Water Quality Monitoring by the Hoopa Tribal Environmental Protection Agency 2008–2012

PREPARED BY THE

HOOPA VALLEY TRIBAL ENVIRONMENTAL PROTECTION AGENCY

IN COOPERATION WITH

KIER ASSOCIATES

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EXECUTIVE SUMMARY

This report presents the results of the Hoopa Tribal Environmental Protection Agency's (Hoopa TEPA) water quality monitoring within the Hoopa Valley Indian Reservation for the years 2008 to 2012. Hoopa TEPA is a member of the Klamath Basin Tribal Water Quality Work Group (Work Group) and has worked to develop and implement shared water quality monitoring protocols with the Yurok Tribe and the Karuk Tribe who also conduct monitoring in the Trinity and Lower Klamath basins.

Samples were collected by Hoopa TEPA staff at two stations: the Klamath River at Saints Rest Bar and the Trinity River at Hoopa. The beginning and end of the sampling season varied by year, with samples collected from mid or late May through early or mid-October. Sampling frequency was generally monthly in 2008 and bi-weekly (every two weeks) in 2009-2012. Water samples were collected and analyzed for nutrients, chlorophyll-*a*, algal toxins, phytoplankton species (i.e., free-floating algae), and other chemical parameters. Periphyton samples (i.e., algae attached the riverbed) were collected by scraping a fixed area from river cobbles and then analyzed for chlorophyll-*a* and algal species. The laboratory analyses of the water and periphyton samples were performed using funds awarded to the Klamath Basin Tribal Water Quality Work Group by the U.S. EPA Region 9.

In the report, sampling results are compared with the water quality standards from the Hoopa Tribe's *Water Quality Control Plan*. Concentrations of most nitrogen, phosphorus, and carbon parameters were almost always higher at the Klamath River site than the Trinity River site. Exceedances of the Tribe's nutrient criteria of 0.035 mg/L total phosphorus (TP) and 0.2 mg/L total nitrogen (TN) were common at the Klamath River site (67% and 60%, respectively) but rare at the Trinity River site (4% and 2%, respectively).

On nearly every sampling date, phytoplankton biovolume and chlorophyll-*a* were higher at the Klamath River site than the Trinity River site. In August through October, the toxic blue-green algal species *Microcystis aeruginosa* was frequently detected in water samples at Klamath River site and exceeded the Tribe's criteria on one occasion: 79,676 cells/mL on September 5, 2012. Microcystin, a liver toxin produced by *Microcystis aeruginosa*, was detected in most August through October Klamath River samples and exceeded the Tribe's criteria once (19 μg/L on September 5, 2012); however, analyses for microcystin did not begin until partway through the 2010 season, so exceedances may have occurred during un-sampled portions of the 2008–2012 period. *Microcystis aeruginosa* and microcystin toxin were not detected at the Trinity River site. The Tribe also has a criteria of 100,000 cells/mL for total potentially toxigenic blue-green algal species (not just *Microcystis*), which was not exceeded in any sample. Diatoms dominated the phytoplankton communities at both sites and the species with the highest average biovolumes were the diatoms *Epithemia sorex*, *Rhopalodia gibba*, *Cocconeis placentula, Synedra ulna*, *Diatoma tenue*, *Cymbella affinis*, and *Diatoma vulgare*. The only blue-green algal species in the top 20 phytoplankton species were *Aphanizomenon flos-aquae* and *Microcystis aeruginosa*.

The Tribe's criteria for periphyton chlorophyll-*a* (a measure of biomass) was exceeded at the Klamath River site once in 2011 and three times in 2012, an overall percent exceedance of 12% in the five-year study period, but was not exceeded at the Trinity River site. There was substantial overlap between the top 20 periphyton species and the top 20 phytoplankton species, indicating that many of the species in the phytoplankton samples are dislodged periphyton.

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1 INTRODUCTION

1.1 ENVIRONMENTAL AND CULTURAL SETTING OF THE HOOPA VALLEY INDIAN RESERVATION

Hoopa Valley Indian Reservation is located in northwestern California, approximately 300 miles north of San Francisco (Figure 1). The reservation is the home of the Hupa People, who have lived there since time immemorial, and was created by Executive Order by president Ulysses S. Grant in 1876. It is a square approximately 12 miles in length with an area of 93,702 acres (approximately 144 square miles). It is the largest reservation in California and encompasses approximately 50% of the Hupa aboriginal territory (Hoopa TEPA 2008).

In the center of the reservation at approximately 320 feet above sea level is the Hoopa Valley, a 3/4 mile wide by six-mile long alluvial plain bisected by the Trinity River, where the majority of the reservation's human population lives. The remainder of the reservation is steep and mountainous, with elevations on the eastern edge of the reservation reaching over 5,000 feet above sea level. The reservation is located within the Klamath River Basin, primarily within the Trinity River sub-basin (the Klamath River's largest tributary). Some streams (Pine Creek on the western edge of the reservation and Hopkins Creek on the northeastern edge of the reservation) drain directly to the Klamath River. Tributaries to the Trinity River within the reservation include: Mill Creek, Hostler Creek, Tish-Tang Creek, Campbell Creek, Supply Creek, and Soctish Creek (Hoopa TEPA 2008) (Figure 1). The reservation intersects the mainstem Klamath River approximately 45 river miles upstream of the Pacific Ocean, or approximately 1.5 miles upstream of the confluence of the Klamath and Trinity rivers. The salmon runs in the Trinity River and its tributaries provide a fishery that is culturally and economically important to the Hupa People. There are also large populations of salmon on the mainstem Klamath River which support harvest by the Yurok Tribe and Karuk Tribe as well as recreational fisherman.

Mean annual precipitation at the Hoopa weather station is approximately 58 inches, three-quarters of which occurs from November through March, and is primarily rain with some snow in the highest elevations. Summers are dry with an average temperature of 71°F while average winter temperate is 45°F. Douglas-fir forest covers much of the reservation and the timber industry is major component of the economy within the reservation (Hoopa TEPA 2008).

1.2 WATER QUALITY IN THE KLAMATH AND TRINITY RIVERS

The Klamath River and some of its tributaries, including the Trinity River, are designated as impaired water bodies on the Clean Water Act (CWA) Section 303(d) list (NCRWQCB 2010, ODEQ 2010, and SWRCB 2010). The list of mainstem Klamath River and mainstem Trinity River impairments varies by state and reaches within states:

- pH (Klamath River mainstem reservoirs in Oregon)
- Water temperature (entire mainstem Klamath River except uppermost reach in Oregon)
- Nutrients (California portion of mainstem Klamath River)
- Organic enrichment/low dissolved oxygen (DO) (entire mainstem Klamath River)
- Sedimentation/siltation (mainstem Klamath River from Seiad Valley to Klamath River mouth, and Trinity River mainstem from Lewiston Dam to Trinity River mouth)
- Ammonia toxicity (uppermost reach of mainstem Klamath River in Oregon)
- Microcystin (mainstem Klamath River from Copco Reservoir to Trinity River confluence)

- Chlorophyll-*a* (uppermost reach of mainstem Klamath River in Oregon)
- Mercury (Trinity Lake)

Total Maximum Daily Loads (TMDLs) have been developed for the mainstem Klamath River by the U.S. Environmental Protection Agency (EPA), Oregon Department of Environmental Quality (ODEQ 2010) and the North Coast Regional Water Quality Control Board (NCRWQCB 2010), for the mainstem Trinity River (U.S. EPA 2001), and for additional tributaries not mentioned here.

Water quality is a concern in the Klamath River because it affects salmon fisheries as well as public health. During the warm summer months, dissolved oxygen and pH follow a 24-hour cycle in which photosynthesis by aquatic plants and algae attached to the streambed (periphyton) elevates pH and dissolved oxygen concentrations during the day. Respiration at night by those same organisms has the reverse effect, depressing dissolved oxygen and pH (Nimick et al. 2011). The resulting low nighttime DO and high daytime pH can exceed water quality standards and be stressful to fish (NCRWQCB 2010).

1.3 WATER QUALITY AUTHORITY OF THE HOOPA VALLEY TRIBE

The following excerpts from the 2008 water quality plan (Hoopa TEPA 2008) describe the tribe's jurisdiction over reservation waters:
"The Hoopa Valley Tribe is a self-governing tribe, which possesses and exercises full control over resources within the exterior boundaries of the Reservation through the actions of various Tribal departments, including legislative and executive branches, as well as through the Tribal Court system." ... "As a sovereign power recognized by the Federal Government, as a co-manager of natural resources, and by the U.S. Environmental Protection Agency for purposes of Water Pollution Control, the Hoopa Valley Tribe maintains jurisdiction over waters that flow into and through the Reservation, regardless of the geographic origins of water sources" … "The Hoopa Valley Tribe applied for treatment as a state with respect to the Water Pollution Control Program under Section 106 of the Clean Water Act (CWA) on July 16, 1989. The United States Environmental Protection Agency (EPA) announced formal approval of the application on July 3, 1990. Upon receiving approval, the Hoopa Valley Tribe became the first tribe in the State of California to receive such approval and qualify for grant funds under the CWA."

1.4 HOOPA TRIBAL ENVIRONMENTAL PROTECTION AGENCY AND THE HOOPA VALLEY INDIAN RESERVATION WATER QUALITY CONTROL PLAN

The Hoopa Tribal Environmental Protection Agency (Hoopa TEPA) develops, monitors, and enforces the tribe's environmental protection program. It was formed in 1981 and performs a variety of services, including environmental protection, public outreach and education, air quality monitoring, water quality planning, solid waste management, hazardous waste protection, and environmental compliance[1]. The Hoopa TEPA developed the *Hoopa Valley Indian Reservation Water Quality Control Plan*, which was approved by the Hoopa Valley Tribal Council and the U.S. EPA in 2002. The *Water Quality Control Plan* includes water quality criteria, standards, anti-degradation policy, and implementation plans for the protection of the quality of surface and ground waters within the reservation. The plan is periodically updated, most recently in 2008 (Hoopa TEPA 2008).

[1] http://www.hoopa-nsn.gov/departments/natural-resources/tribal-environmental-protection-agency-tepa

1.5 HOOPA TEPA'S 2008–2012 WATER QUALITY MONITORING PROGRAM

The Hoopa TEPA monitors water quality within the Hoopa Valley Indian Reservation. Hoopa TEPA is a member of the Klamath Basin Tribal Water Quality Work Group (Work Group), which formed in 2003 and is composed of leaders of five Tribal water quality or environmental departments in the California portion of the Klamath Basin: Hoopa Valley Tribe, Yurok Tribe, Karuk Tribe, Quartz Valley Indian Community, and Resighini Rancheria. The Work Group's activities are supported by annual funding awards from the U.S. EPA. The Work Group collaborates on water quality monitoring as well as participating in basin-scale water quality issues such as Klamath Hydroelectric Project (KHP) and Clean Water Act implementation. Work Group members cooperate in developing common protocols for water quality monitoring.

Beginning in 2008 and continuing through the present, Hoopa TEPA has been collaborating with the Work Group to collect water quality samples in the lower Klamath River and lower Trinity River. This report presents the 2008–2012 results of that monitoring.

2 METHODS

2.1 LOCATIONS AND METHODS FOR WATER SAMPLE COLLECTION

All samples were collected by Hoopa TEPA staff. Water samples were collected at two stations: the Klamath River at Saints Rest Bar (approximately 1.5 miles upstream from the confluence of the Klamath and Trinity rivers) and the Trinity River at Hoopa (approximately 12.4 miles upstream from the confluence of the Klamath and Trinity rivers) (Figure 1, Table 1). The sampling season was designed to encompass the portion of the year when the potential for impaired water quality exists. The beginning and end of the sampling season varied by year, with samples collected from mid or late May through early or mid-October. Sampling frequency was generally monthly in 2008 and bi-weekly (every two weeks) in 2009-2012 (Figure 2). Analysis for phytoplankton species and microcystin toxin did not occur in 2008.

Table 1. Station information for Hoopa TEPA water quality sampling locations.

Station Description	Station Code	River Mile (distance from Pacific Ocean)	Latitude	Longitude	Elevation (ft)
Klamath River at Saints Rest Bat	KR	Klamath 44.9	41.187520	-123.678001	221
Trinity River at Hoopa	TRH	Klamath 43.4 + Trinity 12.4	41.049852	-123.673668	280

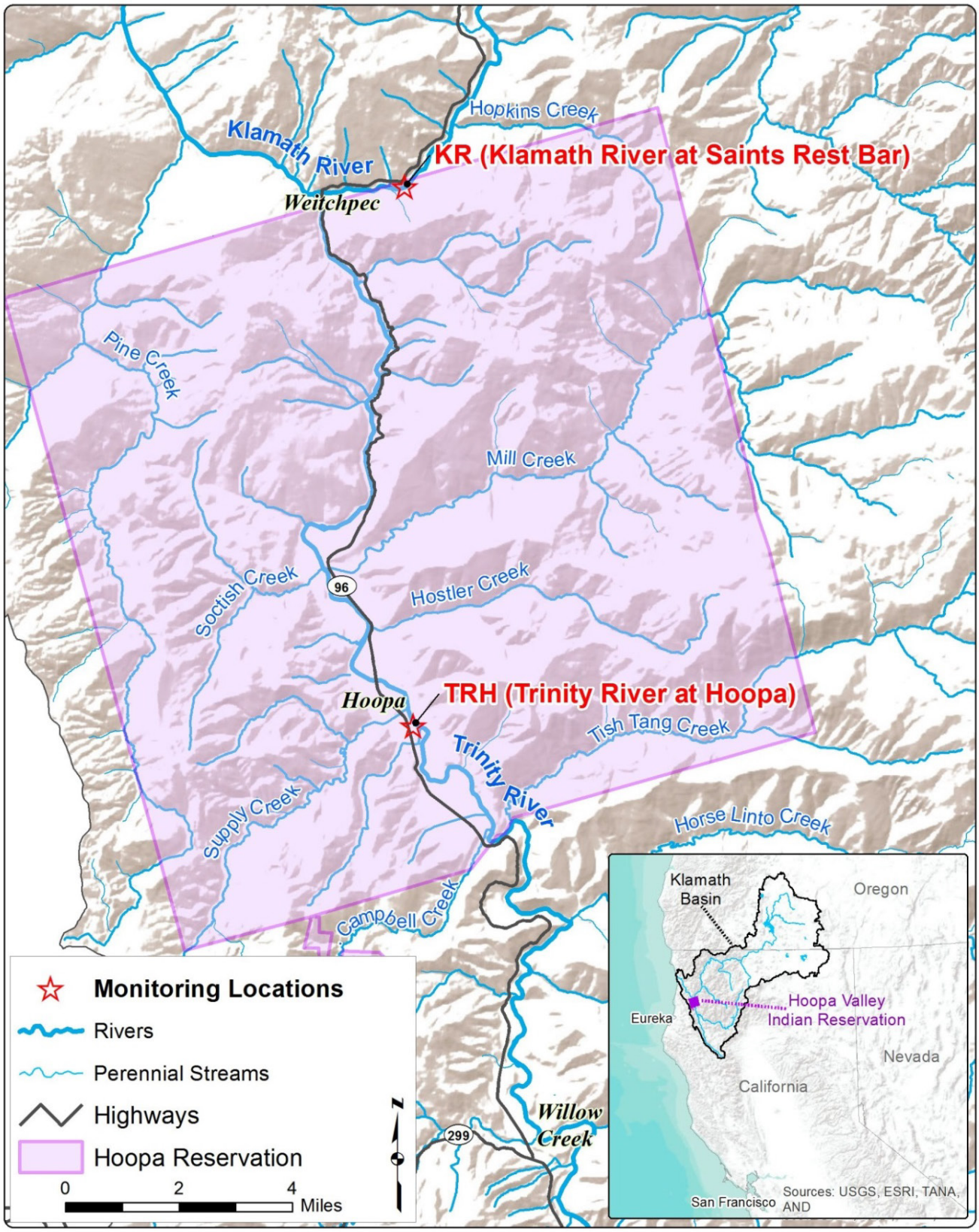

Figure 1. Location of Hoopa TEPA's water quality monitoring stations in the lower Klamath and Trinity rivers.

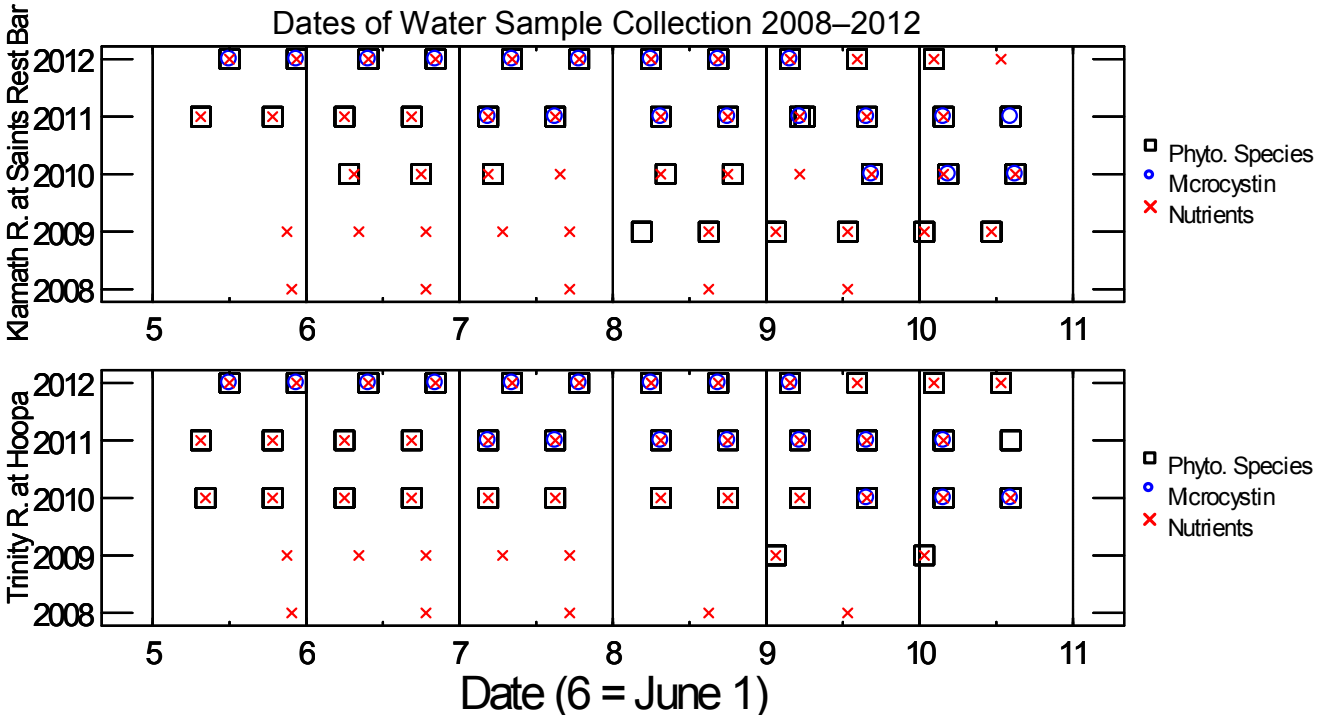

Figure 2. Dates when samples were collected at the Klamath River at Saints Rest Bar (top panel) and Trinity River at Hoopa (bottom panel).

Details of the standard operating procedures, analytical methods, and detection limits are described in detail in the Yurok Tribe (2008) *Sampling and Analysis Plan* and the Karuk Tribe (2011) *Quality Assurance Project Plan*, but are summarized briefly here. The following excerpt from the Yurok Tribe's 2011 nutrient summary report (Sinnott 2012) summarizes the sample collection protocol for water samples:

> "Upon arrival at each site, a sampling churn was rinsed three times with distilled water. After rinsing with distilled water, the churn was rinsed three times with stream water. The churn was then fully submerged into the stream and filled to the lid with sample water. Completely filling the churn allowed for all samples to be filled from one churn; thereby minimizing differences in water properties and quality between samples.
>
> Proper use of the churn guaranteed the water was well mixed before the sample was collected. The churn was stirred at a uniform rate by raising or lowering the splitter at approximately 9 inches per second. Ten complete cycles of stirring were completed before sample bottles were filled. This mixing continued while the bottles were being filled. If filling had stopped for some reason, the stirring rate was resumed before the next sample was drawn from the churn.
>
> The sample bottles used were provided by the contract lab and were considered sterile prior to field usage. Sample bottles were rinsed with stream water from the churn three times before filling with sample water."

Each sampling date included collection of a set of "blind duplicate" quality assurance samples. Quality Assurance (QA) sampling was performed by splitting samples in the field using a churn splitter. One of the pair of split samples was disguised and sent with its associated split for analysis. Because Hoopa TEPA uses a shares the same protocol and laboratories as the Karuk and Yurok Tribe, QA samples are coordinated so that only of the three entities collects QA samples per sampling date.

2.2 METHODS FOR PERIPHYTON SAMPLE COLLECTION

Periphyton samples were collected at the same stations as the water samples (Figure 1, Table 2). Sampling frequency was generally bi-weekly except in 2008 at both sites when only a few samples were collected and in 2009 at the Trinity River when only two samples were collected. The duration of the sampling season increased between 2008 and 2012 (Figure 3).

Hoopa TEPA periphyton sampling protocol is adapted from techniques recommended by U.S. EPA (Peck et al. 2006) and U.S. Geological Survey (Porter et al. 1995) and similar to those previously applied on the Klamath River by Eilers (2005), the Karuk Tribe, and the Yurok Tribe. The protocol is briefly summarized here. Details are included in the Yurok Tribe Environmental Program (2008) *Sampling and Analysis Plan*, the Karuk Tribe (2011) *Quality Assurance Project Plan*, or the *2011 Klamath River Periphyton Pilot Study Summary Report* (Yurok Tribe et al. 2013).

The sampling locations meet the following criteria: depth of 1 to 2 feet, velocity of 1 to 2 feet per second, and with clear solar path (i.e., no major topographic or riparian shading). Sampling location selection is not random, but rather is the area most representative of river cross-section (i.e., not the very-near shore assemblage and not the deep water assemblage, which are less extensive). Five representative cobbles are selected from the stream bed at each sampling location, avoiding the extremes of algal cover. Selected cobbles are placed in a tub with water and transported to a convenient sample-processing area. For each cobble, a 1 inch by 3 inch microscope slide is held against the cobble so that the remainder of the cobble can be scrubbed off with a brush. Then the slide is removed (Figure 4) and the periphyton is scraped into a sample jar using a razor blade. Two samples (one for algal speciation and one for chlorophyll), each composed of five cobbles, are collected at each sampling location. Algal speciation samples are preserved in Lugol's Iodine.

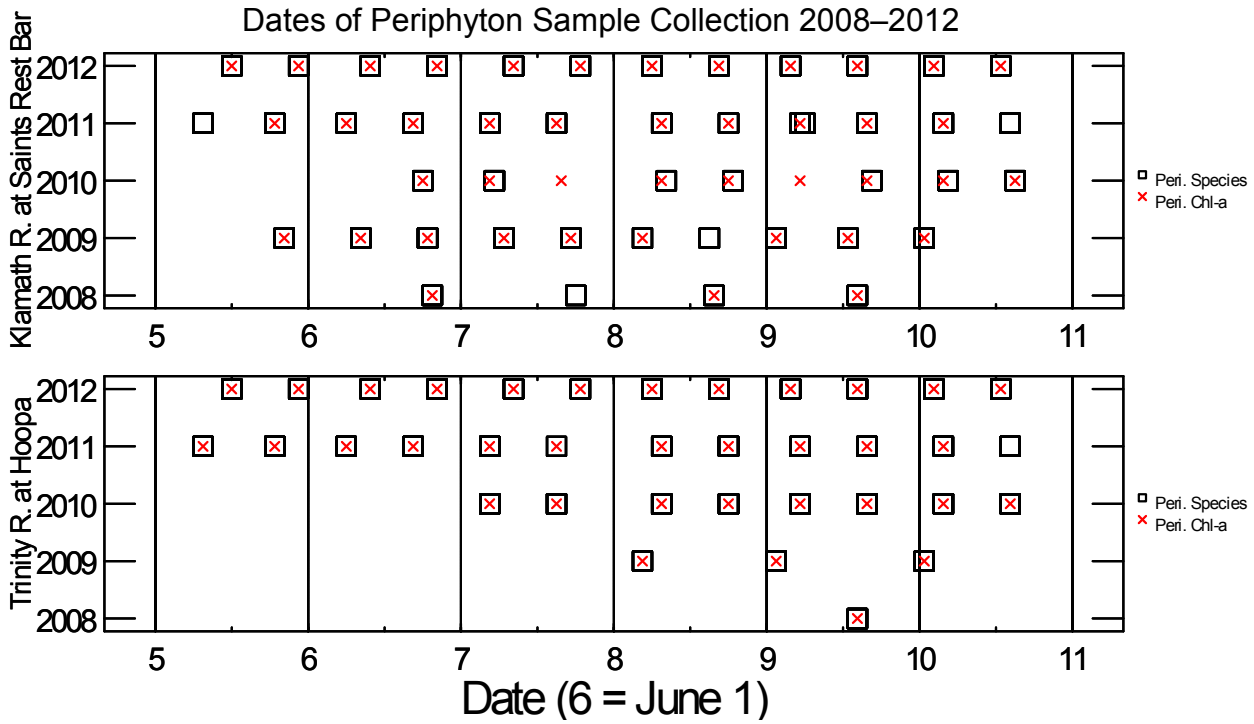

Figure 3. Dates when samples were collected at the Klamath River at Saints Rest Bar (top panel) and Trinity River at Hoopa (bottom panel).

Figure 4. Cobble with periphyton removed from everywhere except the 1-inch x 3-inch sampling area. Photo from the Yurok Tribe Environmental Program.

2.3 PARAMETERS, ANALYTICAL METHODS, AND LABORATORIES

2.3.1 Microcystin toxin

Samples for microcystin toxin were collected in glass vials, which were then frozen and subsequently placed in a cooler with gel-ice and shipped overnight to the USEPA Region 9 Laboratory in Richmond, CA for analysis of microcystin toxin using ELISA methodology. See Fetcho (2007) for a comprehensive description of laboratory methods and detection limits.

2.3.2 Nutrients, chlorophyll, and other chemical water quality

Samples for nutrients, chlorophyll-*a*, and other chemical water quality were placed immediately in coolers with wet ice, transported to FedEx in Arcata, CA and then shipped overnight to Aquatic Research Incorporated in Seattle, Washington for analysis.

Parameters analyzed included ammonia (NH_3), nitrate-plus-nitrite (NO_3+NO_2), total nitrogen (TN), soluble reactive phosphorus (SRP), total phosphorus (TP), Total organic carbon (TOC), alkalinity, calcium, magnesium, total suspended solids (TSS), total dissolved solids (TDS), chlorophyll-*a* (CHLA), and phaeophytin (PHEO); laboratory reporting limits are shown in Table 2. Total inorganic nitrogen (TIN) was computed as NH_3 plus NO_3+NO_2, organic nitrogen (ORGN) was computed as TN minus NH_3 minus NO_3+NO_2, and particulate phosphorus (PP) was calculated as TP minus SRP. For graphical and analytic purposes, non-detect samples were set at 50% of the reporting limit.

2.3.3 Phytoplankton and periphyton identification, density, and biovolume

Samples for microscopic determination of phytoplankton and periphyton density and biovolume were preserved in Lugol's Iodine and sent to Aquatic Analysts in White Salmon, WA where enumeration and biovolume measurements are determined according to APHA Standard Methods (1992).

The concentration of chlorophyll-*a* in periphyton samples was analyzed by Aquatic Analysts in 2008–2009 and Aquatic Research Incorporated in 2010–2012.

Table 2. Laboratory reporting limits for water sample parameters.

Parameter	Reporting Limit
Ammonia	0.01 mg/L
Nitrate + Nitrite	0.01 mg/L
Total Nitrogen	0.05 mg/L
Soluble Reactive Phosphorous	0.001 mg/L
Total Phosphorus	0.002 mg/L
Total Organic Carbon	0.250 mg/L
Volatile Suspended Solids	0.50 mg/L
Total Suspended Solids	0.50 mg/L
Total Dissolved Solids	5.0 mg/L
Chlorophyll-*a*	0.1 ug/L
Phaeophytin-*a*	0.1 ug/L
Alkalinity	1.0 mg $CaCO_3$/L
Calcium	0.1 mg/L
Magnesium	0.1 mg/L
Microcystin	0.18 ug/L or 1.8 ug/L

2.4 COMPARISON TO THRESHOLD VALUES

In this report, monitoring data are compared against water quality criteria from the *Hoopa Valley Indian Reservation Water Quality Control Plan* (Hoopa TEPA 2008) (Table 3).

Table 3. Water quality criteria from Hoopa TEPA (2008).

Parameter	Criteria	Notes
Total Phosphorus (TP)	0.035 mg/L	30-day mean for May-October
Total Nitrogen (TN)	0.200 mg/L	30-day mean for May-October
Total microcystin toxin	8 μg/L	
Microcystis aeruginosa cell density	40,000 cells/mL	
Total potentially toxigenic blue-green algal species	100,000 cells/mL	
Periphyton chlorophyll-*a*	150 mg/m^2	

3 RESULTS AND DISCUSSION

Time series graphs of constituents from water samples are shown in Figure 5 through Figure 10 and results from periphyton sampling are shown in Figure 11. Table 4 provides a summary of the percent of samples exceeding Hoopa TEPA (2008) water quality criteria.

3.1 NUTRIENTS

Concentrations of most nitrogen, phosphorus, and carbon parameters were almost always higher at the Klamath River site than the Trinity River site. Exceptions included ammonia, where the vast majority of samples at both sites were non-detects for that parameter with only slightly more detects at the Klamath River site (Figure 6; bottom panel). In addition, nitrate+nitrite for May and June were similar between the sites, but the Klamath River site had higher concentrations for some of the other months (Figure 6 middle panel).

Total phosphorus, soluble reactive phosphorus, total organic carbon, and total nitrogen all showed a similar seasonal trajectory at the Klamath River site, increasing over the course of each sampling season. Accordingly, the number of samples exceeding the Hoopa Valley Tribe's water quality criteria for total phosphorus and total nitrogen generally increased over the course of each season (Figure 5; top panel and Figure 6 top panel). Seasonal patterns were less evident at the Trinity River site. Over the 5-year study period, exceedances of the Tribe's nutrient criteria for 0.035 mg/L total phosphorus (TP) and 0.2 mg/L total nitrogen (TN) were common at the Klamath River site (67% and 60%, respectively) but rare at the Trinity River site (4% and 2%, respectively) (Table 4).

3.2 OTHER CHEMICAL PARAMETERS

In contrast to nutrients, the concentrations of most other chemical parameters were similar at the Klamath River site and the Trinity River site (Figure 7 and Figure 8). One exception to that pattern was higher volatile suspended solids (a measure of particulate organic matter) at the Klamath River site; however, 2010 was the only year in which that parameter was analyzed (Figure 7 bottom panel). Another exception was higher total suspended solids (TSS) at the Trinity River site in May 2011 and higher TSS at the Klamath River site in the month of October for 2009 and 2011 (Figure 7 middle panel).

Table 4. Number and percentage of samples exceeding Hoopa TEPA (2008) water quality criteria.

Parameter	Criteria	Klamath River at Saints Rest Bar			Trinity River at Hoopa		
		total # samples	# samples exceeding	% samples exceeding	total # samples	# samples exceeding	% samples exceeding
Total Phosphorus (TP)	0.035 mg/L	48	32	67%	47	2	4%
Total Nitrogen (TN)	0.200 mg/L	48	29	60%	47	1	2%
Total microcystin toxin	8 μg/L	20	1	5%	19	0	0%
Microcystis aeruginosa cell density	40,000 cells/mL	38	1	3%	38	0	0%
Total potentially toxigenic blue-green algal species	100,000 cells/mL	38	0	0%	38	0	0%
Periphyton chlorophyll-*a*	150 mg/m^2	43	5	12%	35	0	0%

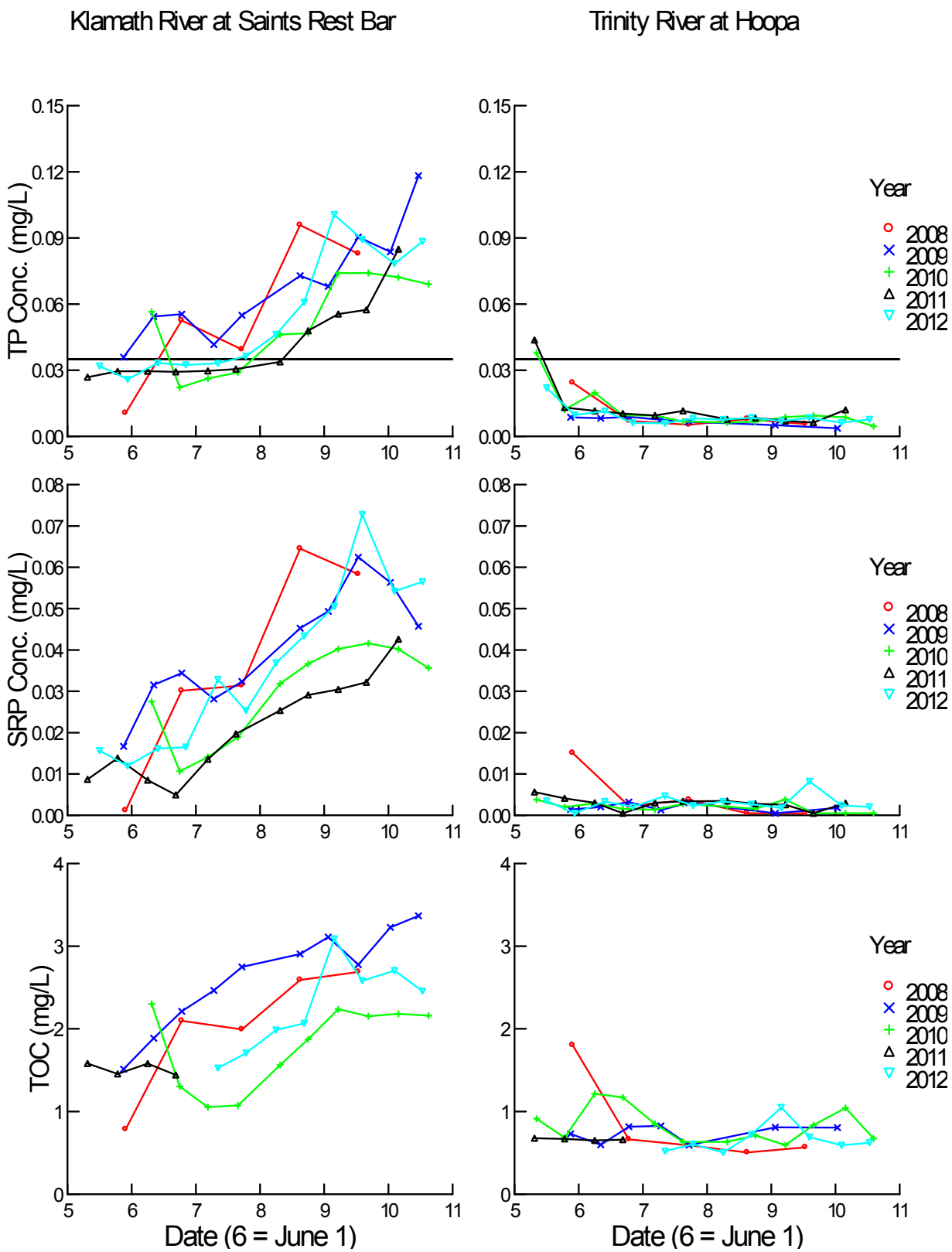

Figure 5. Time series of total phosphorus (TP)(top panels), soluble reactive phosphorus (SRP)(middle panels), and total organic carbon (TOC)(bottom panels) for the months of May–October periods of 2008-2012 at Klamath River at Saints Rest Bar (left panels) and Trinity River at Hoopa (right panels). Reference line at 0.035 mg/L for TP is Hoopa Tribe's water quality criteria.

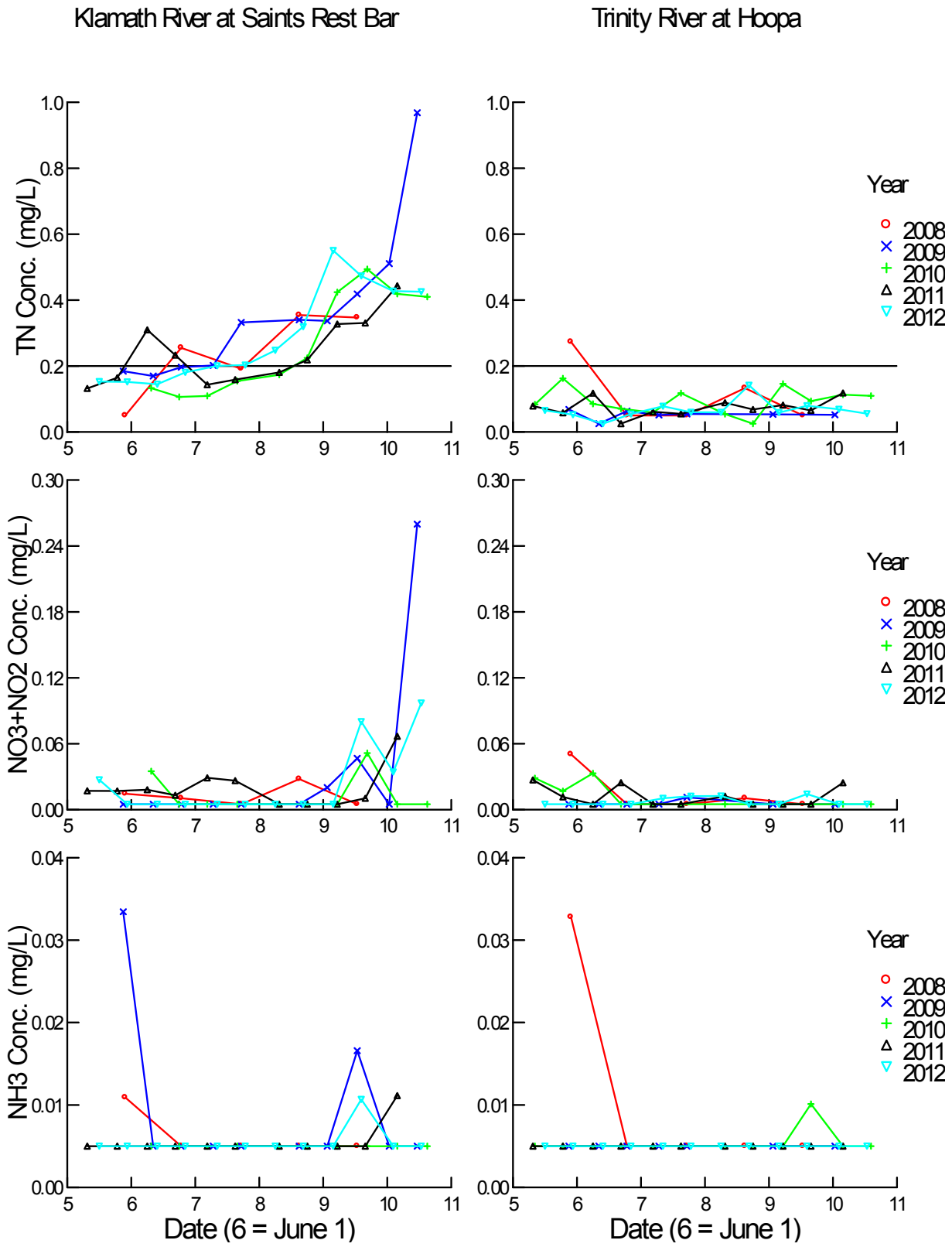

Figure 6. Time series of total nitrogen (TN) (top panels), nitrate+nitrite (NO3+NO2) (middle panels), and ammonia (NH3) (bottom panels) for the months of May–October, 2008-2012 at Klamath River at Saints Rest Bar (left panels) and Trinity River at Hoopa (right panels). Reference line at 0.2 mg/L for TN is Hoopa Tribe's water quality criteria.

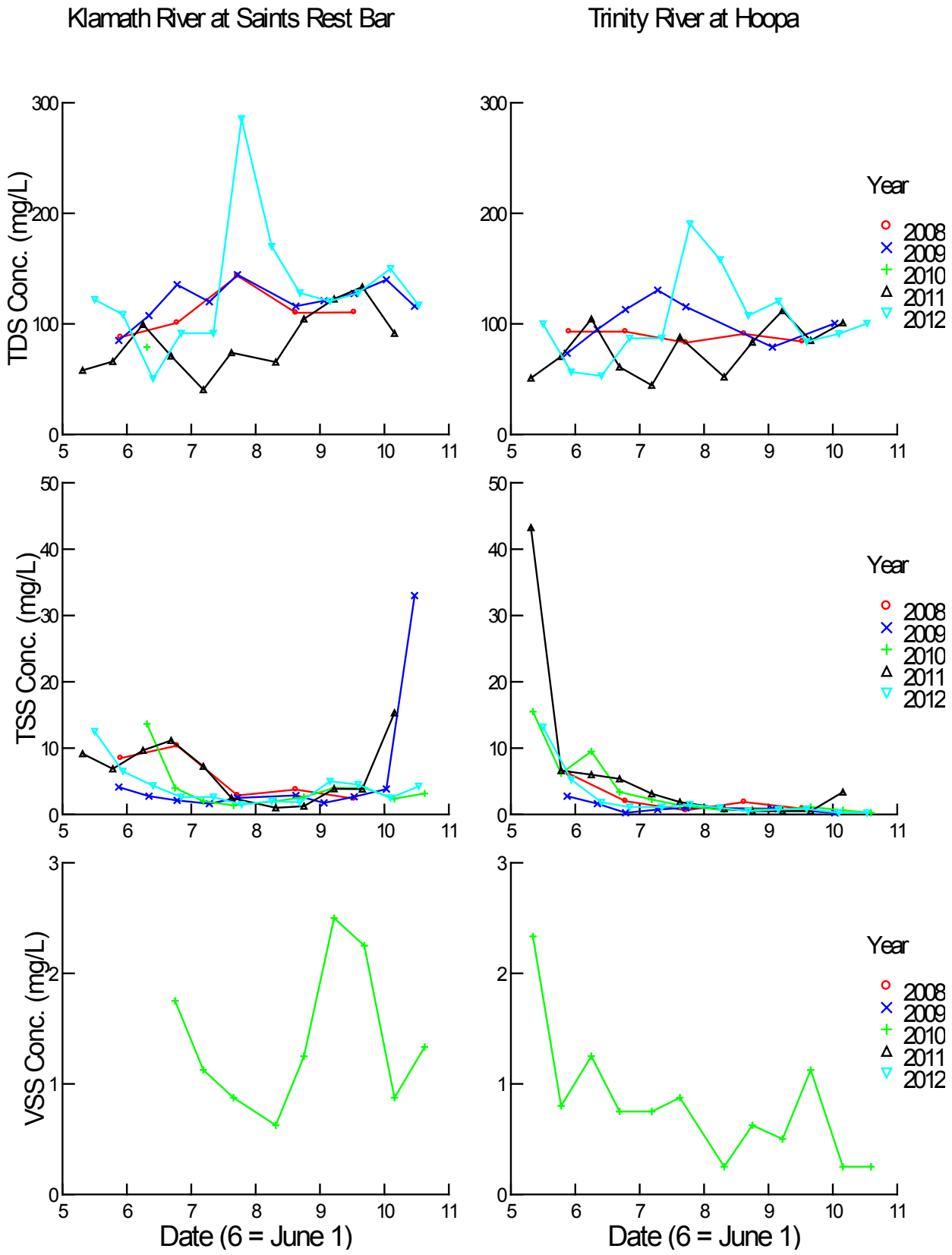

Figure 7. Time series of total dissolved solids (TDS) (top panels), total suspended solids (TSS) (middle panels), and volatile suspended solids (VSS) for the months of May–October, 2008-2012 at Klamath River at Saints Rest Bar (left panels) and Trinity River at Hoopa (right panels).

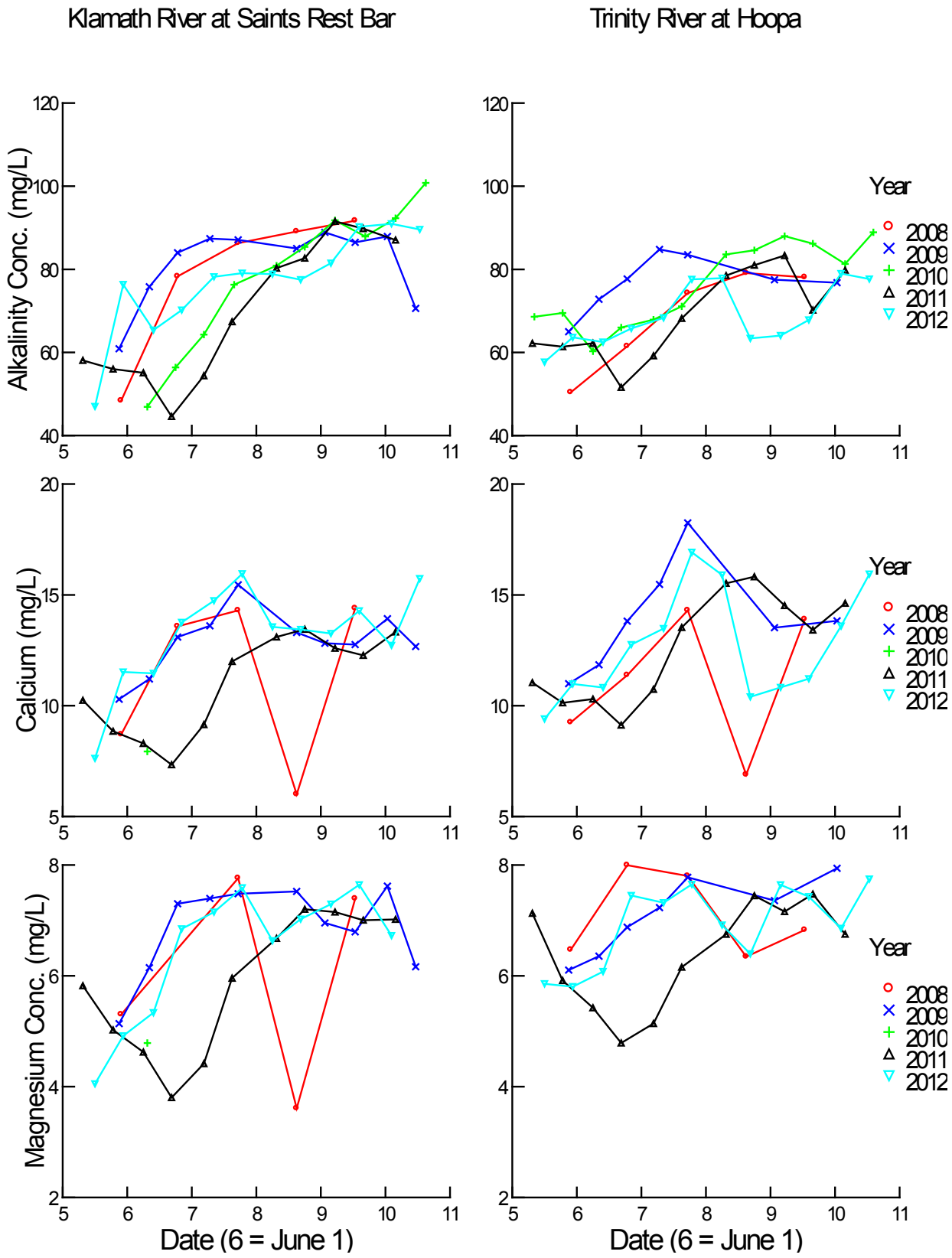

Figure 8. Time series of alkalinity(top panels), calcium (middle panels), and magnesium (bottom panels) for the months of May–October, 2008-2012 at Klamath River at Saints Rest Bar (left panels) and Trinity River at Hoopa (right panels).

3.3 PHYTOPLANKTON, CHLOROPHYLL, AND MICROCYSTIN

On nearly every sampling date, phytoplankton biovolume and chlorophyll were higher at the Klamath River site than the Trinity River site (Figure 9). The difference between the sites was even more dramatic for cell density of the algal species *Microcystis aeruginosa* and accompanying microcystin toxin (a potent hepatotoxin produced by *M. aeruginosa*), because neither were detected at the Trinity River site but were consistently detected at the Klamath River site. Values of 79,676 cells/mL of *Microcystis aeruginosa* and 19 μg/L of microcystin at the Klamath River site on September 5, 2012 were the sole exceedances of the Hoopa Valley Tribe's criteria for those parameters (Figure 10). However, microcystin toxin data were not collected throughout the entire 2008–2012 period (no data in 2008-2009, partial data in 2010, and full seasons in 2011-2012), so additional exceedances may have occurred during un-sampled portions of the 2008–2012 period.

The Hoopa Valley Tribe's criteria of 100,000 cells/mL for the total of potentially toxigenic species was not exceeded in any sample. *Microcystis aeruginosa* comprised the vast majority of the potentially toxigenic blue-green algal species (Figure 10) and was detected in 42% of phytoplankton samples (Table 5). Other potentially toxigenic blue-green algal species present at very low levels in phytoplankton samples included: *Aphanizomenon flos-aquae*, *Anabaena flos-aquae*, *Oscillatoria* sp., *Anabaena* sp., *Anabaena planctonica*, *Anabaena circinalis*, and *Gloeotrichia echinulata*. Of these seven species, only *Aphanizomenon flos-aquae* exceeded 1000 cells/mL in any sample.

Diatoms dominated the phytoplankton communities at both sites and the species with the highest average biovolumes were the diatoms *Epithemia sorex*, *Rhopalodia gibba*, *Cocconeis placentula, Synedra ulna*, *Diatoma tenue*, *Cymbella affinis*, and *Diatoma vulgare* (Table 5). The only blue-green algal species in the top 20 phytoplankton species were *Aphanizomenon flos-aquae* and *Microcystis aeruginosa*.

3.4 PERIPHYTON

The Hoopa Valley Tribe's criteria for periphyton chlorophyll-*a* was exceeded at the Klamath River site once in 2011 and three times in 2012 (Figure 11), for an overall percent exceedance of 12% in the five-year study period (Table 4). The exceedance in May 2011 occurred during unusually high flow and low water temperatures (YTEP 2012) which are typically associated with low periphyton biomass; therefore, that sample is suspect and may be an artifact of patchy periphyton distribution and not representative of reach-wide conditions. The Tribe's criteria for periphyton chlorophyll-*a* was not exceeded at the Trinity River site.

Total periphyton biovolume (derived by summing the biovolume of all species within a sample) appears to have seasonal and inter-annual (i.e., higher in 2009 and 2012 than the other years) patterns somewhat similar to periphyton chlorophyll-*a*, although there were exceptions such as mid-October 2012 when chlorophyll was very high but biovolume was relatively low (Figure 11 top and bottom panels).

Substantial overlap between the top 20 periphyton species and the top 20 phytoplankton species (Table 5 and Table 6) indicated that many of the species in the planktonic samples were dislodged periphytic species. Although some of the species in periphyton samples could have been planktonic species which had settled to the riverbed, the majority of identified species stem from benthic and not planktonic habitats. As with the phytoplankton, the periphyton community is dominated by diatoms although there were some blue-green algal species present (*Calothrix* sp., *Rivularia* sp., *Oscillatoria* sp., and *Anabaena* sp.). The diatom *Epithemia sorex* comprised 48% of the biovolume at the Klamath River site and 18% at the Trinity River site. *Epithemia sorex* contains nitrogen-fixing endosymbiotic cyanobacteria which enable it to become abundant in habitats with a low nitrogen:phoshorus ratios.

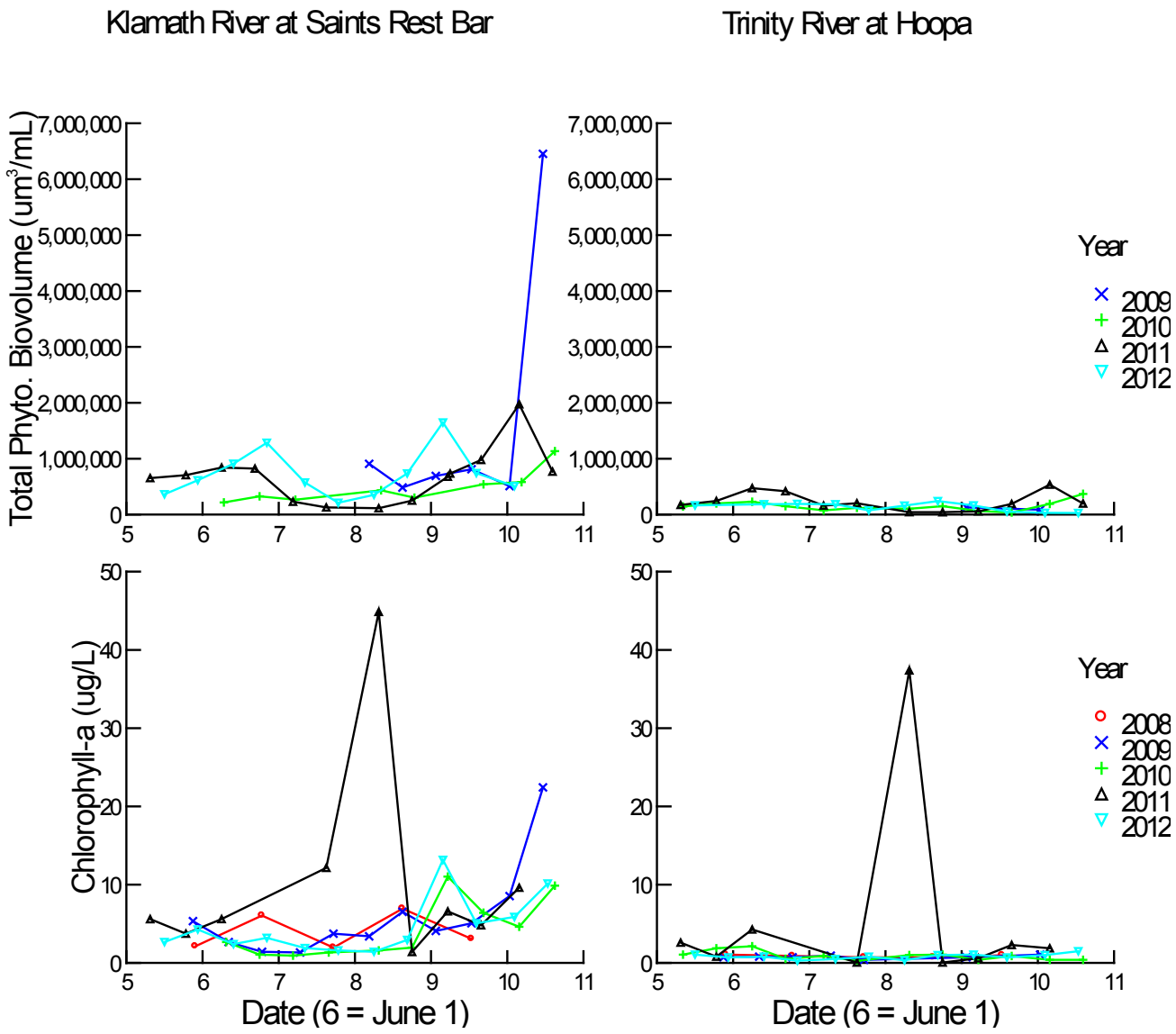

Figure 9. Time series of total phytoplankton biovolume (top panels) and chlorophyll-*a* (bottom panels) for the months of May–October, 2008-2012 at Klamath River at Saints Rest Bar (left panels) and Trinity River at Hoopa (right panels).

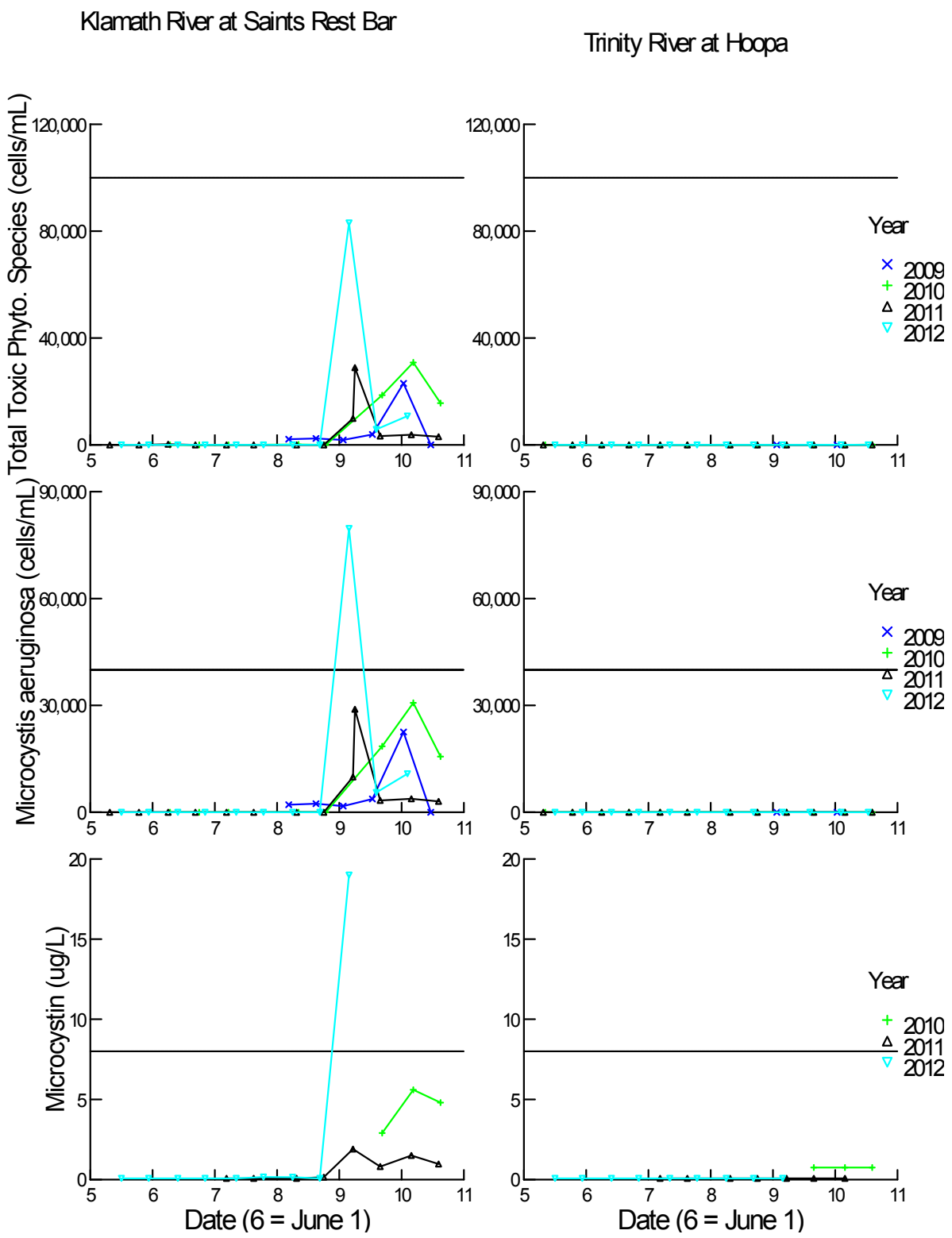

Figure 10. Time series of cell density of toxic phytoplankton (top panels), cell density of *Microcystis aeruginosa* (middle panels), and microcystin toxin concentration (bottom panels) for the months of May–October, 2009-2012 at Klamath River at Saints Rest Bar (left panels) and Trinity River at Hoopa (right panels). Microcystin was not analyzed in 2009 and only a partial season of data is available in 2010. Reference lines for toxic phytoplankton species, *Microcystin aeruginosa*, and microcystin are Hoopa Tribe's water quality criteria (Table 3). The detection limit of microcystin was 1.5 µg/L in 2010 and 0.15 µg/L in 2011–2012.

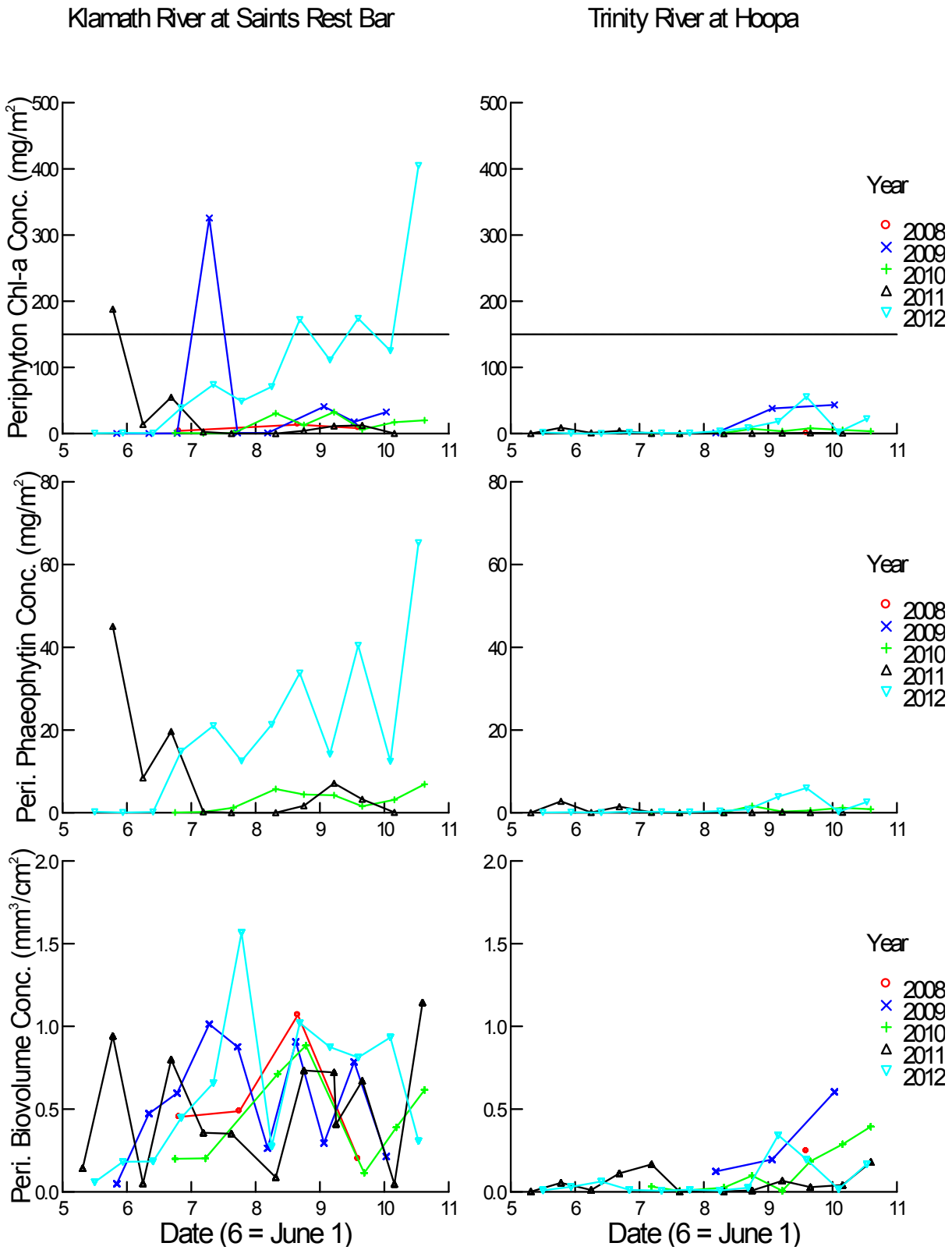

Figure 11. Time series of periphyton chlorophyll-*a* (top panels), periphyton phaeophytin (middle panels), and periphyton total biovolume (bottom panels) for the months of May–October, 2008-2012 at Klamath River at Saints Rest Bar (left panels) and Trinity River at Hoopa (right panels). Reference line at 150 mg/m² for periphyton chlorophyll-*a* is Hoopa Tribe's water quality criteria (Table 3).

Table 5. Top 20 species in phytoplankton samples for each site for the years 2009–2012, ranked by biovolume.

Site	Species Name	Group	Species Biovolume as % of Total Biovolume	% of Samples with Species Present
Klamath River at Saints Rest Bar	*Epithemia sorex*	diatom	19.2	68.4
	Rhopalodia gibba	diatom	12.4	15.8
	Cocconeis placentula	diatom	11.4	94.7
	Synedra ulna	diatom	8.1	73.7
	Diatoma tenue	diatom	6.8	52.6
	Diatoma vulgare	diatom	6.4	73.7
	Microcystis aeruginosa	bluegreen	6.4	42.1
	Gomphoneis herculeana	diatom	4.1	34.2
	Cymbella affinis	diatom	3.7	63.2
	Melosira granulata	diatom	2.0	23.7
	Navicula tripunctata	diatom	1.5	31.6
	Nitzschia frustulum	diatom	1.3	86.8
	Asterionella formosa	diatom	1.2	13.2
	Gomphonema subclavatum	diatom	1.2	52.6
	Nitzschia dissipata	diatom	1.0	44.7
	Cymbella minuta	diatom	1.0	36.8
	Aphanizomenon flos-aquae	bluegreen	0.9	18.4
	Achnanthes minutissima	diatom	0.8	60.5
	Stephanodiscus hantzschii	diatom	0.7	31.6
	Scenedesmus quadricauda	green	0.7	44.7
Trinity River at Hoopa	*Diatoma tenue*	diatom	27.2	84.2
	Cymbella affinis	diatom	9.1	78.9
	Cocconeis placentula	diatom	9.1	94.7
	Rhopalodia gibba	diatom	8.4	10.5
	Synedra ulna	diatom	8.3	68.4
	Epithemia sorex	diatom	6.8	73.7
	Gomphoneis herculeana	diatom	3.3	21.1
	Hannaea arcus	diatom	2.9	18.4
	Diatoma vulgare	diatom	2.9	31.6
	Gomphonema angustatum	diatom	2.5	92.1
	Gomphonema subclavatum	diatom	2.0	60.5
	Cymbella minuta	diatom	1.5	47.4
	Epithemia turgida	diatom	1.4	18.4
	Spirogyra sp.	green	1.2	7.9
	Achnanthes minutissima	diatom	1.2	84.2
	Gomphonema ventricosum	diatom	0.9	34.2
	Navicula tripunctata	diatom	0.9	26.3
	Nitzschia dissipata	diatom	0.7	44.7
	Cymbella sinuata	diatom	0.7	78.9
	Nitzschia linearis	diatom	0.6	13.2

Table 6. Top 20 species in periphyton samples for each site for the years 2008–2012, ranked by biovolume.

Site	Species Name	Group	Species Biovolume as % of Total Biovolume	% of Samples with Species Present
Klamath River at Saints Rest Bar	*Epithemia sorex*	diatom	48.4	76.1
	Cymbella affinis	diatom	12.3	73.9
	Gomphoneis herculeana	diatom	9.8	65.2
	Calothrix sp.	bluegreen	3.5	26.1
	Diatoma tenue	diatom	3.2	63.0
	Synedra ulna	diatom	2.5	63.0
	Rhopalodia gibba	diatom	2.5	8.7
	Cocconeis placentula	diatom	2.2	84.8
	Rivularia sp.	bluegreen	2.2	4.3
	Diatoma vulgare	diatom	2.0	50.0
	Nitzschia frustulum	diatom	1.6	100.0
	Gomphonema subclavatum	diatom	1.0	65.2
	Cymbella minuta	diatom	1.0	37.0
	Oscillatoria sp.	bluegreen	1.0	13.0
	Nitzschia dissipata	diatom	0.9	45.7
	Achnanthes minutissima	diatom	0.8	80.4
	Gomphonema ventricosum	diatom	0.5	41.3
	Nitzschia linearis	diatom	0.4	13.0
	Synedra mazamaensis	diatom	0.4	41.3
	Navicula tripunctata	diatom	0.3	21.7
Trinity River at Hoopa	*Rhopalodia gibba*	diatom	21.7	25.0
	Epithemia sorex	diatom	18.3	80.6
	Cocconeis placentula	diatom	11.6	86.1
	Cymbella affinis	diatom	10.8	91.7
	Spirogyra sp.	green	5.2	11.1
	Epithemia turgida	diatom	5.0	38.9
	Synedra ulna	diatom	4.8	66.7
	Diatoma tenue	diatom	3.7	94.4
	Gomphoneis herculeana	diatom	2.5	27.8
	Diatoma vulgare	diatom	2.3	36.1
	Nitzschia dissipata	diatom	1.4	77.8
	Gomphonema angustatum	diatom	1.2	100.0
	Oscillatoria sp.	bluegreen	1.0	19.4
	Nitzschia frustulum	diatom	1.0	86.1
	Gomphonema subclavatum	diatom	0.9	66.7
	Nitzschia linearis	diatom	0.9	22.2
	Amphipleura pellucida	diatom	0.7	25.0
	Navicula tripunctata	diatom	0.5	25.0
	Navicula cryptocephala	diatom	0.5	55.6
	Anabaena sp.	bluegreen	0.4	2.8

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5 LITERATURE CITED

Eilers, J.M. 2005. Periphyton in Selected Sites of the Klamath River, California. Prepared for Tetra Tech, Inc. Fairfax, VA by J.M. Eilers MaxDepth Aquatics, Inc. Bend, OR. 20 p.

Fetcho, K. 2007. 2006 Klamath River Blue-green Algae Summary Report. Yurok Tribe Environmental Program. Klamath, CA.

Hoopa Valley Tribe Environmental Protection Agency (Hoopa TEPA). 2008. Water Quality Control Plan Hoopa Valley Indian Reservation. Approved September 11, 2002, Amendments Approved February 14, 2008. Hoopa Tribal EPA. Hoopa, CA. 285 p.

Karuk Tribe. 2011. 2011 Quality Assurance Project Plan for Water Quality Sampling and Analysis CWA 106 grant identification # BG-97991209. Prepared by the Karuk Tribe Water Quality Program, Karuk Tribe Department of Natural Resources, Orleans, CA. 102p. plus appendices.

Peck DV, Herlihy AT, Hill BH, Hughes RM, Kaufmann PR, Klemm DJ, Lazorchak JM, McCormick FH, Peterson SA, and Ringold PL. 2006. Environmental Monitoring and Assessment Program–surface Waters: Western Pilot Study Field Operations Manual for Wadeable Streams. EPA/620/R-06/003. Field Operations Manual for Wadeable Streams. 276 pp. plus appendices. Available from: http://www.epa.gov/wed/pages/publications/authored/EPA620R-06003EMAPSWFieldOperationsManualPeck.pdf

Porter, S.D., T.F. Cuffney, M.E. Gurtz, and M.R. Meador. 1995. Methods for collecting algal samples as part of the National Water Quality Assessment Program. U.S. Geologic Survey (USGS) Open-File Report 93-409. 29 p.

Nimick DA, Gammons CH, Parker SR. 2011. Diel biogeochemical processes and their effect on the aqueous chemistry of streams: A review. *Chemical Geology* 283:3–17.

North Coast Regional Water Quality Control Board (NCRWQCB). 2010. Final Staff Report for the Klamath River Total Maximum Daily Loads (TMDLs) Addressing Temperature, Dissolved Oxygen, Nutrient and Microcystin Impairments in California, the Proposed Site Specific Dissolved Oxygen Objectives for the Klamath River and California, and the Klamath River and Lost River Implementation Plans. NCRWQCB, Santa Rosa, CA.

Oregon Department of Environmental Quality. 2010. Upper Klamath and Lost River subbasins; total maximum daily load (TMDL) and water quality management plan (WQMP). Oregon Department of Environmental Quality, Portland, OR. Available online at http://www.deq.state.or.us/WQ/TMDLs/klamath.htm

Sinnott, S. 2012. Final 2011 Klamath River Nutrient Summary Report. Yurok Tribe Environmental Program (YTEP water division), Klamath, CA. 50 p.

State Water Resources Control Board (SWRCB). 2010. 2010 Integrated Report (Clean Water Act Section 303(d) List / 305(b) Report) – Statewide. State Water Resources Control Board, Sacramento, CA. Available online at: http://www.waterboards.ca.gov/water_issues/programs/tmdl/integrated2010.shtml

U.S. Environmental Protection Agency (USEPA). 2001. Trinity River Total Maximum Daily Load for Sediment. USEPA, Region IX. San Francisco, CA. 77 p.

Yurok Tribe Environmental Program (YTEP). 2008. Lower Klamath River Nutrient, Periphyton, Phytoplankton and Algal Toxin Sampling Analysis Plan (SAP). Prepared by YTEP with assistance from Kier Associates, Blue Lake, CA. 47p.

Yurok Tribe Environmental Program. 2012. Final 2011 Klamath River Continuous Water Quality Monitoring Summary Report. Prepared by Scott Sinnott. YTEP Water Division, Klamath, CA. 57 p.

Yurok Tribe, Karuk Tribe, and Watercourse Engineering, Inc. 2013. 2011 Klamath River Periphyton Pilot Study Summary Report. 26 p. plus appendices.