIVER	111SF4640	10/5/2019	*Nostoc*	0.40	---	0.41	---	---
SF EEL RIVER	111SF4640	10/5/2019	*Microcoleus (Phormidium)*	44.07	---	ND	---	---
SF EEL RIVER	111SF6856	8/17/2017	*Nostoc*	8.05	ND	0.18	---	ND
SF EEL RIVER	111SF6856	8/17/2017	*Microcoleus (Phormidium)*	5.17	0.07	0.79	---	0.02
SF EEL RIVER	111SF6856	8/29/2017	*Nostoc*	1.80	---	ND	---	---
SF EEL RIVER	111SF6856	8/29/2017	Sponge	1.53	ND	0.34	---	ND
SF EEL RIVER	111SF6856	9/13/2017	*Nostoc*	0.36	ND	0.14	---	ND

River	Site Code	Date	Genera	ATX (ug/L)	CYL (ug/L)	MCY/NOD (ug/L)	NOD (ug/L)	SXT (ug/L)
SF EEL RIVER	111SF6856	9/13/2017	*Scytonema*	0.47	---	5.57	---	ND
SF EEL RIVER	111SF6856	9/13/2017	Sponge	1.80	---	0.27	---	---
SF EEL RIVER	111SF6856	9/26/2017	*Anabaena*	179.20	ND	---	---	ND
SF EEL RIVER	111SF6856	9/26/2017	*Cylindrospermum*	1.11	ND	---	---	ND
SF EEL RIVER	111SF6856	9/26/2017	*Microcoleus (Phormidium)*	0.28	---	0.21	---	---
SF EEL RIVER	111SF6856	9/26/2017	*Scytonema*	0.32	---	7.88	---	ND
SF EEL RIVER	111SF6856	10/16/2017	*Microcoleus (Phormidium)*	0.22	---	---	---	---
SF EEL RIVER	111SF6856	10/16/2017	*Rivularia*	ND	ND	ND	---	0.05
SF EEL RIVER	111SF6856	6/26/2018	*Calothrix*	ND	ND	75.00	---	---
SF EEL RIVER	111SF6856	8/15/2018	*Anabaena*	0.64	ND	ND	ND	---
SF EEL RIVER	111SF6856	8/15/2018	*Microcoleus (Phormidium)*	0.27	ND	ND	ND	---
SF EEL RIVER	111SF6856	8/15/2018	*Scytonema*	209.37	ND	13.59	2.71	---
SF EEL RIVER	111SF6856	9/12/2018	*Anabaena*	43.46	ND	7.37	ND	---
SF EEL RIVER	111SF6856	9/12/2018	*Anabaena*	212.50	---	---	---	---

River	Site Code	Date	Genera	ATX (ug/L)	CYL (ug/L)	MCY/NOD (ug/L)	NOD (ug/L)	SXT (ug/L)
SF EEL RIVER	111SF6856	9/12/2018	*Cylindrospermum*	496.39	ND	18.19	ND	---
SF EEL RIVER	111SF6856	9/12/2018	*Cylindrospermum*	1.21	---	---	---	---
SF EEL RIVER	111SF6856	9/12/2018	*Nostoc*	230.28	ND	ND	ND	---
SF EEL RIVER	111SF6856	9/12/2018	*Microcoleus (Phormidium)*	43.05	ND	3.40	ND	---
SF EEL RIVER	111SF6856	9/12/2018	*Microcoleus (Phormidium)*	22.76	ND	ND	ND	---
SF EEL RIVER	111SF6856	9/12/2018	*Microcoleus (Phormidium)*	9.11	---	---	---	---
SF EEL RIVER	111SF6856	9/12/2018	*Scytonema*	9.42	ND	11.81	2.09	---
SF EEL RIVER	111SF6856	9/18/2018	*Cylindrospermum*	73.60	---	---	---	---
SF EEL RIVER	111SF6856	9/18/2018	*Microcoleus (Phormidium)*	12.00	---	---	---	---
SF EEL RIVER	111SF6856	10/4/2018	*Cylindrospermum*	---	---	---	---	0.51
SF EEL RIVER	111SF6856	10/4/2018	*Microcoleus (Phormidium)*	17.54	---	---	---	---
SF EEL RIVER	111SF6856	7/16/2019	*Scytonema*	ND	ND	ND	ND	ND
SF EEL RIVER	111SF6856	7/16/2019	*Tolypothrix*	ND	ND	ND	ND	ND
SF EEL RIVER	111SF6856	7/18/2019	*Microcoleus (Phormidium)*	ND	ND	0.21	ND	ND

River	Site Code	Date	Genera	ATX (ug/L)	CYL (ug/L)	MCY/NOD (ug/L)	NOD (ug/L)	SXT (ug/L)
SF EEL RIVER	111SF6856	7/18/2019	*Rivularia*	ND	ND	0.33	ND	ND
SF EEL RIVER	111SF6856	7/18/2019	*Scytonema*	ND	---	0.24	---	ND
SF EEL RIVER	111SF6856	7/31/2019	*Cylindrospermum*	5.94	ND	0.23	ND	ND
SF EEL RIVER	111SF6856	7/31/2019	*Scytonema*	15.23	ND	11.79	ND	0.65
SF EEL RIVER	111SF6856	8/2/2019	*Cylindrospermum*	ND	---	ND	ND	ND
SF EEL RIVER	111SF6856	8/14/2019	*Anabaena*	41.90	32.78	0.49	ND	ND
SF EEL RIVER	111SF6856	8/14/2019	*Nostoc*	30.10	1,366.09	ND	ND	ND
SF EEL RIVER	111SF6856	8/14/2019	*Scytonema*	42.35	ND	6.49	1.74	ND
SF EEL RIVER	111SF6856	9/11/2019	*Anabaena*	2.56	---	---	---	---
SF EEL RIVER	111SF6856	9/11/2019	*Cylindrospermum*	2.37	ND	0.27	ND	ND
SF EEL RIVER	111SF6856	9/11/2019	*Oscillatoria*	0.35	ND	0.29	---	ND
SF EEL RIVER	111SF6856	9/11/2019	*Microcoleus (Phormidium)*	0.79	ND	0.13	---	ND
SF EEL RIVER	111SF6856	9/11/2019	*Scytonema*	0.25	ND	3.43	---	ND
SF EEL RIVER	111SF6856	9/11/2019	Sponge	2.75	ND	0.35	---	ND

River	Site Code	Date	Genera	ATX (ug/L)	CYL (ug/L)	MCY/NOD (ug/L)	NOD (ug/L)	SXT (ug/L)
SF EEL RIVER	111SF6856	9/17/2019	*Rivularia*	ND	ND	0.18	---	ND
SF EEL RIVER	111SF6856	9/17/2019	Sponge	2.43	---	ND	---	---
SF EEL RIVER	111SF6856	10/5/2019	*Anabaena*	0.34	---	---	---	---
SF EEL RIVER	111SF6856	10/5/2019	*Nostoc*	2.03	---	0.25	---	---
SF EEL RIVER	111SF6856	10/5/2019	*Microcoleus (Phormidium)*	1.29	---	0.17	---	---
SF EEL RIVER	111SF6856	10/5/2019	*Rivularia*	ND	---	0.13	---	---
SF EEL RIVER	111SF6856-4640	10/5/2019	*Scytonema*	3.08	---	2.07	---	ND
SF EEL RIVER	111SF6856-4640	10/5/2019	Sponge	0.80	---	0.50	---	---
RUSSIAN RIVER	114EFxxxx	9/11/2019	*Oscillatoria*	133.70	ND	0.73	---	ND
RUSSIAN RIVER	114EFxxxx	9/11/2019	*Microcoleus (Phormidium)*	---	ND	0.60	---	ND
RUSSIAN RIVER	114EFxxxx	9/19/2019	*Oscillatoria*	381.00	---	0.17	---	---
RUSSIAN RIVER	114RR2079	8/30/2017	*Anabaena*	0.26	---	0.14	---	---
RUSSIAN RIVER	114RR2079	9/14/2017	*Anabaena*	1.95	---	0.37	---	---
RUSSIAN RIVER	114RR2079	9/14/2017	*Oscillatoria*	0.19	0.19	ND	---	---

River	Site Code	Date	Genera	ATX (ug/L)	CYL (ug/L)	MCY/NOD (ug/L)	NOD (ug/L)	SXT (ug/L)
RUSSIAN RIVER	114RR2079	9/28/2017	Green Bottom	56.00	---	---	---	ND
RUSSIAN RIVER	114RR2079	9/28/2017	*Nostoc*	ND	---	0.19	---	ND
RUSSIAN RIVER	114RR2079	10/17/2017	*Microcoleus (Phormidium)*	1,195.80	ND	0.37	---	0.02
RUSSIAN RIVER	114RR2655	9/12/2016	*Microcoleus (Phormidium)*	8,115.00	---	0.18	---	ND
RUSSIAN RIVER	114RR2655	9/12/2016	*Microcoleus (Phormidium)*	---	ND	---	---	---
RUSSIAN RIVER	114RR2655	9/14/2017	*Cylindrospermum*	180.90	0.17	ND	---	---
RUSSIAN RIVER	114RR2655	9/14/2017	*Microcoleus (Phormidium)*	1.80	---	---	---	---
RUSSIAN RIVER	114RR2655	9/28/2017	Green Bottom	57.50	---	---	---	ND
RUSSIAN RIVER	114RR2655	9/28/2017	*Oscillatoria*	0.86	---	0.20	---	---
RUSSIAN RIVER	114RR2655	9/28/2017	*Microcoleus (Phormidium)*	35.00	---	---	---	ND
RUSSIAN RIVER	114RR2678	8/30/2017	*Microcoleus (Phormidium)*	220.60	---	ND	---	---
RUSSIAN RIVER	114RR2678	10/17/2017	*Microcoleus (Phormidium)*	369.30	ND	0.13	---	ND
RUSSIAN RIVER	114RR2678	10/17/2017	*Microcoleus (Phormidium)*	91.90	---	---	---	---
RUSSIAN RIVER	114RR2678	10/31/2017	*Oscillatoria*	7,709.10	---	0.23	---	ND

River	Site Code	Date	Genera	ATX (ug/L)	CYL (ug/L)	MCY/NOD (ug/L)	NOD (ug/L)	SXT (ug/L)
RUSSIAN RIVER	114RR2678	10/31/2017	*Microcoleus (Phormidium)*	234.70	---	0.12	---	---
RUSSIAN RIVER	114RR2678	9/25/2018	*Cylindrospermum*	66.10	---	---	---	---
RUSSIAN RIVER	114RR2678	9/25/2018	*Microcoleus (Phormidium)*	0.16	---	---	---	---
RUSSIAN RIVER	114RR2678	9/12/2019	*Anabaena*	0.21	---	---	---	---
RUSSIAN RIVER	114RR2678	9/12/2019	*Microcoleus (Phormidium)*	0.34	ND	ND	---	ND
RUSSIAN RIVER	114RR5407	9/12/2016	*Nostoc*	4.84	ND	0.34	---	ND
RUSSIAN RIVER	114RR5407	9/12/2016	*Microcoleus (Phormidium)*	0.49	ND	ND	---	0.06
RUSSIAN RIVER	114RR5407	9/12/2016	*Microcoleus (Phormidium)*	2,631.00	---	0.26	---	0.05
RUSSIAN RIVER	114RR5407	6/27/2017	*Microcoleus (Phormidium)*	34.90	---	---	---	---
RUSSIAN RIVER	114RR5407	7/18/2017	*Microcoleus (Phormidium)*	89.00	---	---	---	---
RUSSIAN RIVER	114RR5407	8/3/2017	*Anabaena*	46.50	0.06	0.80	---	ND
RUSSIAN RIVER	114RR5407	8/3/2017	*Microcoleus (Phormidium)*	ND	ND	ND	---	ND
RUSSIAN RIVER	114RR5407	8/17/2017	*Anabaena*	12.80	ND	0.24	---	ND
RUSSIAN RIVER	114RR5407	8/17/2017	*Nostoc*	ND	ND	0.20	---	ND

River	Site Code	Date	Genera	ATX (ug/L)	CYL (ug/L)	MCY/NOD (ug/L)	NOD (ug/L)	SXT (ug/L)
RUSSIAN RIVER	114RR5407	8/17/2017	*Microcoleus (Phormidium)*	0.18	ND	0.14	---	ND
RUSSIAN RIVER	114RR5407	8/30/2017	*Anabaena*	31.40	---	0.25	---	---
RUSSIAN RIVER	114RR5407	8/30/2017	*Microcoleus (Phormidium)*	0.85	---	ND	---	---
RUSSIAN RIVER	114RR5407	9/14/2017	*Anabaena*	0.18	---	5.80	---	---
RUSSIAN RIVER	114RR5407	9/14/2017	*Cylindrospermum*	0.17	ND	---	---	---
RUSSIAN RIVER	114RR5407	9/14/2017	*Microcoleus (Phormidium)*	0.34	---	---	---	---
RUSSIAN RIVER	114RR5407	9/27/2017	*Microcoleus (Phormidium)*	0.14	---	0.12	---	---
RUSSIAN RIVER	114RR5407	10/17/2017	*Microcoleus (Phormidium)*	0.31	---	---	---	---
RUSSIAN RIVER	114RR5407	8/2/2018	*Nostoc*	244.30	---	---	---	---
RUSSIAN RIVER	114RR5407	9/13/2018	*Nostoc*	ND	---	---	---	ND
RUSSIAN RIVER	114RR5407	9/19/2018	*Nostoc*	ND	---	---	---	---
RUSSIAN RIVER	114RR5407	9/25/2018	*Microcoleus (Phormidium)*	ND	---	---	---	---
RUSSIAN RIVER	114RR5407	6/19/2019	*Microcoleus (Phormidium)*	ND	ND	ND	---	ND
RUSSIAN RIVER	114RR5407	7/9/2019	*Microcoleus (Phormidium)*	39.85	---	ND	ND	---

River	Site Code	Date	Genera	ATX (ug/L)	CYL (ug/L)	MCY/NOD (ug/L)	NOD (ug/L)	SXT (ug/L)
RUSSIAN RIVER	114RR5407	7/11/2019	*Microcoleus (Phormidium)*	ND	ND	ND	ND	ND
RUSSIAN RIVER	114RR5407	7/24/2019	*Microcoleus (Phormidium)*	ND	ND	0.12	ND	ND
RUSSIAN RIVER	114RR5407	8/1/2019	*Microcoleus (Phormidium)*	8.25	---	ND	ND	---
RUSSIAN RIVER	114RR5407	9/4/2019	*Microcoleus (Phormidium)*	ND	ND	ND	---	ND
RUSSIAN RIVER	114RR5407	9/12/2019	*Anabaena*	ND	---	---	---	---
RUSSIAN RIVER	114RR5407	9/12/2019	*Nostoc*	ND	ND	ND	---	ND
RUSSIAN RIVER	114RR5407	9/12/2019	*Microcoleus (Phormidium)*	ND	ND	0.12	---	ND
RUSSIAN RIVER	114RR5407	10/5/2019	*Anabaena*	0.10	---	---	---	---
RUSSIAN RIVER	114RR5407	10/5/2019	*Microcoleus (Phormidium)*	0.60	---	ND	---	---
RUSSIAN RIVER	114RR7396	8/17/2017	*Microcoleus (Phormidium)*	0.19	ND	0.23	---	ND
RUSSIAN RIVER	114RR7396	9/26/2017	*Microcoleus (Phormidium)*	0.24	---	0.28	---	ND
RUSSIAN RIVER	114RR7396	6/12/2018	*Microcoleus (Phormidium)*	12.89	137.16	6.02	---	ND
RUSSIAN RIVER	114RR7396	9/13/2018	*Oscillatoria*	53.00	ND	0.66	0.66	---
RUSSIAN RIVER	114RR7396	9/13/2018	*Oscillatoria*	233.10	---	---	---	---

River	Site Code	Date	Genera	ATX (ug/L)	CYL (ug/L)	MCY/NOD (ug/L)	NOD (ug/L)	SXT (ug/L)
RUSSIAN RIVER	114RR7396	9/25/2018	*Oscillatoria*	1,878.40	---	---	---	---
RUSSIAN RIVER	114RR7396	6/25/2019	*Microcoleus (Phormidium)*	ND	ND	ND	---	ND
RUSSIAN RIVER	114RR7396	8/1/2019	*Microcoleus (Phormidium)*	1.38	ND	0.14	ND	ND

Appendix 4. Cyanotoxin concentrations in cyanobacterial reachwide mat samples by sampling site and date in the Eel River, South Fork Eel River, and Russian River in 2016. ATX, anatoxins; CYN, cylindrospermopsins; MCY, microcystins; NOD, nodularins; STX, saxitoxins; ND, non-detect; ---, no analysis was performed.

River	Site Code	Date	ATX (ug/L)	CYL (ug/L)	MCY/NOD (ug/L)	NOD (ug/L)	SXT (ug/L)
EEL RIVER	111ER6381	7/12/2016	224.00	---	ND	---	---
EEL RIVER	111ER6381	8/1/2016	2.77	ND	ND	---	ND
EEL RIVER	111ER6381	8/15/2016	1.40	---	0.74	---	---
EEL RIVER	111ER6381	8/29/2016	35.80	---	0.19	---	ND
EEL RIVER	111ER8102	7/13/2016	0.64	---	0.25	---	---
EEL RIVER	111ER8102	8/1/2016	1.30	ND	ND	---	6.77
EEL RIVER	111ER8102	8/15/2016	18.50	---	0.51	---	---
EEL RIVER	111ER8102	9/6/2016	13.60	---	ND	---	ND
SF EEL RIVER	111SF2423	7/12/2016	5.90	---	3.94	---	---
SF EEL RIVER	111SF2423	8/1/2016	90.91	ND	3.35	---	ND
SF EEL RIVER	111SF2423	8/15/2016	4.96	---	0.37	---	---
SF EEL RIVER	111SF2423	8/17/2016	31.50	---	0.84	---	---
SF EEL RIVER	111SF2423	9/1/2016	11.90	---	0.11	---	ND
SF EEL RIVER	111SF2423	10/2/2016	14.30	---	2.19	---	0.04
SF EEL RIVER	111SF6856	7/12/2016	3.75	---	1.11	---	---
SF EEL RIVER	111SF6856	8/1/2016	6.75	ND	ND	---	ND
SF EEL RIVER	111SF6856	8/15/2016	31.50	---	0.84	---	---
SF EEL RIVER	111SF6856	8/17/2016	4.96	---	0.37	---	---
SF EEL RIVER	111SF6856	9/1/2016	0.68	---	0.32	---	ND
RUSSIAN RIVER	114RR0804	7/12/2016	0.50	---	22.90	---	---
RUSSIAN RIVER	114RR0804	7/13/2016	0.50	---	22.90	---	---
RUSSIAN RIVER	114RR1159	8/2/2016	0.49	ND	ND	---	ND
RUSSIAN RIVER	114RR1159	8/15/2016	1.18	---	0.22	---	---
RUSSIAN RIVER	114RR1159	8/30/2016	0.85	---	0.23	---	ND

River	Site Code	Date	ATX (ug/L)	CYL (ug/L)	MCY/NOD (ug/L)	NOD (ug/L)	SXT (ug/L)
RUSSIAN RIVER	114RR2401	7/13/2016	0.41	---	ND	---	---
RUSSIAN RIVER	114RR2401	8/1/2016	0.44	---	ND	---	---
RUSSIAN RIVER	114RR2401	8/1/2016	---	ND	---	---	ND
RUSSIAN RIVER	114RR2655	8/15/2016	2,204.00	---	0.11	---	---
RUSSIAN RIVER	114RR2655	8/30/2016	2,054.00	---	0.13	---	ND
RUSSIAN RIVER	114RR2655	9/11/2016	15,750.00	ND	0.45	---	0.48
RUSSIAN RIVER	114RR3119	7/12/2016	1.01	---	1.85	---	---
RUSSIAN RIVER	114RR4234	7/12/2016	7.10	---	ND	---	---
RUSSIAN RIVER	114RR4234	8/1/2016	365.00	ND	ND	---	ND
RUSSIAN RIVER	114RR4234	8/15/2016	246.00	---	0.63	---	---
RUSSIAN RIVER	114RR4234	8/30/2016	391.00	---	0.14	---	ND
RUSSIAN RIVER	114RR5407	8/2/2016	53.29	ND	0.55	---	ND
RUSSIAN RIVER	114RR5407	8/15/2016	1,002.00	---	0.60	---	---
RUSSIAN RIVER	114RR5407	8/30/2016	619.00	---	0.13	---	ND
RUSSIAN RIVER	114RR5407	9/11/2016	3,396.00	ND	0.41	---	0.06
RUSSIAN RIVER	114RR7396	7/13/2016	0.47	---	1.07	---	---
RUSSIAN RIVER	114RR7396	8/2/2016	0.58	ND	ND	---	ND
RUSSIAN RIVER	114RR7396	8/15/2016	0.86	---	86.60	---	---
RUSSIAN RIVER	114RR7396	8/30/2016	0.61	---	ND	---	ND

Appendix 5. Ash free dry mass (AFDM) and standardized cyanotoxin concentrations for cyanobacterial single species dominant mat samples by sampling site and date in the Eel River, South Fork Eel River, and Russian River, from 2016 to 2019. ATX, anatoxins; CYN, cylindrospermopsins; MCY, microcystins; NOD, nodularins; STX, saxitoxins; ND, non-detect; ---, no analysis was performed.

River	Site Code	Date	Genera	AFDM (mg/L)	ATX (mg/kg)	CYL (mg/kg)	MCY/NOD (mg/kg)	SXT (mg/kg)	NOD (mg/kg)
Eel River	111ER6381	9/14/2016	Oscillatoria	4,950	7.68	ND	0.17	ND	---
Eel River	111ER8102	9/15/2016	Cylindrospermum	1,850	8.43	ND	0.18	0.08	---
Eel River	111ER8102	9/15/2016	Cylindrospermum	6,690	1.08	ND	0.07	0.02	---
Eel River	111ER8102	9/15/2016	Phormidium	12,400	1.00	ND	0.07	0.01	---
Eel River	111ER8102	7/12/2017	Anabaena	8,000	0.16	---	---	---	---
Eel River	111ER8102	7/12/2017	Phormidium	2,400	0.18	---	0.09	ND	---
Eel River	111ER8102	7/12/2017	Phormidium	3,820	0.12	---	0.06	ND	---
Eel River	111ER8102	8/17/2017	Phormidium	9,600	64.21	ND	0.06	ND	---
Eel River	111ER8102	8/17/2017	Phormidium	10,000	3.75	ND	0.03	ND	---
Eel River	111ER8102	8/17/2017	Phormidium	2,940	6.99	ND	0.10	0.01	---
Eel River	111ER8102	8/29/2017	Phormidium	10,300	79.55	---	0.07	---	---
Eel River	111ER8102	8/29/2017	Phormidium	8,460	5.87	---	0.04	---	---
Eel River	111ER8102	8/29/2017	Phormidium	6,760	3.05	---	0.06	0.01	---

River	Site Code	Date	Genera	AFDM (mg/L)	ATX (mg/kg)	CYL (mg/kg)	MCY/NOD (mg/kg)	SXT (mg/kg)	NOD (mg/kg)
Eel River	111ER8102	9/13/2017	Phormidium	6,560	0.55	---	0.12	0.39	---
Eel River	111ER8102	9/27/2017	Phormidium	8,390	6.53	---	---	---	---
Eel River	111ER8102	9/27/2017	Phormidium	1,890	4.53	ND	0.12	3.05	---
Eel River	111ER8102	6/30/2019	Phormidium	1,770	1.78	---	ND	---	ND
Eel River	111ER8102	7/3/2019	Phormidium	2,360	0.75	---	0.84	---	---
Eel River	111ER8102	7/9/2019	Phormidium	3,670	3.45	---	ND	---	ND
Eel River	111ER8102	7/11/2019	Phormidium	3,380	3.70	---	ND	---	ND
Eel River	111ER8102	7/22/2019	Phormidium	20,200	0.22	---	0.03	---	ND
Eel River	111ER8102	7/24/2019	Phormidium	5,500	1.25	---	0.05	---	ND
Eel River	111ER8102	8/1/2019	Phormidium	2,550	1.93	---	ND	---	ND
Eel River	111ER8102	8/1/2019	Phormidium	3,880	1.27	---	ND	---	ND
Eel River	111ER8102	8/1/2019	Phormidium	640	ND	---	ND	ND	ND
Eel River	111ER8102	8/14/2019	Phormidium	2,970	1.63	---	---	---	---
Eel River	111ER8102	8/14/2019	Phormidium	1,070	ND	ND	ND	ND	---
Eel River	111ER8102	9/4/2019	Phormidium	7,230	0.13	ND	0.03	ND	---

River	Site Code	Date	Genera	AFDM (mg/L)	ATX (mg/kg)	CYL (mg/kg)	MCY/NOD (mg/kg)	SXT (mg/kg)	NOD (mg/kg)
Eel River	111ER8102	9/4/2019	Phormidium	4,260	2.33	ND	0.04	ND	---
Eel River	111ER8102	9/4/2019	Phormidium	6,510	0.03	ND	0.03	ND	---
SF Eel River	111SF2423	9/14/2016	Phormidium	10,200	0.27	ND	0.05	ND	---
SF Eel River	111SF2423	9/14/2016	Scytonema	10,300	0.24	ND	0.48	ND	---
SF Eel River	111SF2423	7/31/2019	Anabaena	750	11.07	---	0.35	---	---
SF Eel River	111SF2423	7/31/2019	Phormidium	5,950	0.47	---	ND	---	ND
SF Eel River	111SF2423	8/14/2019	Anabaena	2,200	266.05	ND	0.14	ND	ND
SF Eel River	111SF4640	8/17/2017	NOSTOC	3,200	0.44	ND	ND	ND	---
SF Eel River	111SF4640	8/29/2017	Anabaena	4,980	35.20	---	0.23	---	---
SF Eel River	111SF4640	8/29/2017	Nostoc	6,000	0.29	---	ND	---	---
SF Eel River	111SF4640	8/29/2017	Nostoc	5,900	2.03	---	0.05	---	---
SF Eel River	111SF4640	8/29/2017	Phormidium	1,420	29.05	---	0.15	---	---
SF Eel River	111SF4640	8/29/2017	Scytonema	3,540	0.91	ND	0.92	ND	---
SF Eel River	111SF4640	9/13/2017	Phormidium	6,360	4.72	---	ND	---	---
SF Eel River	111SF4640	9/13/2017	Scytonema	5,790	0.13	---	0.39	---	---

River	Site Code	Date	Genera	AFDM (mg/L)	ATX (mg/kg)	CYL (mg/kg)	MCY/NOD (mg/kg)	SXT (mg/kg)	NOD (mg/kg)
SF Eel River	111SF4640	9/26/2017	Anabaena	5,160	5.06	ND	0.15	ND	---
SF Eel River	111SF4640	9/26/2017	Phormidium	5,460	22.56	---	0.08	---	---
SF Eel River	111SF4640	9/26/2017	Scytonema	1,060	0.25	---	4.06	ND	---
SF Eel River	111SF4640	7/9/2019	Phormidium	630	ND	---	ND	---	ND
SF Eel River	111SF4640	7/31/2019	Phormidium	3,800	0.56	---	0.05	---	ND
SF Eel River	111SF4640	7/31/2019	Scytonema	800	11.98	ND	0.58	ND	ND
SF Eel River	111SF4640	8/14/2019	Anabaena	1,400	48.00	ND	0.11	ND	ND
SF Eel River	111SF4640	8/14/2019	Nostoc	6,480	19.21	41.37	0.04	ND	ND
SF Eel River	111SF4640	8/14/2019	Phormidium	3,360	3.82	---	---	---	---
SF Eel River	111SF4640	9/11/2019	Nostoc	8,740	0.08	ND	0.03	ND	---
SF Eel River	111SF4640	10/5/2019	Phormidium	6,400	6.89	---	ND	---	---
SF Eel River	111SF6856	8/17/2017	Nostoc	1,570	5.13	ND	0.11	ND	---
SF Eel River	111SF6856	8/17/2017	Phormidium	8,370	0.62	0.01	0.09	0.00	---
SF Eel River	111SF6856	9/13/2017	Scytonema	1,900	0.25	---	2.93	ND	---
SF Eel River	111SF6856	9/26/2017	Anabaena	170	1,054.12	ND	---	ND	---

River	Site Code	Date	Genera	AFDM (mg/L)	ATX (mg/kg)	CYL (mg/kg)	MCY/NOD (mg/kg)	SXT (mg/kg)	NOD (mg/kg)
SF Eel River	111SF6856	9/26/2017	Cylindrospermum	1,930	0.58	ND	---	ND	---
SF Eel River	111SF6856	9/26/2017	Scytonema	3,600	0.09	---	2.19	ND	---
SF Eel River	111SF6856	10/16/2017	Rivularia	2,310	ND	ND	ND	0.02	---
SF Eel River	111SF6856	7/31/2019	Cylindrospermum	740	8.03	0.01	0.31	ND	ND
SF Eel River	111SF6856	7/31/2019	Scytonema	2,630	5.79	ND	4.86	0.25	ND
SF Eel River	111SF6856	8/14/2019	Anabaena	1,750	23.94	---	18.73	ND	ND
SF Eel River	111SF6856	8/14/2019	Nostoc	2,170	13.87	629.53	ND	ND	ND
SF Eel River	111SF6856	8/14/2019	Scytonema	2,820	15.02	ND	2.30	ND	0.62
SF Eel River	111SF6856	9/11/2019	Oscillatoria	3,140	0.11	ND	0.09	ND	---
SF Eel River	111SF6856	9/11/2019	Phormidium	5,340	0.15	ND	0.02	ND	---
SF Eel River	111SF6856	10/5/2019	Phormidium	1,880	0.69	---	0.09	---	---
SF Eel River	111SF6856	10/5/2019	Rivularia	690	ND	---	0.19	---	---
SF Eel River	114EFxxxx	9/11/2019	Oscillatoria	7,460	17.92	ND	0.10	---	ND
SF Eel River	114EFxxxx	9/18/2019	Oscillatoria	10,600	35.94	---	0.02	---	---
Russian River	114RR2079	9/14/2017	Anabaena	3,380	0.58	---	0.11	---	---

River	Site Code	Date	Genera	AFDM (mg/L)	ATX (mg/kg)	CYL (mg/kg)	MCY/NOD (mg/kg)	SXT (mg/kg)	NOD (mg/kg)
Russian River	114RR2079	10/17/2017	Phormidium	9,910	120.67	ND	0.18	0.00	---
Russian River	114RR2079	10/17/2017	Phormidium	8,340	67.84	ND	0.04	ND	---
Russian River	114RR2655	9/12/2016	Phormidium	9,030	1,744.19	ND	0.05	ND	---
Russian River	114RR2655	9/12/2016	Phormidium	6,670	1,216.64	ND	0.03	ND	---
Russian River	114RR2655	9/14/2017	Cylindrospermum	12,300	14.71	ND	0.01	---	---
Russian River	114RR2655	9/14/2017	Phormidium	1,780	1.01	---	---	---	---
Russian River	114RR2655	9/28/2017	Phormidium	3,800	10.71	---	---	---	---
Russian River	114RR2655	9/28/2017	Phormidium	3,340	10.48	---	---	ND	---
Russian River	114RR2678	8/30/2017	Phormidium	4,410	50.02	---	ND	---	---
Russian River	114RR2678	10/17/2017	Phormidium	6,500	56.82	ND	0.02	ND	---
Russian River	114RR2678	10/17/2017	Phormidium	6,020	15.27	---	---	---	---
Russian River	114RR2678	10/17/2017	Phormidium	8,260	0.18	---	---	---	---
Russian River	114RR2678	9/12/2019	Phormidium	6,180	0.06	ND	ND	ND	---
Russian River	114RR4234	9/12/2016	Anabaena	3,980	0.43	ND	0.06	ND	---
Russian River	114RR5407	9/12/2016	Nostoc	2,140	2.26	ND	0.16	ND	---

River	Site Code	Date	Genera	AFDM (mg/L)	ATX (mg/kg)	CYL (mg/kg)	MCY/NOD (mg/kg)	SXT (mg/kg)	NOD (mg/kg)
Russian River	114RR5407	9/12/2016	Phormidium	1,940	1,356.19	ND	0.13	ND	---
Russian River	114RR5407	9/12/2016	Phormidium	7,290	465.84	ND	0.06	ND	---
Russian River	114RR5407	9/12/2016	Phormidium	9,930	0.05	ND	ND	ND	---
Russian River	114RR5407	8/17/2017	Anabaena	5,060	2.53	ND	0.05	ND	---
Russian River	114RR5407	8/17/2017	Phormidium	5,760	0.03	ND	0.02	ND	---
Russian River	114RR5407	9/14/2017	Anabaena	3,420	0.05	---	1.70	---	---
Russian River	114RR5407	9/14/2017	Phormidium	7,280	0.05	---	---	---	---
Russian River	114RR5407	10/17/2017	Phormidium	6,190	0.05	---	---	---	---
Russian River	114RR5407	8/1/2019	Phormidium	1,630	5.06	---	ND	---	ND
Russian River	114RR5407	9/12/2019	Nostoc	1,160	ND	ND	ND	ND	---
Russian River	114RR5407	9/12/2019	Phormidium	6,400	ND	ND	0.02	ND	---
Russian River	114RR7396	8/17/2017	Phormidium	3,360	0.06	ND	0.07	ND	---
Russian River	114RR7396	8/1/2019	Phormidium	1,760	0.78	ND	0.08	ND	ND

Appendix 6. Cyanotoxin concentrations for ambient water column grab samples by sampling site and date in the Eel River, South Fork Eel River, and Russian River, from 2016 to 2019. ATX, anatoxins; CYN, cylindrospermopsins; MCY, microcystins; NOD, nodularins; STX, saxitoxins; ND, non-detect; ---, no analysis was performed.

River	Site Code	Date	ATX (ug/L)	CYN (ug/L)	MCY/NOD (ug/L)	NOD (ug/L)	SXT (ug/L)
EEL RIVER	111ER6140	6/26/2018	ND	ND	0.35	ND	---
EEL RIVER	111ER6140	7/19/2018	ND	ND	ND	ND	ND
EEL RIVER	111ER6140	8/15/2018	ND	ND	ND	ND	ND
EEL RIVER	111ER6140	9/12/2018	ND	ND	0.13	ND	ND
EEL RIVER	111ER6140	9/18/2018	ND	ND	ND	ND	ND
EEL RIVER	111ER6140	10/4/2018	ND	ND	ND	---	ND
EEL RIVER	111ER6140	6/30/2019	ND	ND	ND	ND	ND
EEL RIVER	111ER6140	7/31/2019	ND	ND	ND	---	ND
EEL RIVER	111ER6140	9/17/2019	ND	ND	ND	---	ND
EEL RIVER	111ER6381	6/28/2016	ND	ND	ND	ND	ND
EEL RIVER	111ER6381	7/13/2016	ND	ND	ND	ND	---
EEL RIVER	111ER6381	8/2/2016	ND	ND	ND	ND	---
EEL RIVER	111ER6381	8/18/2016	ND	ND	0.63	ND	ND
EEL RIVER	111ER6381	8/31/2016	ND	ND	ND	ND	---
EEL RIVER	111ER6381	9/1/2016	ND	---	---	---	ND
EEL RIVER	111ER6381	9/14/2016	ND	ND	0.11	---	ND
EEL RIVER	111ER6381	9/15/2016	ND	ND	1.58	ND	ND
EEL RIVER	111ER6381	10/2/2016	ND	ND	0.11	ND	ND
EEL RIVER	111ER8102	6/28/2016	ND	ND	ND	ND	---
EEL RIVER	111ER8102	7/13/2016	ND	ND	ND	0.07	---
EEL RIVER	111ER8102	8/2/2016	ND	ND	ND	ND	---
EEL RIVER	111ER8102	8/18/2016	ND	ND	0.35	ND	ND
EEL RIVER	111ER8102	8/31/2016	ND	ND	ND	ND	---
EEL RIVER	111ER8102	9/15/2016	ND	ND	0.23	ND	---

River	Site Code	Date	ATX (ug/L)	CYN (ug/L)	MCY/NOD (ug/L)	NOD (ug/L)	SXT (ug/L)
EEL RIVER	111ER8102	10/2/2016	ND	ND	0.11	ND	ND
EEL RIVER	111ER8102	5/23/2017	ND	---	ND	---	---
EEL RIVER	111ER8102	6/14/2017	ND	ND	ND	---	ND
EEL RIVER	111ER8102	6/27/2017	ND	ND	ND	---	---
EEL RIVER	111ER8102	7/12/2017	ND	ND	ND	---	---
EEL RIVER	111ER8102	8/17/2017	ND	ND	ND	---	---
EEL RIVER	111ER8102	8/29/2017	ND	ND	ND	---	---
EEL RIVER	111ER8102	9/13/2017	ND	ND	ND	---	---
EEL RIVER	111ER8102	9/27/2017	ND	ND	ND	---	---
EEL RIVER	111ER8102	10/31/2017	ND	ND	ND	---	---
EEL RIVER	111ER8102	6/12/2018	ND	ND	ND	ND	ND
EEL RIVER	111ER8102	6/25/2018	ND	ND	ND	ND	ND
EEL RIVER	111ER8102	7/17/2018	ND	ND	ND	ND	ND
EEL RIVER	111ER8102	8/15/2018	ND	ND	ND	ND	ND
EEL RIVER	111ER8102	9/12/2018	ND	ND	ND	ND	ND
EEL RIVER	111ER8102	9/18/2018	ND	ND	ND	ND	ND
EEL RIVER	111ER8102	10/4/2018	ND	ND	ND	---	ND
EEL RIVER	111ER8102	6/24/2019	ND	0.06	ND	ND	ND
EEL RIVER	111ER8102	6/27/2019	ND	ND	ND	---	ND
EEL RIVER	111ER8102	6/30/2019	ND	ND	ND	ND	ND
EEL RIVER	111ER8102	7/9/2019	ND	ND	ND	ND	ND
EEL RIVER	111ER8102	7/16/2019	ND	ND	ND	6.11	ND
EEL RIVER	111ER8102	7/24/2019	ND	ND	ND	ND	ND
EEL RIVER	111ER8102	7/30/2019	ND	ND	ND	---	ND
EEL RIVER	111ER8102	8/14/2019	0.26	ND	ND	ND	ND
EEL RIVER	111ER8102	9/4/2019	ND	ND	ND	---	ND
SF EEL RIVER	111SF2423	7/13/2016	ND	ND	ND	ND	ND
SF EEL RIVER	111SF2423	8/2/2016	ND	ND	ND	ND	ND

River	Site Code	Date	ATX (ug/L)	CYN (ug/L)	MCY/NOD (ug/L)	NOD (ug/L)	SXT (ug/L)
SF EEL RIVER	111SF2423	8/18/2016	ND	ND	0.39	ND	ND
SF EEL RIVER	111SF2423	8/31/2016	ND	ND	0.22	ND	---
SF EEL RIVER	111SF2423	9/14/2016	ND	ND	ND	---	ND
SF EEL RIVER	111SF2423	9/15/2016	ND	ND	ND	ND	ND
SF EEL RIVER	111SF2423	10/1/2016	ND	---	---	---	---
SF EEL RIVER	111SF2423	10/2/2016	ND	ND	0.14	ND	ND
SF EEL RIVER	111SF2423	6/19/2019	ND	---	ND	ND	ND
SF EEL RIVER	111SF2423	7/31/2019	ND	ND	ND	---	ND
SF EEL RIVER	111SF2423	8/14/2019	ND	ND	ND	ND	ND
SF EEL RIVER	111SF2423	8/26/2019	ND	ND	0.28	ND	ND
SF EEL RIVER	111SF2423	8/28/2019	ND	ND	0.19	ND	ND
SF EEL RIVER	111SF2423	8/29/2019	ND	ND	0.18	ND	---
SF EEL RIVER	111SF2423	9/17/2019	ND	ND	ND	---	ND
SF EEL RIVER	111SF4640	5/25/2017	ND	---	ND	---	ND
SF EEL RIVER	111SF4640	6/14/2017	ND	ND	ND	---	ND
SF EEL RIVER	111SF4640	6/27/2017	ND	ND	ND	---	ND
SF EEL RIVER	111SF4640	7/12/2017	ND	ND	ND	---	ND
SF EEL RIVER	111SF4640	8/17/2017	ND	ND	ND	---	ND
SF EEL RIVER	111SF4640	8/29/2017	ND	ND	ND	---	ND
SF EEL RIVER	111SF4640	9/13/2017	ND	ND	ND	---	ND
SF EEL RIVER	111SF4640	9/26/2017	ND	ND	ND	---	ND
SF EEL RIVER	111SF4640	6/12/2018	ND	ND	0.55	ND	ND
SF EEL RIVER	111SF4640	6/26/2018	ND	ND	ND	---	ND
SF EEL RIVER	111SF4640	7/19/2018	ND	ND	ND	ND	ND
SF EEL RIVER	111SF4640	8/15/2018	ND	ND	ND	ND	ND
SF EEL RIVER	111SF4640	9/12/2018	ND	ND	2.27	ND	ND
SF EEL RIVER	111SF4640	9/18/2018	ND	ND	0.10	ND	ND
SF EEL RIVER	111SF4640	10/4/2018	ND	ND	ND	---	ND

River	Site Code	Date	ATX (ug/L)	CYN (ug/L)	MCY/NOD (ug/L)	NOD (ug/L)	SXT (ug/L)
SF EEL RIVER	111SF4640	6/19/2019	ND	---	ND	ND	ND
SF EEL RIVER	111SF4640	7/9/2019	ND	ND	ND	ND	ND
SF EEL RIVER	111SF4640	7/16/2019	ND	ND	ND	ND	ND
SF EEL RIVER	111SF4640	7/31/2019	ND	ND	ND	---	ND
SF EEL RIVER	111SF4640	8/14/2019	0.55	ND	ND	ND	ND
SF EEL RIVER	111SF4640	8/27/2019	ND	ND	0.17	ND	ND
SF EEL RIVER	111SF4640	8/28/2019	ND	ND	0.16	ND	ND
SF EEL RIVER	111SF4640	8/29/2019	ND	ND	0.26	ND	ND
SF EEL RIVER	111SF4640	8/30/2019	ND	ND	0.18	ND	ND
SF EEL RIVER	111SF4640	9/11/2019	2.19	---	---	---	ND
SF EEL RIVER	111SF4640	9/17/2019	ND	ND	ND	---	ND
SF EEL RIVER	111SF4640	10/5/2019	ND	ND	ND	---	ND
SF EEL RIVER	111SF4640	10/11/2019	ND	ND	ND	---	ND
SF EEL RIVER	111SF6856	7/13/2016	ND	ND	ND	ND	ND
SF EEL RIVER	111SF6856	8/2/2016	ND	ND	ND	ND	ND
SF EEL RIVER	111SF6856	8/18/2016	ND	ND	0.34	ND	ND
SF EEL RIVER	111SF6856	8/31/2016	ND	ND	ND	ND	ND
SF EEL RIVER	111SF6856	9/14/2016	ND	ND	ND	---	ND
SF EEL RIVER	111SF6856	9/15/2016	ND	ND	ND	ND	ND
SF EEL RIVER	111SF6856	10/1/2016	ND	---	---	---	---
SF EEL RIVER	111SF6856	10/2/2016	ND	ND	ND	ND	ND
SF EEL RIVER	111SF6856	5/25/2017	ND	---	ND	---	ND
SF EEL RIVER	111SF6856	6/14/2017	ND	ND	0.15	---	ND
SF EEL RIVER	111SF6856	6/27/2017	ND	ND	ND	---	ND
SF EEL RIVER	111SF6856	7/12/2017	ND	ND	ND	---	ND
SF EEL RIVER	111SF6856	8/17/2017	ND	ND	ND	---	ND
SF EEL RIVER	111SF6856	8/29/2017	ND	ND	ND	---	ND
SF EEL RIVER	111SF6856	9/13/2017	ND	ND	ND	---	ND

River	Site Code	Date	ATX (ug/L)	CYN (ug/L)	MCY/NOD (ug/L)	NOD (ug/L)	SXT (ug/L)
SF EEL RIVER	111SF6856	9/26/2017	ND	ND	ND	---	ND
SF EEL RIVER	111SF6856	6/12/2018	ND	ND	0.54	ND	ND
SF EEL RIVER	111SF6856	6/26/2018	ND	ND	ND	---	ND
SF EEL RIVER	111SF6856	7/19/2018	ND	ND	ND	ND	ND
SF EEL RIVER	111SF6856	8/15/2018	ND	ND	ND	ND	ND
SF EEL RIVER	111SF6856	9/12/2018	ND	ND	0.18	ND	---
SF EEL RIVER	111SF6856	9/18/2018	ND	ND	ND	ND	ND
SF EEL RIVER	111SF6856	10/4/2018	ND	ND	ND	---	ND
SF EEL RIVER	111SF6856	6/19/2019	ND	---	0.19	ND	ND
SF EEL RIVER	111SF6856	7/16/2019	ND	ND	ND	ND	ND
SF EEL RIVER	111SF6856	7/31/2019	ND	ND	ND	---	ND
SF EEL RIVER	111SF6856	8/14/2019	ND	ND	ND	ND	ND
SF EEL RIVER	111SF6856	8/26/2019	ND	ND	0.18	ND	ND
SF EEL RIVER	111SF6856	8/27/2019	ND	ND	0.19	ND	---
SF EEL RIVER	111SF6856	8/28/2019	ND	ND	0.20	ND	---
SF EEL RIVER	111SF6856	8/29/2019	ND	ND	0.17	ND	ND
SF EEL RIVER	111SF6856	8/30/2019	ND	ND	0.19	ND	---
SF EEL RIVER	111SF6856	9/17/2019	ND	ND	ND	---	ND
RUSSIAN RIVER	114RR1159	8/2/2016	ND	ND	ND	ND	ND
RUSSIAN RIVER	114RR1159	8/18/2016	ND	ND	0.68	ND	ND
RUSSIAN RIVER	114RR1159	8/31/2016	ND	ND	0.14	ND	ND
RUSSIAN RIVER	114RR1159	9/15/2016	ND	ND	0.11	ND	ND
RUSSIAN RIVER	114RR1159	9/30/2016	0.15	ND	0.12	ND	ND
RUSSIAN RIVER	114RR1644	8/18/2016	ND	ND	0.68	ND	ND
RUSSIAN RIVER	114RR1644	8/31/2016	ND	ND	0.14	ND	ND
RUSSIAN RIVER	114RR1644	9/15/2016	ND	ND	ND	ND	ND
RUSSIAN RIVER	114RR1644	9/29/2016	ND	---	---	---	---
RUSSIAN RIVER	114RR1644	10/2/2016	ND	ND	0.14	ND	ND

River	Site Code	Date	ATX (ug/L)	CYN (ug/L)	MCY/NOD (ug/L)	NOD (ug/L)	SXT (ug/L)
RUSSIAN RIVER	114RR2079	5/25/2017	ND	---	ND	---	---
RUSSIAN RIVER	114RR2079	6/15/2017	ND	ND	ND	---	---
RUSSIAN RIVER	114RR2079	6/28/2017	ND	ND	ND	---	---
RUSSIAN RIVER	114RR2079	7/18/2017	ND	ND	ND	---	---
RUSSIAN RIVER	114RR2079	8/3/2017	ND	ND	ND	---	---
RUSSIAN RIVER	114RR2079	8/15/2017	ND	ND	ND	---	---
RUSSIAN RIVER	114RR2079	8/30/2017	ND	ND	ND	---	---
RUSSIAN RIVER	114RR2079	9/14/2017	ND	ND	ND	---	ND
RUSSIAN RIVER	114RR2079	9/28/2017	ND	ND	ND	---	ND
RUSSIAN RIVER	114RR2655	8/18/2016	ND	ND	0.70	ND	ND
RUSSIAN RIVER	114RR2655	8/31/2016	ND	ND	0.12	ND	ND
RUSSIAN RIVER	114RR2655	9/15/2016	ND	ND	ND	ND	ND
RUSSIAN RIVER	114RR2655	9/29/2016	0.18	ND	0.13	ND	ND
RUSSIAN RIVER	114RR2655	9/14/2017	ND	ND	ND	---	ND
RUSSIAN RIVER	114RR2655	9/28/2017	ND	ND	ND	---	ND
RUSSIAN RIVER	114RR2678	5/25/2017	ND	---	ND	---	ND
RUSSIAN RIVER	114RR2678	6/15/2017	ND	ND	ND	---	ND
RUSSIAN RIVER	114RR2678	6/28/2017	ND	ND	ND	---	ND
RUSSIAN RIVER	114RR2678	7/18/2017	ND	ND	ND	---	ND
RUSSIAN RIVER	114RR2678	8/3/2017	ND	ND	ND	---	ND
RUSSIAN RIVER	114RR2678	8/15/2017	ND	ND	ND	---	ND
RUSSIAN RIVER	114RR2678	8/30/2017	ND	ND	ND	---	ND
RUSSIAN RIVER	114RR2678	6/27/2018	ND	ND	ND	---	ND
RUSSIAN RIVER	114RR2678	7/17/2018	ND	ND	ND	ND	ND
RUSSIAN RIVER	114RR2678	8/2/2018	ND	ND	ND	ND	---
RUSSIAN RIVER	114RR2678	9/13/2018	ND	ND	ND	ND	ND
RUSSIAN RIVER	114RR2678	9/19/2018	ND	ND	ND	ND	---
RUSSIAN RIVER	114RR2678	9/25/2018	ND	ND	ND	---	ND

River	Site Code	Date	ATX (ug/L)	CYN (ug/L)	MCY/NOD (ug/L)	NOD (ug/L)	SXT (ug/L)
RUSSIAN RIVER	114RR2678	6/25/2019	ND	0.09	ND	ND	ND
RUSSIAN RIVER	114RR2678	6/27/2019	ND	ND	ND	---	1.50
RUSSIAN RIVER	114RR2678	7/9/2019	ND	ND	ND	ND	ND
RUSSIAN RIVER	114RR2678	7/11/2019	ND	ND	ND	---	ND
RUSSIAN RIVER	114RR2678	7/30/2019	ND	ND	ND	---	0.29
RUSSIAN RIVER	114RR2678	9/11/2019	1.79	---	---	---	ND
RUSSIAN RIVER	114RR4234	6/28/2016	ND	ND	ND	ND	ND
RUSSIAN RIVER	114RR4234	7/13/2016	ND	ND	ND	0.03	ND
RUSSIAN RIVER	114RR4234	8/2/2016	ND	ND	ND	ND	ND
RUSSIAN RIVER	114RR4234	8/18/2016	ND	ND	0.19	ND	---
RUSSIAN RIVER	114RR4234	8/31/2016	ND	ND	ND	ND	ND
RUSSIAN RIVER	114RR4234	9/15/2016	ND	ND	ND	ND	ND
RUSSIAN RIVER	114RR4234	9/30/2016	ND	ND	ND	ND	ND
RUSSIAN RIVER	114RR5407	8/2/2016	ND	ND	ND	ND	ND
RUSSIAN RIVER	114RR5407	8/18/2016	ND	ND	0.81	ND	ND
RUSSIAN RIVER	114RR5407	8/31/2016	ND	ND	0.23	ND	---
RUSSIAN RIVER	114RR5407	9/15/2016	ND	ND	0.32	ND	ND
RUSSIAN RIVER	114RR5407	10/2/2016	ND	ND	ND	ND	ND
RUSSIAN RIVER	114RR5407	10/3/2016	ND	---	0.20	---	ND
RUSSIAN RIVER	114RR5407	5/24/2017	ND	---	ND	---	ND
RUSSIAN RIVER	114RR5407	6/15/2017	ND	ND	ND	---	ND
RUSSIAN RIVER	114RR5407	6/27/2017	ND	ND	ND	---	ND
RUSSIAN RIVER	114RR5407	7/18/2017	ND	ND	ND	---	ND
RUSSIAN RIVER	114RR5407	8/3/2017	ND	ND	ND	---	ND
RUSSIAN RIVER	114RR5407	8/17/2017	ND	ND	ND	---	ND
RUSSIAN RIVER	114RR5407	8/30/2017	ND	ND	ND	---	ND
RUSSIAN RIVER	114RR5407	9/14/2017	ND	ND	ND	---	ND
RUSSIAN RIVER	114RR5407	9/27/2017	ND	ND	ND	---	ND

River	Site Code	Date	ATX (ug/L)	CYN (ug/L)	MCY/NOD (ug/L)	NOD (ug/L)	SXT (ug/L)
RUSSIAN RIVER	114RR5407	6/25/2018	ND	ND	ND	ND	ND
RUSSIAN RIVER	114RR5407	7/17/2018	ND	ND	ND	0.22	ND
RUSSIAN RIVER	114RR5407	7/31/2018	ND	ND	ND	ND	ND
RUSSIAN RIVER	114RR5407	8/2/2018	ND	ND	ND	ND	ND
RUSSIAN RIVER	114RR5407	9/13/2018	ND	ND	ND	ND	ND
RUSSIAN RIVER	114RR5407	9/19/2018	ND	ND	ND	ND	ND
RUSSIAN RIVER	114RR5407	9/25/2018	ND	ND	ND	---	ND
RUSSIAN RIVER	114RR5407	6/25/2019	ND	0.10	ND	ND	ND
RUSSIAN RIVER	114RR5407	6/27/2019	ND	ND	ND	---	ND
RUSSIAN RIVER	114RR5407	7/9/2019	ND	ND	ND	ND	ND
RUSSIAN RIVER	114RR5407	7/24/2019	ND	ND	ND	ND	ND
RUSSIAN RIVER	114RR5407	7/30/2019	ND	ND	ND	---	ND
RUSSIAN RIVER	114RR5407	9/4/2019	ND	ND	ND	---	ND
RUSSIAN RIVER	114RR5407	9/11/2019	1.75	---	---	---	ND
RUSSIAN RIVER	114RR5407	10/5/2019	ND	ND	ND	---	ND
RUSSIAN RIVER	114RR5407	10/11/2019	ND	ND	ND	---	ND
RUSSIAN RIVER	114RR7396	6/28/2016	ND	ND	ND	ND	ND
RUSSIAN RIVER	114RR7396	7/13/2016	ND	ND	ND	ND	ND
RUSSIAN RIVER	114RR7396	8/2/2016	ND	ND	ND	ND	---
RUSSIAN RIVER	114RR7396	8/18/2016	ND	ND	0.83	ND	ND
RUSSIAN RIVER	114RR7396	8/31/2016	ND	ND	0.13	ND	ND
RUSSIAN RIVER	114RR7396	9/15/2016	ND	ND	0.14	ND	ND
RUSSIAN RIVER	114RR7396	9/30/2016	0.15	ND	0.20	ND	ND
RUSSIAN RIVER	114RR7396	5/24/2017	ND	---	ND	---	---
RUSSIAN RIVER	114RR7396	6/15/2017	ND	ND	ND	---	ND
RUSSIAN RIVER	114RR7396	6/27/2017	ND	ND	ND	---	ND
RUSSIAN RIVER	114RR7396	7/12/2017	ND	ND	ND	---	ND
RUSSIAN RIVER	114RR7396	8/3/2017	ND	ND	ND	---	ND

River	Site Code	Date	ATX (ug/L)	CYN (ug/L)	MCY/NOD (ug/L)	NOD (ug/L)	SXT (ug/L)
RUSSIAN RIVER	114RR7396	8/17/2017	ND	ND	ND	---	ND
RUSSIAN RIVER	114RR7396	8/30/2017	ND	ND	ND	---	ND
RUSSIAN RIVER	114RR7396	9/14/2017	ND	ND	ND	---	ND
RUSSIAN RIVER	114RR7396	9/26/2017	ND	ND	ND	---	ND
RUSSIAN RIVER	114RR7396	6/12/2018	ND	ND	ND	ND	ND
RUSSIAN RIVER	114RR7396	6/25/2018	ND	ND	ND	ND	ND
RUSSIAN RIVER	114RR7396	7/19/2018	ND	ND	ND	ND	ND
RUSSIAN RIVER	114RR7396	8/2/2018	ND	ND	ND	ND	ND
RUSSIAN RIVER	114RR7396	8/15/2018	ND	ND	ND	ND	ND
RUSSIAN RIVER	114RR7396	9/13/2018	ND	ND	ND	ND	ND
RUSSIAN RIVER	114RR7396	9/25/2018	ND	ND	ND	---	ND
RUSSIAN RIVER	114RR7396	6/25/2019	ND	0.07	0.31	ND	---
RUSSIAN RIVER	114RR7396	6/27/2019	ND	ND	ND	---	0.88
RUSSIAN RIVER	114RR7396	7/30/2019	ND	ND	ND	---	ND
RUSSIAN RIVER	114RR7396	9/4/2019	ND	ND	ND	---	ND

Appendix 7. Cyanotoxin concentrations for SPATT samples by sampling site and date in the Eel River, South Fork Eel River, and Russian River, from 2016 to 2019. ATX, anatoxins; CYN, cylindrospermopsins; MCY, microcystins; NOD, nodularins; STX, saxitoxins; ND, non-detect; ---, no analysis was performed.

River	Site Code	Date	ATX (ug/L)	CYL (ug/L)	MCY/NOD (ug/L)	NOD (ug/L)	SXT (ug/L)
EEL RIVER	111ER6140	6/26/2018	ND	---	63.67	---	---
EEL RIVER	111ER6140	6/26/2018	ND	ND	---	---	---
EEL RIVER	111ER6140	7/19/2018	21.86	ND	1,000.00	40.62	ND
EEL RIVER	111ER6140	8/15/2018	ND	ND	ND	ND	---
EEL RIVER	111ER6140	9/12/2018	3.19	ND	103.21	3.73	---
EEL RIVER	111ER6140	9/18/2018	193.04	ND	ND	ND	---
EEL RIVER	111ER6140	10/4/2018	5.05	ND	159.80	---	ND
EEL RIVER	111ER6140	7/3/2019	10.23	5.33	1,657.00	936.45	ND
EEL RIVER	111ER6140	7/18/2019	ND	ND	ND	1.58	ND
EEL RIVER	111ER6140	8/2/2019	ND	6.45	414.25	9.26	ND
EEL RIVER	111ER6140	9/24/2019	9.97	---	210.70	---	---
EEL RIVER	111ER6381	6/27/2016	ND	ND	ND	ND	ND
EEL RIVER	111ER6381	7/12/2016	ND	ND	10.22	8.57	ND
EEL RIVER	111ER6381	8/1/2016	ND	ND	35.86	35.86	ND
EEL RIVER	111ER6381	8/15/2016	ND	ND	29.47	28.21	ND
EEL RIVER	111ER6381	8/29/2016	ND	ND	5.12	3.64	ND
EEL RIVER	111ER6381	9/11/2016	ND	ND	27.21	23.39	ND
EEL RIVER	111ER6381	10/2/2016	ND	ND	0.06	0.06	ND
EEL RIVER	111ER8102	6/27/2016	ND	ND	ND	ND	ND
EEL RIVER	111ER8102	7/12/2016	ND	ND	183.51	67.88	ND
EEL RIVER	111ER8102	8/1/2016	ND	ND	252.65	55.38	ND
EEL RIVER	111ER8102	8/15/2016	ND	ND	180.46	62.70	ND
EEL RIVER	111ER8102	8/29/2016	ND	ND	119.72	7.02	ND
EEL RIVER	111ER8102	9/11/2016	ND	ND	215.14	46.96	ND
EEL RIVER	111ER8102	10/2/2016	ND	ND	418.19	1.32	ND

River	Site Code	Date	ATX (ug/L)	CYL (ug/L)	MCY/NOD (ug/L)	NOD (ug/L)	SXT (ug/L)
EEL RIVER	111ER8102	6/14/2017	6.80	0.73	33.50	---	ND
EEL RIVER	111ER8102	6/27/2017	ND	0.87	260.90	---	ND
EEL RIVER	111ER8102	6/12/2018	ND	ND	1,497.23	1,294.77	ND
EEL RIVER	111ER8102	6/12/2018	ND	ND	44.62	44.62	ND
EEL RIVER	111ER8102	6/12/2018	ND	ND	44.13	ND	---
EEL RIVER	111ER8102	7/17/2018	ND	ND	124.00	7.18	---
EEL RIVER	111ER8102	7/17/2018	ND	ND	34.08	ND	---
EEL RIVER	111ER8102	7/17/2018	ND	---	---	---	ND
EEL RIVER	111ER8102	8/15/2018	ND	ND	ND	ND	---
EEL RIVER	111ER8102	9/12/2018	493.07	ND	28.90	5.75	---
EEL RIVER	111ER8102	9/18/2018	ND	ND	40.37	ND	---
EEL RIVER	111ER8102	10/4/2018	4.56	ND	112.80	---	ND
EEL RIVER	111ER8102	6/13/2019	ND	---	ND	ND	ND
EEL RIVER	111ER8102	6/18/2019	ND	---	ND	ND	ND
EEL RIVER	111ER8102	6/24/2019	ND	---	ND	ND	ND
EEL RIVER	111ER8102	6/24/2019	ND	---	ND	ND	ND
EEL RIVER	111ER8102	6/27/2019	ND	---	ND	ND	ND
EEL RIVER	111ER8102	7/3/2019	14.39	5.67	15.79	ND	ND
EEL RIVER	111ER8102	7/11/2019	11.89	ND	9.69	ND	ND
EEL RIVER	111ER8102	7/11/2019	14.19	10.92	3.49	ND	ND
EEL RIVER	111ER8102	7/11/2019	16.25	6.08	8.65	ND	ND
EEL RIVER	111ER8102	7/18/2019	ND	ND	ND	1.58	ND
EEL RIVER	111ER8102	7/24/2019	ND	37.08	ND	2.39	ND
EEL RIVER	111ER8102	8/1/2019	32.50	4.76	ND	ND	ND
EEL RIVER	111ER8102	8/16/2019	5.19	ND	38.11	5.93	ND
EEL RIVER	111ER8102	9/11/2019	ND	ND	ND	ND	3.50
EEL RIVER	111ER8102	9/19/2019	3.06	---	13.05	---	---
SF EEL RIVER	111SF2423	8/1/2016	ND	ND	9.54	9.54	ND
SF EEL RIVER	111SF2423	8/15/2016	ND	ND	4.45	1.72	ND

River	Site Code	Date	ATX (ug/L)	CYL (ug/L)	MCY/NOD (ug/L)	NOD (ug/L)	SXT (ug/L)
SF EEL RIVER	111SF2423	8/29/2016	ND	ND	0.69	0.69	ND
SF EEL RIVER	111SF2423	9/11/2016	ND	ND	ND	ND	ND
SF EEL RIVER	111SF2423	10/2/2016	ND	ND	ND	ND	ND
SF EEL RIVER	111SF2423	6/21/2019	ND	---	94.12	94.12	ND
SF EEL RIVER	111SF2423	8/2/2019	125.67	ND	18.67	1.38	ND
SF EEL RIVER	111SF2423	8/16/2019	176.50	ND	27.00	1.69	ND
SF EEL RIVER	111SF2423	8/27/2019	9.16	ND	ND	ND	---
SF EEL RIVER	111SF2423	8/28/2019	8.28	ND	ND	ND	---
SF EEL RIVER	111SF2423	8/28/2019	12.33	ND	14.67	ND	---
SF EEL RIVER	111SF2423	8/28/2019	14.57	ND	ND	ND	---
SF EEL RIVER	111SF2423	8/28/2019	18.21	ND	ND	ND	---
SF EEL RIVER	111SF2423	8/29/2019	5.40	ND	15.42	6.56	---
SF EEL RIVER	111SF2423	8/29/2019	15.88	ND	ND	ND	---
SF EEL RIVER	111SF2423	8/30/2019	6.41	ND	34.42	3.26	---
SF EEL RIVER	111SF2423	8/30/2019	6.33	ND	15.92	3.12	---
SF EEL RIVER	111SF2423	8/30/2019	10.27	ND	15.42	2.92	---
SF EEL RIVER	111SF2423	8/30/2019	11.48	ND	27.50	1.85	---
SF EEL RIVER	111SF2423	8/30/2019	9.80	ND	ND	1.83	---
SF EEL RIVER	111SF2423	9/11/2019	120.00	ND	19.58	ND	ND
SF EEL RIVER	111SF2423	9/17/2019	18.50	ND	21.27	---	ND
SF EEL RIVER	111SF2423	9/27/2019	4.72	---	4.86	---	---
SF EEL RIVER	111SF4640	6/14/2017	7.40	ND	470.00	---	ND
SF EEL RIVER	111SF4640	6/27/2017	ND	0.81	720.80	---	ND
SF EEL RIVER	111SF4640	6/12/2018	ND	ND	20.70	ND	ND
SF EEL RIVER	111SF4640	6/25/2018	ND	ND	1,000.00	---	ND
SF EEL RIVER	111SF4640	7/19/2018	5.23	ND	227.17	17.56	ND
SF EEL RIVER	111SF4640	8/15/2018	ND	ND	73.76	73.76	---
SF EEL RIVER	111SF4640	9/12/2018	20.35	ND	165.40	17.10	---
SF EEL RIVER	111SF4640	10/4/2018	5.39	ND	207.30	---	ND

River	Site Code	Date	ATX (ug/L)	CYL (ug/L)	MCY/NOD (ug/L)	NOD (ug/L)	SXT (ug/L)
SF EEL RIVER	111SF4640	6/7/2019	ND	---	67.33	ND	ND
SF EEL RIVER	111SF4640	6/21/2019	ND	---	171.93	171.93	ND
SF EEL RIVER	111SF4640	7/11/2019	15.78	7.08	296.95	239.47	ND
SF EEL RIVER	111SF4640	7/11/2019	19.39	7.25	205.08	147.75	ND
SF EEL RIVER	111SF4640	7/11/2019	26.35	6.33	153.11	136.49	ND
SF EEL RIVER	111SF4640	7/11/2019	ND	0.95	204.80	---	ND
SF EEL RIVER	111SF4640	7/18/2019	ND	19.17	40.17	5.04	ND
SF EEL RIVER	111SF4640	8/2/2019	134.33	7.40	ND	1.03	ND
SF EEL RIVER	111SF4640	8/16/2019	869.77	ND	48.50	4.78	ND
SF EEL RIVER	111SF4640	8/27/2019	411.99	ND	ND	15.49	---
SF EEL RIVER	111SF4640	8/27/2019	438.46	ND	43.00	10.24	---
SF EEL RIVER	111SF4640	8/28/2019	453.12	ND	ND	3.47	---
SF EEL RIVER	111SF4640	8/28/2019	545.13	ND	---	ND	---
SF EEL RIVER	111SF4640	8/29/2019	280.24	ND	ND	5.41	---
SF EEL RIVER	111SF4640	8/29/2019	253.26	ND	ND	4.58	---
SF EEL RIVER	111SF4640	8/29/2019	323.37	ND	ND	ND	---
SF EEL RIVER	111SF4640	8/30/2019	1,093.29	ND	49.50	23.47	---
SF EEL RIVER	111SF4640	8/30/2019	646.15	ND	19.92	15.55	---
SF EEL RIVER	111SF4640	8/30/2019	320.11	ND	ND	14.56	---
SF EEL RIVER	111SF4640	8/30/2019	501.68	ND	26.92	14.53	---
SF EEL RIVER	111SF4640	8/30/2019	307.51	ND	22.25	13.39	---
SF EEL RIVER	111SF4640	8/30/2019	214.25	ND	ND	3.89	---
SF EEL RIVER	111SF4640	9/11/2019	ND	ND	ND	ND	ND
SF EEL RIVER	111SF4640	9/17/2019	18.55	ND	12.71	---	ND
SF EEL RIVER	111SF4640	9/27/2019	62.20	---	24.37	---	---
SF EEL RIVER	111SF4640	10/1/2019	1.88	ND	98.92	ND	---
SF EEL RIVER	111SF4640	10/1/2019	4.29	ND	133.80	ND	---
SF EEL RIVER	111SF4640	10/3/2019	1.81	ND	118.88	ND	---
SF EEL RIVER	111SF4640	10/3/2019	1.99	ND	96.74	ND	---

River	Site Code	Date	ATX (ug/L)	CYL (ug/L)	MCY/NOD (ug/L)	NOD (ug/L)	SXT (ug/L)
SF EEL RIVER	111SF4640	10/3/2019	2.55	ND	106.30	ND	---
SF EEL RIVER	111SF4640	10/3/2019	6.13	ND	68.91	ND	---
SF EEL RIVER	111SF4640	10/3/2019	6.65	ND	76.71	ND	---
SF EEL RIVER	111SF4640	10/3/2019	8.45	ND	136.06	ND	---
SF EEL RIVER	111SF4640	10/5/2019	1.82	ND	49.29	ND	---
SF EEL RIVER	111SF4640	10/5/2019	2.66	ND	149.39	ND	---
SF EEL RIVER	111SF4640	10/5/2019	4.14	ND	90.37	ND	---
SF EEL RIVER	111SF4640	10/5/2019	5.28	ND	ND	ND	---
SF EEL RIVER	111SF4640	10/5/2019	8.99	ND	103.62	ND	---
SF EEL RIVER	111SF4640	10/5/2019	9.68	ND	119.46	ND	---
SF EEL RIVER	111SF4640	10/7/2019	1.68	ND	120.22	ND	---
SF EEL RIVER	111SF4640	10/7/2019	1.71	ND	101.61	ND	---
SF EEL RIVER	111SF4640	10/7/2019	1.73	ND	98.09	ND	---
SF EEL RIVER	111SF4640	10/7/2019	2.47	ND	95.23	ND	---
SF EEL RIVER	111SF4640	10/7/2019	5.12	ND	ND	ND	---
SF EEL RIVER	111SF4640	10/7/2019	5.70	ND	55.58	ND	---
SF EEL RIVER	111SF4640	10/7/2019	6.83	ND	ND	ND	---
SF EEL RIVER	111SF4640	10/7/2019	8.77	ND	79.98	ND	---
SF EEL RIVER	111SF4640	10/9/2019	3.69	ND	52.14	ND	---
SF EEL RIVER	111SF4640	10/9/2019	7.31	ND	ND	ND	---
SF EEL RIVER	111SF4640	10/11/2019	ND	ND	54.16	ND	---
SF EEL RIVER	111SF4640	10/11/2019	ND	ND	ND	ND	---
SF EEL RIVER	111SF4640	10/11/2019	1.43	ND	78.97	ND	---
SF EEL RIVER	111SF4640	10/11/2019	1.68	ND	128.94	ND	---
SF EEL RIVER	111SF4640	10/11/2019	2.23	ND	93.73	ND	---
SF EEL RIVER	111SF4640	10/11/2019	2.25	ND	59.02	ND	---
SF EEL RIVER	111SF4640	10/11/2019	2.46	ND	61.20	ND	---
SF EEL RIVER	111SF4640	10/11/2019	2.66	ND	79.14	ND	---
SF EEL RIVER	111SF4640	10/11/2019	3.91	ND	ND	ND	---

River	Site Code	Date	ATX (ug/L)	CYL (ug/L)	MCY/NOD (ug/L)	NOD (ug/L)	SXT (ug/L)
SF EEL RIVER	111SF4640	10/11/2019	4.13	ND	82.66	ND	---
SF EEL RIVER	111SF4640	10/11/2019	4.35	ND	ND	ND	---
SF EEL RIVER	111SF4640	10/11/2019	5.29	ND	138.33	ND	---
SF EEL RIVER	111SF4640	10/11/2019	6.48	ND	82.74	ND	---
SF EEL RIVER	111SF4640	10/11/2019	6.77	ND	92.05	ND	---
SF EEL RIVER	111SF4640	10/11/2019	6.80	ND	76.29	ND	---
SF EEL RIVER	111SF4640	10/11/2019	8.01	ND	119.97	ND	---
SF EEL RIVER	111SF4640	10/11/2019	8.17	ND	ND	ND	---
SF EEL RIVER	111SF4640	10/11/2019	8.75	ND	136.06	ND	---
SF EEL RIVER	111SF4640	10/11/2019	8.94	ND	193.40	ND	---
SF EEL RIVER	111SF4640	10/11/2019	11.54	ND	114.43	ND	---
SF EEL RIVER	111SF4640	10/11/2019	6.23	ND	42.70	---	ND
SF EEL RIVER	111SF4640	10/11/2019	6.53	0.55	42.90	---	ND
SF EEL RIVER	111SF6856	7/12/2016	ND	ND	581.15	450.75	ND
SF EEL RIVER	111SF6856	8/1/2016	ND	ND	139.25	111.51	ND
SF EEL RIVER	111SF6856	8/15/2016	ND	ND	172.21	156.01	ND
SF EEL RIVER	111SF6856	8/29/2016	ND	ND	30.87	15.27	ND
SF EEL RIVER	111SF6856	9/11/2016	ND	ND	103.78	89.49	ND
SF EEL RIVER	111SF6856	10/2/2016	ND	ND	2.66	2.66	ND
SF EEL RIVER	111SF6856	6/14/2017	7.20	ND	1,247.00	---	ND
SF EEL RIVER	111SF6856	6/27/2017	ND	0.83	3,465.00	---	ND
SF EEL RIVER	111SF6856	6/12/2018	ND	ND	1,272.95	1,116.05	ND
SF EEL RIVER	111SF6856	6/12/2018	ND	ND	777.48	680.98	ND
SF EEL RIVER	111SF6856	7/19/2018	ND	ND	1,000.00	199.40	ND
SF EEL RIVER	111SF6856	8/15/2018	ND	ND	61.08	61.08	---
SF EEL RIVER	111SF6856	9/12/2018	80.76	ND	13.66	13.66	---
SF EEL RIVER	111SF6856	9/18/2018	49.29	ND	9.38	9.38	---
SF EEL RIVER	111SF6856	10/4/2018	4.67	ND	339.70	---	ND
SF EEL RIVER	111SF6856	6/7/2019	ND	---	134.42	ND	ND

River	Site Code	Date	ATX (ug/L)	CYL (ug/L)	MCY/NOD (ug/L)	NOD (ug/L)	SXT (ug/L)
SF EEL RIVER	111SF6856	6/21/2019	ND	---	1,137.50	987.04	ND
SF EEL RIVER	111SF6856	7/18/2019	ND	4.33	1,513.00	73.07	ND
SF EEL RIVER	111SF6856	8/2/2019	ND	ND	316.00	4.53	ND
SF EEL RIVER	111SF6856	8/16/2019	17.63	ND	163.58	3.18	ND
SF EEL RIVER	111SF6856	8/27/2019	ND	ND	75.33	39.13	---
SF EEL RIVER	111SF6856	8/28/2019	4.47	ND	372.58	109.11	---
SF EEL RIVER	111SF6856	8/28/2019	ND	ND	105.08	59.65	---
SF EEL RIVER	111SF6856	8/29/2019	5.27	ND	304.58	103.99	---
SF EEL RIVER	111SF6856	8/29/2019	5.82	ND	87.25	67.81	---
SF EEL RIVER	111SF6856	8/30/2019	8.59	ND	223.08	97.43	---
SF EEL RIVER	111SF6856	8/30/2019	4.83	ND	195.67	94.51	---
SF EEL RIVER	111SF6856	8/30/2019	4.24	ND	81.42	52.57	---
SF EEL RIVER	111SF6856	9/11/2019	34.06	ND	325.50	ND	ND
SF EEL RIVER	111SF6856	9/17/2019	7.08	0.79	227.60	---	ND
SF EEL RIVER	111SF6856	9/27/2019	3.46	---	86.50	---	---
RUSSIAN RIVER	114RR1159	8/1/2016	ND	ND	16.19	16.19	ND
RUSSIAN RIVER	114RR1159	8/15/2016	ND	ND	13.87	9.87	ND
RUSSIAN RIVER	114RR1159	8/29/2016	ND	ND	1.32	1.32	ND
RUSSIAN RIVER	114RR1159	9/11/2016	ND	ND	16.78	11.31	ND
RUSSIAN RIVER	114RR1159	9/30/2016	ND	ND	ND	ND	ND
RUSSIAN RIVER	114RR1644	8/29/2016	ND	ND	0.90	0.90	ND
RUSSIAN RIVER	114RR1644	9/11/2016	ND	ND	6.01	6.01	ND
RUSSIAN RIVER	114RR1644	10/2/2016	ND	ND	3.46	ND	ND
RUSSIAN RIVER	114RR1644	6/24/2019	ND	ND	ND	ND	ND
RUSSIAN RIVER	114RR2079	6/15/2017	6.60	0.95	13.10	---	ND
RUSSIAN RIVER	114RR2079	6/28/2017	ND	1.23	103.00	---	ND
RUSSIAN RIVER	114RR2079	8/3/2017	3.91	0.67	105.80	---	0.15
RUSSIAN RIVER	114RR2655	6/27/2016	ND	ND	62.50	47.40	ND
RUSSIAN RIVER	114RR2655	7/12/2016	ND	ND	14.19	14.19	ND

River	Site Code	Date	ATX (ug/L)	CYL (ug/L)	MCY/NOD (ug/L)	NOD (ug/L)	SXT (ug/L)
RUSSIAN RIVER	114RR2655	8/1/2016	ND	ND	17.01	17.01	ND
RUSSIAN RIVER	114RR2655	8/15/2016	ND	ND	10.64	10.64	ND
RUSSIAN RIVER	114RR2655	8/29/2016	ND	ND	1.64	1.64	ND
RUSSIAN RIVER	114RR2655	9/11/2016	ND	ND	12.36	8.89	ND
RUSSIAN RIVER	114RR2655	10/2/2016	ND	ND	ND	0.33	ND
RUSSIAN RIVER	114RR2678	6/15/2017	5.90	0.80	9.30	---	ND
RUSSIAN RIVER	114RR2678	8/3/2017	4.66	0.62	81.20	---	ND
RUSSIAN RIVER	114RR2678	6/27/2018	ND	ND	90.00	---	ND
RUSSIAN RIVER	114RR2678	7/17/2018	ND	ND	3.49	ND	ND
RUSSIAN RIVER	114RR2678	7/17/2018	ND	ND	36.00	ND	ND
RUSSIAN RIVER	114RR2678	8/2/2018	ND	ND	41.00	ND	ND
RUSSIAN RIVER	114RR2678	9/13/2018	1,716.97	ND	24.37	ND	---
RUSSIAN RIVER	114RR2678	9/19/2018	ND	ND	30.48	ND	---
RUSSIAN RIVER	114RR2678	9/19/2018	16.48	ND	18.46	ND	---
RUSSIAN RIVER	114RR2678	9/19/2018	35.63	ND	59.00	ND	---
RUSSIAN RIVER	114RR2678	9/19/2018	4.87	ND	31.50	---	ND
RUSSIAN RIVER	114RR2678	9/25/2018	2.38	ND	9.10	---	ND
RUSSIAN RIVER	114RR2678	6/27/2019	ND	ND	ND	ND	ND
RUSSIAN RIVER	114RR2678	7/11/2019	1.70	0.63	17.81	---	ND
RUSSIAN RIVER	114RR2678	8/1/2019	239.50	5.09	ND	ND	ND
RUSSIAN RIVER	114RR2678	9/11/2019	ND	ND	ND	ND	ND
RUSSIAN RIVER	114RR4234	6/27/2016	ND	ND	331.70	29.94	ND
RUSSIAN RIVER	114RR4234	7/12/2016	ND	ND	16.81	16.81	ND
RUSSIAN RIVER	114RR4234	8/1/2016	ND	ND	17.55	17.55	ND
RUSSIAN RIVER	114RR4234	8/15/2016	ND	ND	14.06	14.06	ND
RUSSIAN RIVER	114RR4234	8/29/2016	ND	ND	0.87	0.87	ND
RUSSIAN RIVER	114RR4234	9/11/2016	ND	ND	10.62	9.13	ND
RUSSIAN RIVER	114RR4234	9/30/2016	ND	ND	ND	ND	ND
RUSSIAN RIVER	114RR4234	6/24/2019	ND	ND	ND	ND	ND

River	Site Code	Date	ATX (ug/L)	CYL (ug/L)	MCY/NOD (ug/L)	NOD (ug/L)	SXT (ug/L)
RUSSIAN RIVER	114RR5407	8/15/2016	ND	ND	5.19	5.19	ND
RUSSIAN RIVER	114RR5407	8/29/2016	ND	ND	0.42	0.42	ND
RUSSIAN RIVER	114RR5407	9/11/2016	ND	ND	ND	ND	ND
RUSSIAN RIVER	114RR5407	10/2/2016	ND	ND	5.06	ND	ND
RUSSIAN RIVER	114RR5407	6/15/2017	7.20	0.75	5.30	---	ND
RUSSIAN RIVER	114RR5407	6/27/2017	ND	0.88	97.80	---	ND
RUSSIAN RIVER	114RR5407	7/18/2017	7.08	0.81	86.00	---	ND
RUSSIAN RIVER	114RR5407	8/3/2017	5.71	0.80	67.50	---	ND
RUSSIAN RIVER	114RR5407	7/17/2018	ND	ND	271.33	ND	ND
RUSSIAN RIVER	114RR5407	7/31/2018	ND	ND	400.67	ND	ND
RUSSIAN RIVER	114RR5407	8/2/2018	ND	ND	43.67	ND	ND
RUSSIAN RIVER	114RR5407	9/19/2018	ND	ND	38.39	ND	---
RUSSIAN RIVER	114RR5407	9/19/2018	ND	ND	49.72	ND	---
RUSSIAN RIVER	114RR5407	9/19/2018	4.51	ND	18.20	---	ND
RUSSIAN RIVER	114RR5407	9/25/2018	1.66	ND	3.45	---	ND
RUSSIAN RIVER	114RR5407	9/25/2018	2.41	ND	8.20	---	ND
RUSSIAN RIVER	114RR5407	6/13/2019	ND	---	ND	ND	1.75
RUSSIAN RIVER	114RR5407	6/18/2019	ND	---	ND	ND	ND
RUSSIAN RIVER	114RR5407	6/18/2019	ND	---	ND	ND	ND
RUSSIAN RIVER	114RR5407	6/27/2019	ND	ND	ND	ND	ND
RUSSIAN RIVER	114RR5407	7/11/2019	25.53	ND	ND	ND	ND
RUSSIAN RIVER	114RR5407	7/11/2019	33.50	ND	ND	ND	ND
RUSSIAN RIVER	114RR5407	7/11/2019	35.08	ND	ND	ND	ND
RUSSIAN RIVER	114RR5407	7/11/2019	ND	ND	8.99	---	ND
RUSSIAN RIVER	114RR5407	7/24/2019	1.48	46.25	ND	ND	ND
RUSSIAN RIVER	114RR5407	8/1/2019	255.33	28.09	ND	ND	ND
RUSSIAN RIVER	114RR5407	8/19/2019	11.88	62.34	52.17	8.61	ND
RUSSIAN RIVER	114RR5407	9/11/2019	ND	ND	ND	ND	ND
RUSSIAN RIVER	114RR5407	9/19/2019	5.47	---	24.57	---	---

River	Site Code	Date	ATX (ug/L)	CYL (ug/L)	MCY/NOD (ug/L)	NOD (ug/L)	SXT (ug/L)
RUSSIAN RIVER	114RR5407	10/1/2019	ND	ND	39.23	25.30	---
RUSSIAN RIVER	114RR5407	10/1/2019	ND	ND	ND	13.30	---
RUSSIAN RIVER	114RR5407	10/3/2019	4.13	ND	ND	55.54	---
RUSSIAN RIVER	114RR5407	10/3/2019	5.29	ND	75.20	52.95	---
RUSSIAN RIVER	114RR5407	10/3/2019	7.22	ND	45.27	35.52	---
RUSSIAN RIVER	114RR5407	10/3/2019	5.31	ND	ND	34.34	---
RUSSIAN RIVER	114RR5407	10/3/2019	4.84	ND	50.47	28.44	---
RUSSIAN RIVER	114RR5407	10/3/2019	4.08	ND	45.44	27.69	---
RUSSIAN RIVER	114RR5407	10/5/2019	5.81	ND	320.41	95.85	---
RUSSIAN RIVER	114RR5407	10/5/2019	3.31	ND	101.94	63.28	---
RUSSIAN RIVER	114RR5407	10/5/2019	4.07	ND	71.43	51.78	---
RUSSIAN RIVER	114RR5407	10/5/2019	4.16	ND	92.05	49.10	---
RUSSIAN RIVER	114RR5407	10/5/2019	3.31	ND	64.05	46.10	---
RUSSIAN RIVER	114RR5407	10/5/2019	3.71	ND	81.74	39.37	---
RUSSIAN RIVER	114RR5407	10/7/2019	4.45	ND	321.67	96.11	---
RUSSIAN RIVER	114RR5407	10/7/2019	5.44	ND	95.23	59.00	---
RUSSIAN RIVER	114RR5407	10/7/2019	12.93	ND	77.21	56.82	---
RUSSIAN RIVER	114RR5407	10/7/2019	13.37	ND	63.55	42.50	---
RUSSIAN RIVER	114RR5407	10/7/2019	5.92	ND	52.14	38.44	---
RUSSIAN RIVER	114RR5407	10/7/2019	5.71	ND	ND	32.29	---
RUSSIAN RIVER	114RR5407	10/7/2019	7.24	ND	ND	26.94	---
RUSSIAN RIVER	114RR5407	10/7/2019	6.28	ND	ND	25.42	---
RUSSIAN RIVER	114RR5407	10/9/2019	ND	ND	ND	43.63	---
RUSSIAN RIVER	114RR5407	10/9/2019	2.89	ND	ND	34.59	---
RUSSIAN RIVER	114RR5407	10/11/2019	4.54	ND	100.60	120.67	---
RUSSIAN RIVER	114RR5407	10/11/2019	7.37	ND	ND	88.66	---
RUSSIAN RIVER	114RR5407	10/11/2019	7.74	ND	192.40	80.31	---
RUSSIAN RIVER	114RR5407	10/11/2019	3.21	ND	63.63	63.16	---
RUSSIAN RIVER	114RR5407	10/11/2019	ND	ND	115.69	57.39	---

River	Site Code	Date	ATX (ug/L)	CYL (ug/L)	MCY/NOD (ug/L)	NOD (ug/L)	SXT (ug/L)
RUSSIAN RIVER	114RR5407	10/11/2019	8.49	ND	115.19	53.37	---
RUSSIAN RIVER	114RR5407	10/11/2019	13.35	ND	38.06	49.85	---
RUSSIAN RIVER	114RR5407	10/11/2019	6.71	ND	72.43	48.18	---
RUSSIAN RIVER	114RR5407	10/11/2019	4.36	ND	102.36	47.65	---
RUSSIAN RIVER	114RR5407	10/11/2019	25.19	ND	89.37	45.72	---
RUSSIAN RIVER	114RR5407	10/11/2019	7.14	ND	83.16	44.90	---
RUSSIAN RIVER	114RR5407	10/11/2019	2.09	ND	ND	40.98	---
RUSSIAN RIVER	114RR5407	10/11/2019	13.49	ND	59.19	38.97	---
RUSSIAN RIVER	114RR5407	10/11/2019	ND	ND	ND	33.07	---
RUSSIAN RIVER	114RR5407	10/11/2019	8.47	ND	144.61	32.34	---
RUSSIAN RIVER	114RR5407	10/11/2019	3.41	ND	ND	30.41	---
RUSSIAN RIVER	114RR5407	10/11/2019	8.70	ND	73.94	30.33	---
RUSSIAN RIVER	114RR5407	10/11/2019	10.95	ND	37.89	26.06	---
RUSSIAN RIVER	114RR5407	10/11/2019	3.79	ND	ND	24.83	---
RUSSIAN RIVER	114RR5407	10/11/2019	4.83	ND	ND	ND	---
RUSSIAN RIVER	114RR7396	6/27/2016	ND	ND	ND	ND	ND
RUSSIAN RIVER	114RR7396	7/12/2016	ND	ND	ND	ND	ND
RUSSIAN RIVER	114RR7396	8/1/2016	ND	ND	ND	ND	ND
RUSSIAN RIVER	114RR7396	8/15/2016	ND	ND	ND	ND	ND
RUSSIAN RIVER	114RR7396	8/29/2016	ND	ND	ND	ND	ND
RUSSIAN RIVER	114RR7396	9/11/2016	ND	ND	ND	ND	ND
RUSSIAN RIVER	114RR7396	9/30/2016	ND	ND	ND	ND	ND
RUSSIAN RIVER	114RR7396	6/15/2017	6.30	0.73	4.70	---	ND
RUSSIAN RIVER	114RR7396	6/27/2017	5.96	1.11	50.30	---	ND
RUSSIAN RIVER	114RR7396	8/3/2017	4.36	0.70	16.90	---	ND
RUSSIAN RIVER	114RR7396	6/12/2018	ND	ND	6.02	4.57	ND
RUSSIAN RIVER	114RR7396	8/2/2018	ND	ND	54.17	ND	ND
RUSSIAN RIVER	114RR7396	8/15/2018	ND	ND	ND	ND	---
RUSSIAN RIVER	114RR7396	9/13/2018	20.70	ND	34.47	ND	---

River	Site Code	Date	ATX (ug/L)	CYL (ug/L)	MCY/NOD (ug/L)	NOD (ug/L)	SXT (ug/L)
RUSSIAN RIVER	114RR7396	9/25/2018	3.57	ND	8.45	---	ND
RUSSIAN RIVER	114RR7396	6/27/2019	ND	ND	ND	ND	ND
RUSSIAN RIVER	114RR7396	8/1/2019	166.67	ND	45.25	1.31	ND
RUSSIAN RIVER	114RR7396	9/11/2019	ND	ND	ND	ND	1.75