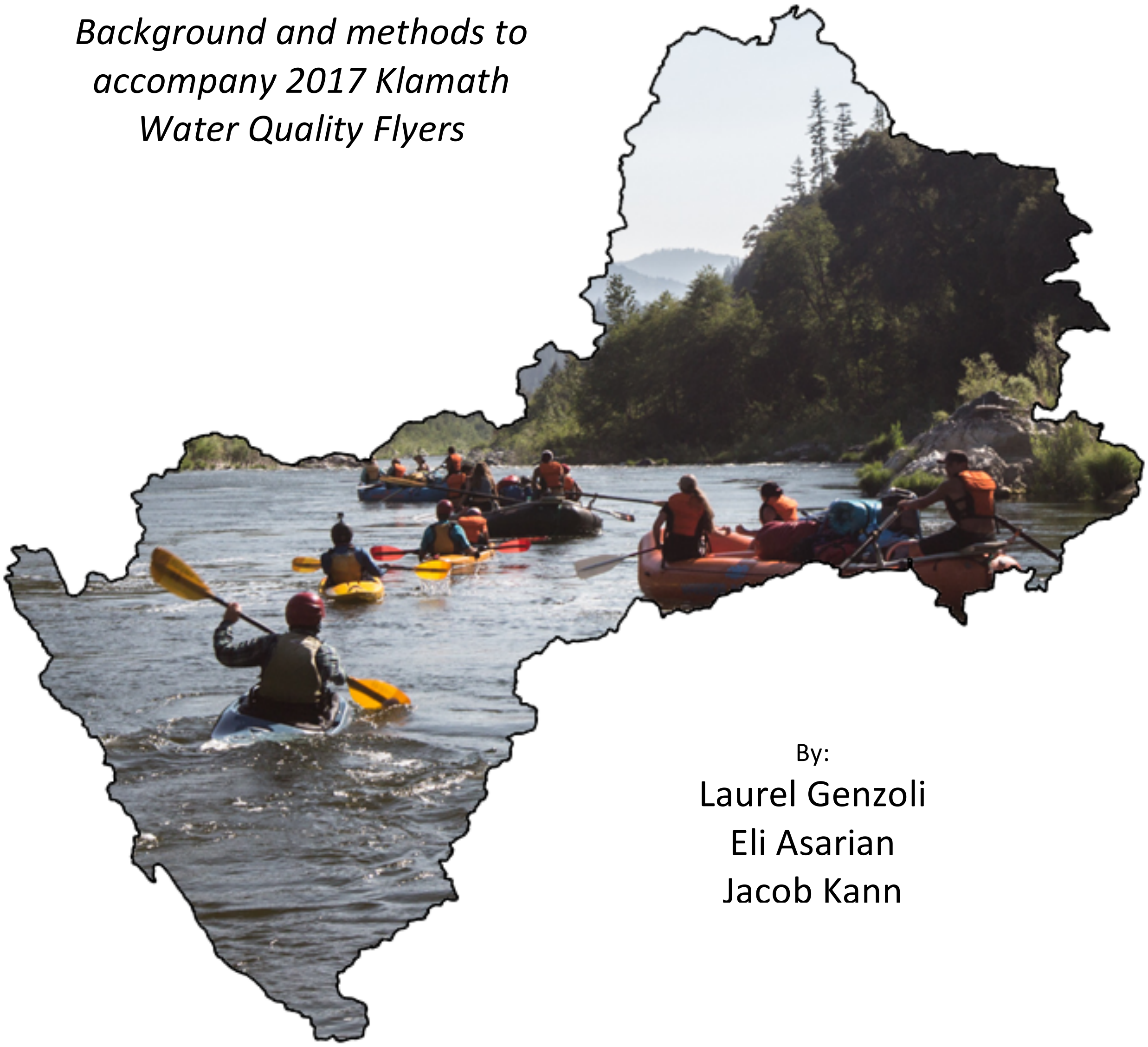
State of the Basin:

Klamath River Water Quality 2017

Background and methods to accompany 2017 Klamath Water Quality Flyers



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Executive Summary

In order to communicate water quality conditions to a broad audience, the Klamath Tribal Water Quality Consortium produced water quality flyers for two sub-basins in the Klamath River Watershed displaying water quality data from summer and autumn 2017. These flyers are the first iteration of broadly accessible water quality reports produced by the Klamath Tribal Water Quality Consortium.

These water quality flyers use data collected primarily from Tribal water quality departments along the Klamath River and its tributaries. Klamath River Tribes owed their prosperity, in large part, to the river's abundant runs of salmon and other fish species, and the people of the Klamath River Tribes continue to rely on a healthy river ecosystem. Tribal water quality departments collect extensive water quality data in the Klamath Basin to monitor the current degradation from agricultural activities, hydroelectric dams, and a legacy of mining, logging, and fire suppression.

Prior to the State of the Basin 2017 Water Quality flyers, monitoring data along the Klamath River and its tributaries have been analyzed and presented in comprehensive technical reports. These reports are used to inform Tribal, state and federal processes including identifying and listing impaired waterways and informing processes related to Klamath River dam removal and other restoration activities. The level of detail needed to describe the complex patterns in large water quality data sets on the Klamath River results in reports that are not geared toward a general audience. Thus our goal was to strike a balance of simplicity while still including data from many sites and water quality parameters. Independent flyers for the Mid and Lower Klamath River were targeted to residents, visitors, natural resource professionals and policy makers in the sub-basins where they live, recreate, and work.

Water quality directly affects people who live along the Klamath River, as well as people who visit the river. Many residents and visitors to the Klamath Basin have a general notion that water quality is impaired, but lack information about what poor water quality means, when the water quality is impaired, how it affects them, and how water quality issues change from year to year. This includes understanding the risk from microcystin toxin from blue-green algae, which is a major human health concern in the hydroelectric reservoirs and in the river below these reservoirs. Concise, clear, and simple presentation of water quality data will increase basin residents' and visitors' understanding of the river's status and support policy makers and natural resource professionals in making informed decisions. It is our intent that these flyers will lead to a more informed public, and that this information will empower people to make decisions about their personal water contact choices and to be involved in water quality issues in their communities.

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Acknowledgements:

Klamath River State of the Basin flyers were produced in collaboration with representatives from the Klamath River Tribal Water Quality Consortium. Additional suggestions from Tribal water quality department staff helped direct the design and content of the flyers. Weston Boyles and Paul Wilson contributed photos to these documents.

Background

Klamath River Geography, Land Use, and Water Quality Conditions

The Klamath River is one of the most important salmon spawning and rearing rivers of the Western United States (ESSA 2017). The river spans Southern Oregon and Northern California, with a basin covering nearly 16,000 square miles. The uppermost tributaries originate in Southern Oregon and drain into Upper Klamath Lake, Oregon's largest lake by surface area. The outflow of Upper Klamath Lake is referred to as the Link River, which flows for just over a mile before widening out into Lake Ewauna, a natural Lake that is now managed for irrigation supply by the Keno Dam. The Klamath River officially begins at the outflow of Lake Ewauna, below Keno Dam.

The river flows through a series of hydroelectric impoundments, including J.C. Boyle, Copco (No. 1 and No. 2), and Iron Gate Reservoirs. These dams block the passage of salmon and other fish, and the associated reservoirs receive high nutrient loads, which in the stagnant reservoir environment promote blooms of *Microcystis aeruginosa*, a toxin-producing blue-green algae.

Below Iron Gate Dam, the river flows for approximately 190 miles before reaching the Pacific Ocean, mostly through a confined, bedrock canyon. The climate is Mediterranean, with cool, wet winters featuring rainfall at lower elevations and snow at higher elevations, and hot, dry summers. High winter and spring flows are derived from heavy rain and snowmelt. During summer and early autumn when flows are low, the Upper Klamath Basin (i.e., upstream of Iron Gate Dam) provides a greater percentage of the Klamath River's flow than during winter and spring when downstream tributaries such as the Shasta, Scott, Salmon, and Trinity rivers contribute large volumes of water.

Water quality in the Klamath River is degraded from agricultural activities, hydroelectric dams, and a legacy of mining, logging, and fire suppression throughout the basin. Microcystin toxin from blue-green algae is a major human health concern in the hydroelectric reservoirs and in the river below these reservoirs (NCRWCB 2010, Genzoli and Kann 2017). High water temperatures can be stressful for fish and other tribal trust species (ESSA 2017). High nutrients drive excessive algae growth in the Klamath River, resulting in high pH and low dissolved oxygen levels (Genzoli et al. 2015) that cause additional stress to native species that are adapted to more moderate conditions. Klamath River fish face high levels of disease due to reduced water flows, impassable dams, and poor water quality (US DOI and CDFG 2012, ESSA 2017). The U.S. Environmental Protection Agency (U.S. EPA), the Oregon Department of Environmental Quality (ODEQ), and California's North Coast Regional Water Quality Control Board (NCRWQCB) have developed Total Maximum Daily Load (TMDL) regulations defining the maximum amount of human-caused pollutants allowed to be discharged into the river (NCRWQCB 2010).

Tribal Water Quality Monitoring and Cooperation

The indigenous people of the Klamath River Basin have lived in harmony with the river and the adjoining lands for thousands of years. Klamath River Tribes owed their prosperity, in large part, to the river's abundant runs of salmon and other fish species. The Tribes in California maintain active fisheries today, which are often a mainstay of Tribal subsistence and also an important economic factor, although low numbers of returning salmon in recent years has limited the Tribes' access to this historically abundant resource. The Tribes depend upon a healthy river to support a broad range of subsistence, cultural and ceremonial activities. Klamath Basin Tribes maintain water quality departments that monitor water quality to inform state and federal processes, to observe changing conditions, and to inform the public about the status of the river.

Following a massive adult salmon kill in September 2002, the lower basin Tribes formed the Klamath Basin Tribal Water Quality Work Group (later formalizing its collaboration by creating the Klamath Tribal Water Quality Consortium) to "prevent future disasters through sound scientific research, data analysis, and thorough planning." The Consortium is comprised of the Yurok, Hoopa Valley, and Karuk Tribes, the Quartz Valley Indian Community, and the Resighini Rancheria (KTWQC 2017).

Communicating Water Quality Conditions

Historically, monitoring data along the Klamath River and its tributaries have been analyzed and presented in technical reports. These reports are used to inform state and federal processes including identifying and listing impaired waterways and informing processes related to Klamath River dam removal and other restoration activities. The level of detail needed to describe the complex patterns in large water quality data sets on the Klamath River results in reports that are time-consuming to read and too technical for a general audience to easily understand.

Water quality directly affects people who live along the Klamath River, as well as people who visit the river. Many residents and visitors to the Klamath Basin have a general notion that water quality is impaired, but lack information about what poor water quality means, when the water quality is impaired, how it affects them, and how water quality issues change from year to year. Concise, clear, and simple presentation of water quality data will increase basin residents' and visitors' understanding of the river's status and provide them with the information they need to make informed decisions about water contact activities. Succinct materials can also support policy makers and natural resource professionals in making informed decisions.

State of the Basin: Report Goals

The goal for the 2017 State of the Basin project was to create succinct flyers displaying water quality data in the Klamath Basin. We sought to strike a balance of simplicity while still including data from as many sites and water quality parameters as possible. We created independent flyers for sub-basins within the Klamath Basin, with the idea that residents, visitors and policy makers would be most interested in knowing the water quality conditions for specific river reaches where they live, recreate, and work. We hope these flyers will lead to a more informed public, and that this information will make people feel empowered to make decisions about their personal water contact choices and to be involved in water quality issues in their communities.

Methods

Geographic Area of the 2017 State of the Basin

We focused the initial State of the Basin report on the Lower Klamath Basin below Iron Gate Dam (Figure **1**). To define the sub-basins, we modified the 8-digit Hydrologic Unit Codes (HUC-8) boundaries from the U.S. Geological Survey to reflect how the people who live along the river refer to the river, and to divide the watersheds based on which water quality department samples each sub-basin. Thus, in our designation, the Lower Klamath sub-basin extends from the estuary to a few miles upstream of Weitchpec, while the Mid-Klamath sub-basin extends from up-river of Weitchpec to Iron Gate Dam.

In 2017, we produced independent flyers for the Lower and Middle Klamath sub-basins. The remainder of the sub-basins in the Lower Klamath Basin will be prioritized in future years, including the Trinity, Salmon, Scott, and Shasta watersheds. At some point in the future, Upper Klamath Basin (sub-basins above Iron Gate Dam) reports may be produced in collaboration with the entities that collect data in those areas.

Figure 1. Map of the sub-basins in the Klamath Basin. Flyers were produced in 2017 for sub-basins in blue, and future efforts will prioritize sub-basins in green, with watersheds in orange being considered at a later time.

Review of Previous Water Quality Outreach Products

We reviewed outreach materials produced in other watershed to inform the design and final outcomes of Klamath River water quality flyers. We searched for water quality scorecards, report cards, state of the basin reports, and other material produced for diverse audiences. We found examples of report cards displaying basin-wide water quality data condensed to a letter grading system that were designed for public audiences, but these reports generally did not directly display the water quality data and were longer than two pages (examples include: http://ian.umces.edu/press/report_cards/, https://www.oregon.gov/deq/wq/Pages/watershed.aspx). Examples of publically accessible two-page flyers displaying data were commonly produced for municipal water agencies, but these documents generally displayed data from limited sampling events and sites, so were not good models to use for condensing the extensive data sets available from multiple sites and many sampling dates (examples include: https://www.ashland.or.us/SIB/files/2013%20Water%20Quality%20Report%20CCR%20.pdf, https://www.klamathfalls.city/sites/www.klamathfalls.city/assets/files/Klamath_Falls_Water_Quality_Report.pdf). Performance reports produced by various regional California Water Boards were good general models in that they were single page flyers that displayed data directly in the context of water quality goals (https://www.waterboards.ca.gov/about_us/performance_report_1617/plan_assess/11112_tmdl_outcomes.shtml#r5). Although these flyers were a useful example of a single page water quality report, they were generally focused on one or few parameters, and at single site. Although we integrated ideas from many of the materials we reviewed, we created a novel format in order to maintain our goals of presenting data from multiple sites and sampling events into a simple two-page flyer geared toward a broad audience.

Water Quality Parameters

We presented data describing six water quality parameters in the Lower and Middle Klamath State of the Basin flyers. We selected water quality parameters where data were readily available over multiple years and at multiple sites, with a focus on the water quality parameters that have been identified as impaired in the Klamath River. Of the water quality parameters we presented, all but pH are directly addressed in the Klamath River TMDL (NCRWQCB 2010, Table **1**).

Table 1. Water quality parameters presented in the Klamath River State of the Basin flyers, with brief description of parameter and justification for inclusion on the flyers.

<table>
<tr><th>Parameter</th><th>Explanation</th></tr>
<tr><td>Microcystin Toxin</td><td>Public health concern; toxin from Microcystis aeruginosa blooms in Iron Gate and Copco reservoirs and is transported into the river, affecting the entire length of the Klamath below the dams.</td></tr>
<tr><td>Total Phosphorus</td><td rowspan="2">Essential nutrients but when too concentrated can promote excess growth of algae, which can lead to unhealthy levels of pH and dissolved oxygen.</td></tr>
<tr><td>Total Nitrogen</td></tr>
<tr><td>Dissolved Oxygen (DO)</td><td>Adequate levels of DO are essential for fish and other aquatic organism. Low levels of DO can cause stress to organisms, making them more susceptible to disease or predation, while extreme low levels can cause direct mortality.</td></tr>
<tr><td>Water Temperature</td><td>High water temperatures are associated with low dissolved oxygen, can promote the spread and growth of disease-causing organisms, and disrupt fish behaviors and lifecycles.</td></tr>
<tr><td>pH</td><td>pH describes the acidity of water. pH in the Klamath is can be high, and have wide fluctuations from day to night. These changes can stress fish and aquatic organisms that are accustomed to more stable conditions.</td></tr>
</table>

Site selection and data sources

We selected sites with long-term data monitoring conducted by the Karuk and Yurok Tribes and PacifiCorp on the Middle and Lower Klamath River. We used data from three sites from the Middle Klamath River and three from the Lower Klamath River to present data for all of the six water quality parameters described below (Table **1**, Table 2). These sites are part of the baseline monitoring program and had both long-term continuous data (measured every 30 minutes by automated sensors called Sondes) and grab sample data (water samples collected by water quality technicians generally every two weeks and sent to laboratories for chemical analysis). For microcystin, we also included additional sites from the public health sampling program (Table 2).

Data presented in the State of the Basin flyers were collected as part of the Klamath Hydrologic Settlement Agreement (KHSA) monitoring program and through the region 9 U.S. EPA. Beginning in 2009, baseline water quality monitoring for microcystin toxins and nutrients, including total phosphorus and total nitrogen, were generally collected every two weeks from May through October, with monthly collection from November through April in some years. Baseline samples in the river were collected from the upper one-foot of flowing well-mixed water using a 14 liter churn splitter, which keeps the water in the sample bucket well mixed while filling individual sample bottles. At Walker Bridge, a Van Dorn bottle was used to collect the water sample by lowering the Van Dorn bottle from the bridge to gather the sample from the river below. Baseline samples collected using Van Dorn bottles were put into a churn splitter prior to filling sample bottles for analysis of microcystin toxin and nutrients.

Nutrient samples were filled from the churn and analyzed for total nitrogen and total phosphorus by IEH Aquatic Research (formerly known as Aquatic Research Incorporated). Detailed methods are available from U.S. EPA approved Sampling Analysis Plans (Karuk Tribe 2009, Yurok Tribe 2008).

In addition to collecting microcystin samples as part of the baseline program, public health samples were also collected. The public health monitoring program targets surface algal material taken from shoreline or river-edge areas, where human and animal contact is common. These samples were collected weekly once toxin or toxin producing species were identified or suspected in the river, generally from July through October. The protocol requires the person collecting the sample to seek out the area of "Reasonable Maximum Exposure" within the public health access point. Surveyors conducted an initial visual survey of the public access area to identify a location likely having a greater presence of cyanobacteria. Samples were collected from the top 10 centimeters of the water column at the identified location using a wide-mouth jar, and sample bottles were filled from the jar after gently inverting the jar to maintain a well-mixed sample.

Both baseline and public health sampling programs for microcystin utilized the standard operating procedure (SOP) developed by the Klamath Blue-Green Algae Working Group (2009).

Samples for microcystin toxin were collected in glass vials, frozen, and then placed in a cooler with gel-ice and shipped overnight air to the USEPA Region 9 Laboratory in Richmond, CA for analysis of microcystin toxin using ELISA[1] methodology. Between sample collection and shipping, samples were placed in a cooler with ice to keep cool and protect from light.

Continuous, multi-parameter water quality data Sondes were deployed by the Karuk and Yurok Tribes at six Klamath River stations from just below Iron Gate Dam to Turwar. Sondes were generally equipped with probes for water temperature, dissolved oxygen, pH, conductivity, phycocyanin (a pigment in cyanobacteria), and chlorophyll (a pigment found in all algae including cyanobacteria). The Sondes were programmed to record continuously over the monitoring period (generally May through October) at 30-minute intervals. Sondes were cleaned and re-calibrated every two weeks.

Table 2. Site locations and description of data type collected at each of the Klamath River sites that contributed data to the Klamath Water Quality Flyers.

Klamath River sites below Iron Gate Dam						
Site Code	North Latitude	West Longitude	River Mile	Site Name	Data Collection Method and Type	Data Collection Agency
IG	41°55.865	122°26.532	189	Below Iron Gate Dam	Sonde and Grab*	PacifiCorp, Karuk Tribe
IB	41°51.417	122°34.233	176	I-5 Bridge	Grab: Public Health	Karuk Tribe
WA	41°50.252	122°51.811	157	Walker Bridge	Grab: Baseline	Karuk Tribe
BB	41°49.399	122°57.650	150	Brown Bear Access	Grab: Public Health	Karuk Tribe
SV	41°50.561	123°13.132	128	Seiad Valley	Sonde and Grab*	Karuk Tribe
HC	41°43.780	123°25.775	108	Happy Camp	Grab: Both	Karuk Tribe
OR	41°18.336	123°31.895	59	Orleans	Sonde and Grab*	Karuk Tribe
WE	41°11.150	123°42.333	43	Weitchpec	Sonde and Grab*	Yurok Tribe
TC	41°13.684	123°46.333	38	Tully Creek	Sonde and Grab*	Yurok Tribe
TG	41°30.967	123°59.950	6	Turwar	Sonde and Grab*	Yurok Tribe
LES	41°32.718	124°04.377	0.5	Lower Estuary	Grab: Baseline	Yurok Tribe
SS	41°32.183	124°04.538	0.2	South Slough	Grab: Public Health	Yurok Tribe

* All sites with both Sonde and Grab data had grab samples collected for baseline and public health monitoring programs with the exception of Tully Creek, which only had grab samples collected for baseline monitoring.

[1] Enzyme-Linked ImmunoSorbent Assay using EnviroLogix QuantiPlate Kit designed for quantitative laboratory detection of microcystin toxin in surface water samples (quantitation limit is 0.18 μg/L)

Data selection and Quality Assurance Measures

Using the continuous water quality data from Sondes, we calculated daily minimum, maximum, and mean values of water temperature, dissolved oxygen, and pH at each site. Prior to selecting the minimum and maximum as the statistic to use, we also calculated and graphed the 0.1 and 0.9 quantiles of daily data, and we compared these statistics to the daily minimums and maximums to be sure that the Sonde was not recording spikes for maximum and minimum values that would have been representative of sensor error rather than true water quality conditions. Upon seeing that the minimum and maximums were only slightly off-set from the 0.1 and 0.9 quantiles, we continued to use the minimums and maximum values in our data quality assurance process and for data presentation. We eliminated days from the data set when more than five 30-minute measurements were missing during any 24-hour period.

Sonde data was post-calibrated to account for sensor drift and questionable data values were flagged according to USGS protocols (Wagner et al. 2006). Data was removed from this analysis when values exceeded expected ranges. Sonde data from Lower Klamath River sites prior to 2010 did not go through the post calibration process, while data from subsequent years were post calibrated either in standard excel databases, or using the Aquarius platform. For all data collected by the Karuk Tribe, and data collected by the Yurok Tribe between 2014-2017, the post calibration process was conducted in Aquarius (Aquatic Informatics Inc., Vancouver BC), using the USGS protocol. To account for data that did not go through the USGS data correction process, and to conduct a more thorough quality assurance process on all data, we further assessed the Sonde data for unrealistic values and shifts in calibration by graphing the minimum, maximum, and mean daily values for water temperature, dissolved oxygen, and pH data. We identified extreme low values and data shifts lasting approximately two weeks (the calibration period). When questionable data was identified, we looked at raw (30-minute interval data) for additional clues and we compared the data to the other parameters and discharge data for possible reasons that outlier or off-set values would have occurred. Further, for Iron Gate Sonde data, we compared the questionable values to the PacifiCorp Iron Gate Sonde data, and for all Sondes, we looked at data at nearby sites to see if similar patterns occurred. We removed daily Sonde data when outlier or off-set values where not explained by other data parameters or supported by near-by Sonde data.

Water Quality Thresholds

Numeric water quality thresholds are values that represent a water quality goal. Thresholds are generally selected to mimic the range of natural conditions that do not adversely affect aquatic organisms (including fish) or humans (who contact water during recreational or cultural activities). In preparation for choosing water quality thresholds for use in the water quality flyers, we reviewed numeric threshold values for each of the six presented water quality parameters from the Klamath River TMDLs (NCRWQCB 2010), the Karuk Tribe Water Quality

Control Plan (2014), and the Yurok Tribe Water Quality Control Plan (2004)(Table **3**). Generally, there was not a single threshold for each parameter. Instead, many thresholds varied by location on the river, season, time scale (i.e., daily vs. monthly goals), statistic (i.e., minimum vs. mean) and by agency or document presenting the thresholds. Many thresholds relied on averaging daily values or weekly samples over a defined period, resulting in statistics such as the seven-day average daily maximum, or the monthly average of all samples collected during the 30-day period. Some parameters also had multiple thresholds to indicate multiple tiers of water quality impairment.

Nutrient thresholds were variable by both time and location on the Klamath River. We selected the 0.022 mg/L threshold for total phosphorus and 0.182 mg/L threshold for total nitrogen because these were the thresholds for the halfway point of the river (Happy Camp to Orleans Reach) in mid-summer (July and August). Although these thresholds represent the lowest of the monthly and site-specific thresholds, use of the highest monthly and site-specific thresholds (Table **3**) did not change the interpretation that nutrient concentrations commonly exceeding the thresholds (Figure **2**).

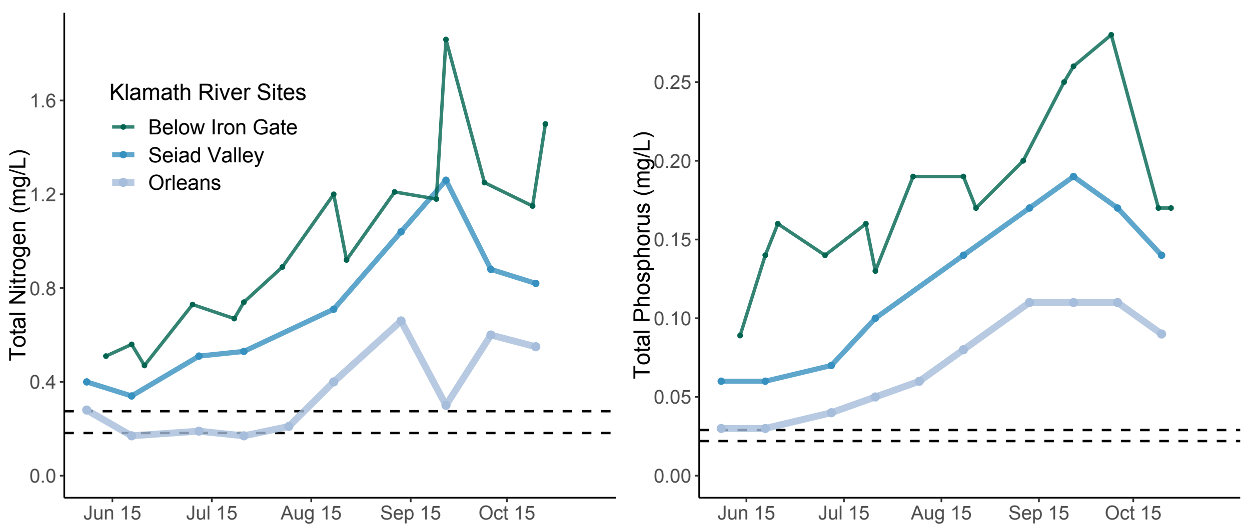

Figure 2. Total nitrogen (left panel) and total phosphorus (right panel) by date for the three mid-Klamath sample sites in 2017. The lower dotted line represents the lowest of the nutrient thresholds and the upper dotted line represents the highest nutrient threshold presented for the Klamath River below Iron Gate dam.

For the final numeric water quality thresholds presented in the flyers (Table 4) we simplified the water quality thresholds by applying the numeric thresholds to daily statistics (for daily data) or individual sample values (for grab sample data). We recognize that in some cases these thresholds were not designed to be directly compared with daily or single sample data for regulatory purposes, but we feel that the simplifications are necessary to make the thresholds more easily understand by a wide audience.

Table 3. List of numeric water quality thresholds from three different Klamath River regulatory documents.

Parameter	Document	Threshold	Statistic	Season	Location
Water Temperature	Yurok Tribe Water Quality Control Plan	<21˚C	Not specified	Not specified	Klamath River on the Yurok Reservation
	Karuk Tribe Water Quality Control Plan	<18˚C	7-day average daily max	All year	Klamath River
	Karuk Tribe Water Quality Control Plan	<13˚C	7-day average daily max	Sep-Jun	Klamath River
pH	Yurok Tribe Water Quality Control Plan	6.5–8.5	Range	Not Specified	Klamath River on the Yurok Reservation
	Karuk Tribe Water Quality Control Plan	7.0–8.5	Range	Not Specified	Klamath River
Dissolved oxygen	Karuk Tribe Water Quality Control Plan	> 90%	Daily minima	All year	Scott River to Orleans
	Karuk Tribe Water Quality Control Plan	> 85%	Daily minima	April –Sep	Doggett Creek to Scott River
	Klamath River TMDLs	> 90%	Daily minima	Oct – Mar	Iron Gate Dam to Scott River
	Klamath River TMDLs	> 85%	Daily minima	Apr –Sep	Iron Gate Dam to Scott River
	Klamath River TMDLs	> 90%	Daily minima	All year	Scott River to Weitchpec
	Klamath River TMDLs	> 85%	Daily minima	Jun – Aug	Weitchpec to Turwar
	Klamath River TMDLs	> 90%	Daily minima	Sep – May	Weitchpec to Turwar
Total phosphorus*	Klamath River TMDLs	0.022-0.026 mg/L	Monthly mean	May – Oct	Klamath Below the Salmon River
	Karuk Tribe Water Quality Control Plan	0.027-0.032 mg/L	Monthly mean	May – Oct	Doggett Creek to Scott River
	Karuk Tribe Water Quality Control Plan	0.025-0.029 mg/L	Monthly mean	May – Oct	Scott River to Happy Camp
	Karuk Tribe Water Quality Control Plan	0.022-0.026 mg/L	Monthly mean	May – Oct	Happy Camp to Orleans
Total nitrogen*	Klamath River TMDLs	0.182-0.242 mg/L	Monthly mean	May – Oct	Klamath Below the Salmon River
	Karuk Tribe Water Quality Control Plan	0.217-0.327 mg/L	Monthly mean	May – Oct	Scott River to Happy Camp
	Karuk Tribe Water Quality Control Plan	0.208-0.299 mg/L	Monthly mean	May – Oct	Happy Camp to Orleans
	Karuk Tribe Water Quality Control Plan	0.182-0.242 mg/L	Monthly mean	May – Oct	Klamath Below the Salmon River
Microcystin	Karuk Tribe Water Quality Control Plan	<0.8 µg/L	All Samples	All year	All locations
	Karuk Tribe Water Quality Control Plan	<4.0 µg/L	All Samples	All year	All locations
	Klamath River TMDLs	<4.0 µg/L	All Samples	All year	All locations

*Total phosphorus and total nitrogen are assigned specific thresholds by month in both the Karuk Tribe water quality control plan and the Klamath River TMDLs. See those documents for further detail.

Table 4. Selected water quality objects for Klamath River flyers with justification for each threshold

Parameter	Selected Threshold	Justification
Water temperature	18˚C (daily max)	We selected the year-round water temperature target from the Karuk Tribe Water Quality Control Plan, and applied it to the daily maximum water temperature for all Klamath River sites. Numeric temperature thresholds were presented in the Klamath River TMDL for Iron Gate Hatchery (monthly range from July-October of 19.1-10.4 ˚C), but not for down river locations.
pH	8.5 (daily max)	pH of 8.5 is the upper threshold listed in both the Karuk and Yurok Tribes' Water Quality Control Plans.
Dissolved oxygen	90% (daily min)	In the documents we reviewed, minimum daily dissolved Oxygen thresholds were set at 85 or 90% depending on the river section and season. We selected the 90% threshold for all sites for consistency because 90% was the year-round threshold for the longest reach of river, and the other reaches contained the 90% threshold for part of the season in which we presented data.
Total phosphorus	0.022 mg/L (daily max)	Thresholds for Total Phosphorus and Total Nitrogen were variable for river reaches and by month in both the Karuk Tribe Water Quality Control Plan and the Klamath River TMDLs, but thresholds in these documents were consistent for location and month. We selected 0.022 mg/L for Total Phosphorus and 0.182 mg/L for Total Nitrogen because these were the thresholds for the halfway point of the river (reach Happy Camp to Orleans) in mid-summer (July/August).
Total nitrogen	0.182 mg/L (daily max)	
Microcystin	0.8 µg/L (sample max)	Caution Action Trigger Level for human health - California Water Quality Monitoring Council; 0.8 µg/L was adopted as the action level by the Karuk Tribe and the warning level for the Yurok Tribe.

State of the Basin Plots

To describe algal toxin levels in the Klamath River, we presented microcystin data from grab samples collected in the Middle and Lower Klamath River (see methods section for detail of sample schedule and collection method). For the Mid-Klamath flyers we calculated how many times greater the average microcystin concentrations were than the 0.8 ug/L caution level by taking the mean of all microcystin samples collected in August and September at each site and dividing the mean value by 0.8 (Figure 1 on Mid-Klamath flyer). For example, if the mean August and September microcystin concentration was 1.6µg/L, then we would say that this value was 2x higher than the threshold. For the Lower Klamath flyer we displayed microcystin values in a table (Table 1 on Lower Klamath flyer) because the locations of Lower Klamath sites were too close in proximity to be clearly legible on the map. Additionally, microcystin values were highly variable, so we displayed the September and August mean, as well as the maximum microcystin. In both flyers, we displayed general seasonal trends (i.e., timing and magnitude) in microcystin values for each year from 2009–2017 (Figure 2 on Mid-Klamath flyer, Figure 1 on

Lower Klamath flyer). These figures show flexible curves[2] that are fit through all individual samples (including public health and baseline samples), with a different colored curve for each year. For simplicity and clarity, we do not show the individual data points, only the flexible curves.

Each State of the Basin flyer includes a matrix (Figure 3 on Mid-Klamath flyer, Figure 2 on Lower Klamath flyer) colored according to the percent of samples and daily statistics in the period that exceeded selected thresholds by site and year for each of the six water quality parameters from July through October (Table **4**). For sites and years when more thank 25% the data were missing or removed due to quality concerns, the figures show NA (not applicable due to lack of data) rather than incomplete values.

We plotted the 2017 time series of water quality data from three long-term monitoring sites for each water quality flyer. We plotted nutrient concentration from grab samples, daily minimum dissolved oxygen values, and daily maximum values of water temperature and pH by date, with horizontal lines showing the water quality thresholds. We compared these plots of 2017 water quality sample values and daily statistics to plots from previous years (2009-2017; Appendix A) to develop brief narratives comparing water quality conditions in 2017 to previous years.

Results and Conclusions

Klamath River State of the Basin water quality reports show compiled water quality data from sites along the Mid and Lower Klamath River in a succinct format that will be more accessible than commonly produced, long-format reports (Appendix B). Microcystin toxin was highlighted to inform river users of actual concentrations and the seasonal timing of algal toxin as it relates to public health risk, while water quality parameters including dissolved oxygen, pH, water temperature, and nutrients were displayed to show the water quality components that affect ecosystem health and fisheries. Inevitably, less information and a lower level of detail is included in these reports than previous more comprehensive ones, but we anticipate that water quality data from the Klamath River will reach a much wider audience through these two-page flyers.

Data displaying microcystin toxin concentrations showed similar patterns in both the Mid and Lower Klamath River score cards, as would be expected because microcystin is transported throughout the Klamath River from upstream reservoirs (Otten et al. 2015, Genzoli and Kann 2017). Microcystin toxins were highest in the Klamath River in August and September, with high values extending into October in some years (Figure 2, Mid Klamath and Figure 1, Lower Klamath). Microcystin toxin values in the Mid Klamath were highest in 2010, followed by 2017 (Figure 2, Mid Klamath), while in the Lower Klamath River the highest toxin concentrations

[2] The technical name for these curves is LOESS (Locally Estimated Scatterplot Smoothing), which is a type of polynomial regression.

occurred in 2017, followed by 2010 (Figure 1, Lower Klamath). There was a general downstream decline in microcystin toxin concentrations, with the highest August through September average concentrations exceeding the Karuk Tribe's caution level by 23-fold at the I5 Bridge sample site.

Water quality parameters describing ecosystem health were displayed for multiple years and sites, by color-coding each parameter by the number of samples that exceeded the water quality thresholds. These matrixes showed that nutrients; total phosphorus and total nitrogen; were the water quality parameter that most commonly exceeded the thresholds at all Klamath River sites. Generally, water quality increased from upstream to downstream sites, although some parameters showed exceptions to this pattern, including pH more frequently exceeding the threshold at Seiad Valley and Weitchpec than at downstream sites. Finally, although there was variation in the water quality exceedances among years, there was no clear pattern of water quality improving or worsening over the nine-year period presented based on the graphical analysis we displayed in these water quality flyers.

The 2017 State of the Basin water quality flyers represent the first iteration of succinct and broadly accessible water quality reports produced by the Klamath Tribal Water Quality Consortium. We sought to strike a balance of simplicity while still including data from many sites and water quality parameters. Independent water quality flyers for the Mid and Lower Klamath River were targeted to residents, visitors, natural resource professionals and policy makers in the sub-basins where they live, recreate, and work. We hope these flyers will lead to a more informed public, and that this information will make people feel empowered to make decisions about their personal water contact choices and to be involved in water quality issues in their communities.

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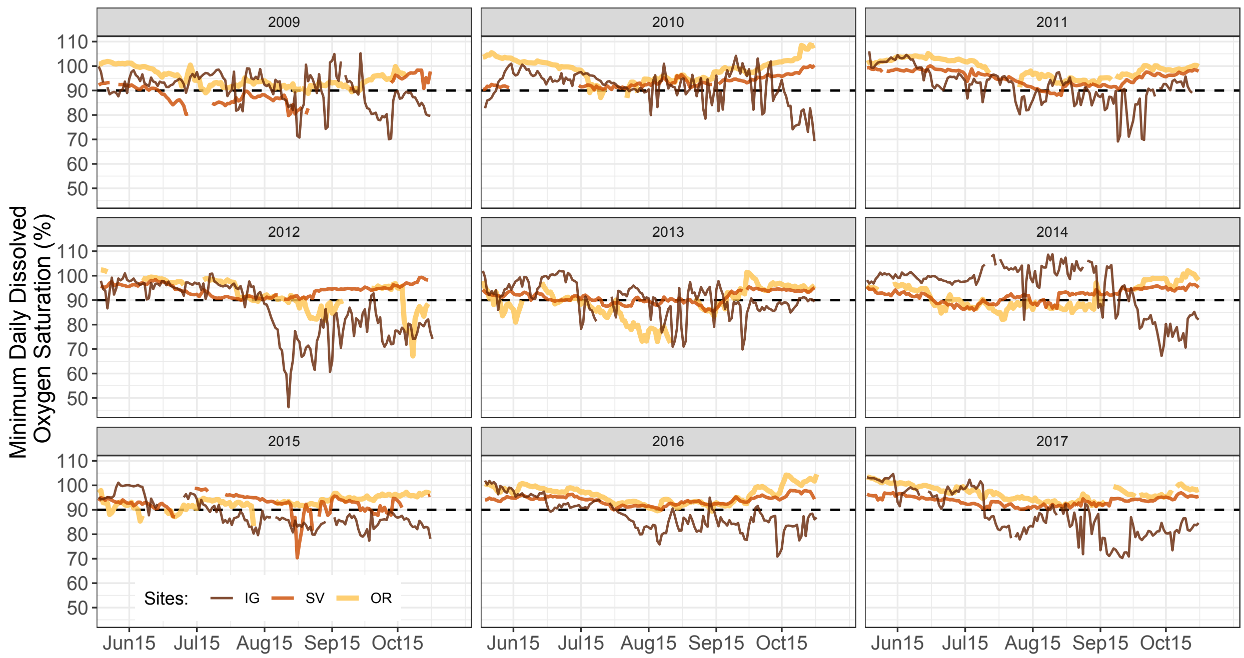
Appendix A: Time series water quality data graphs 2009–2017



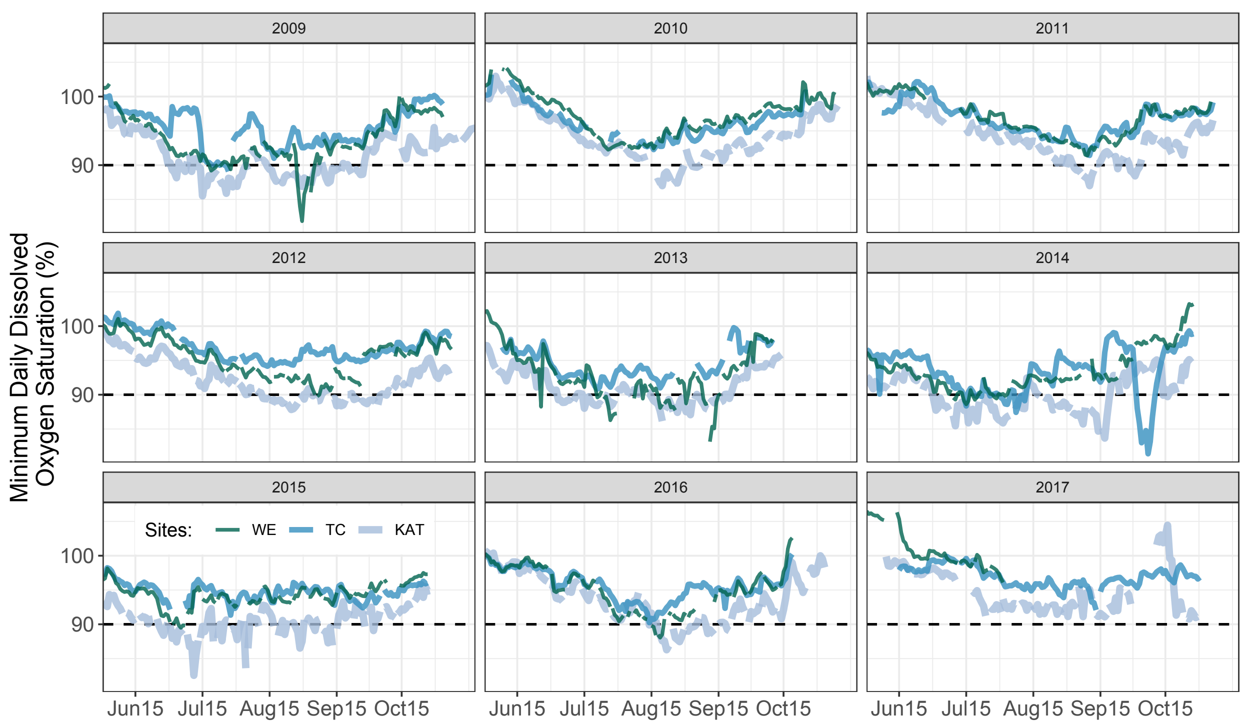


Figure A-1. Minimum daily dissolved oxygen saturation by date at three Mid-Klamath River sites (top panel) and three Lower Klamath River sites (bottom panel) from 2009 through 2017.

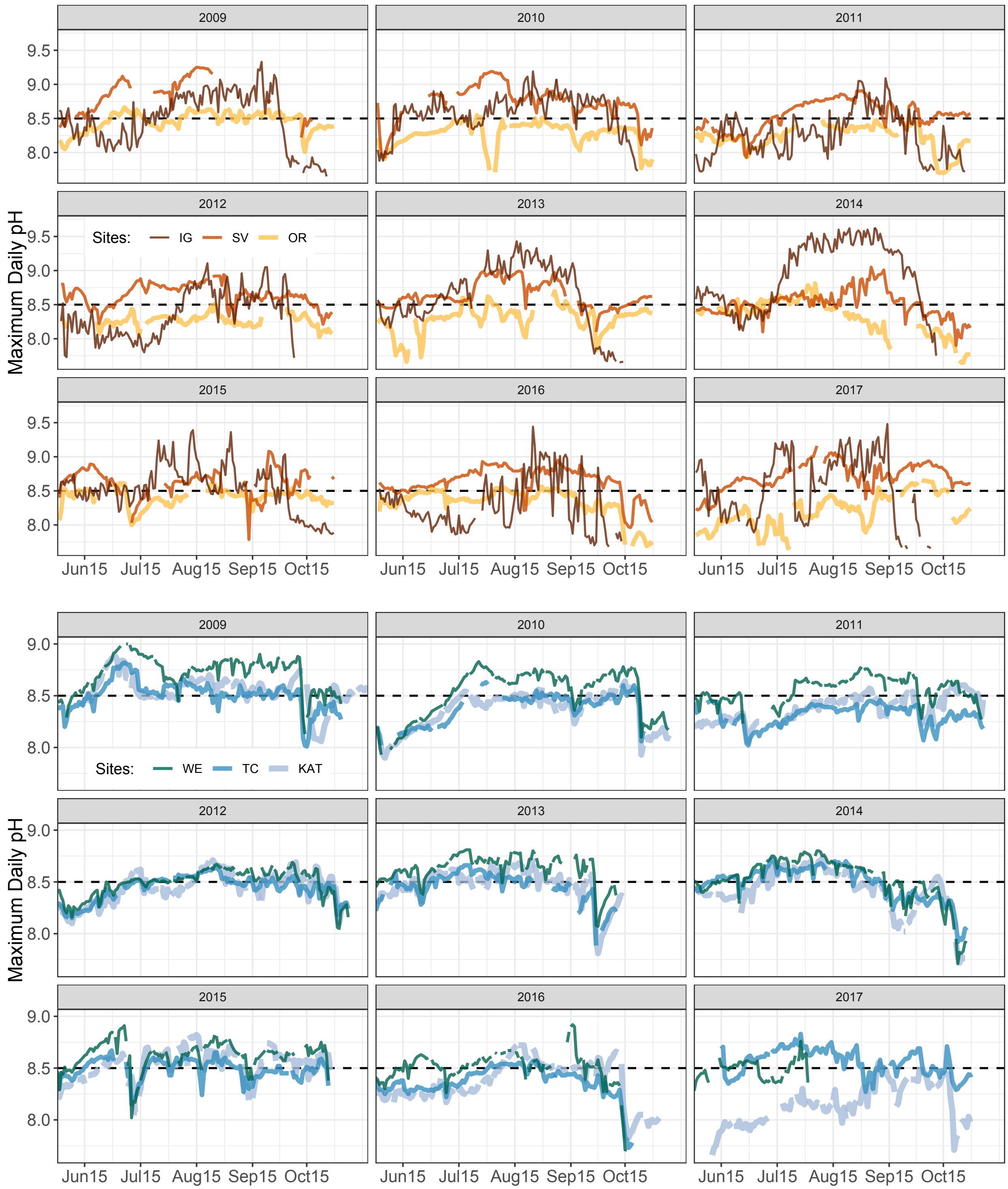


Figure A-2. Maximum daily pH by date at three Mid-Klamath River sites (top panel) and three Lower Klamath River sites (bottom panel) from 2009 through 2017.

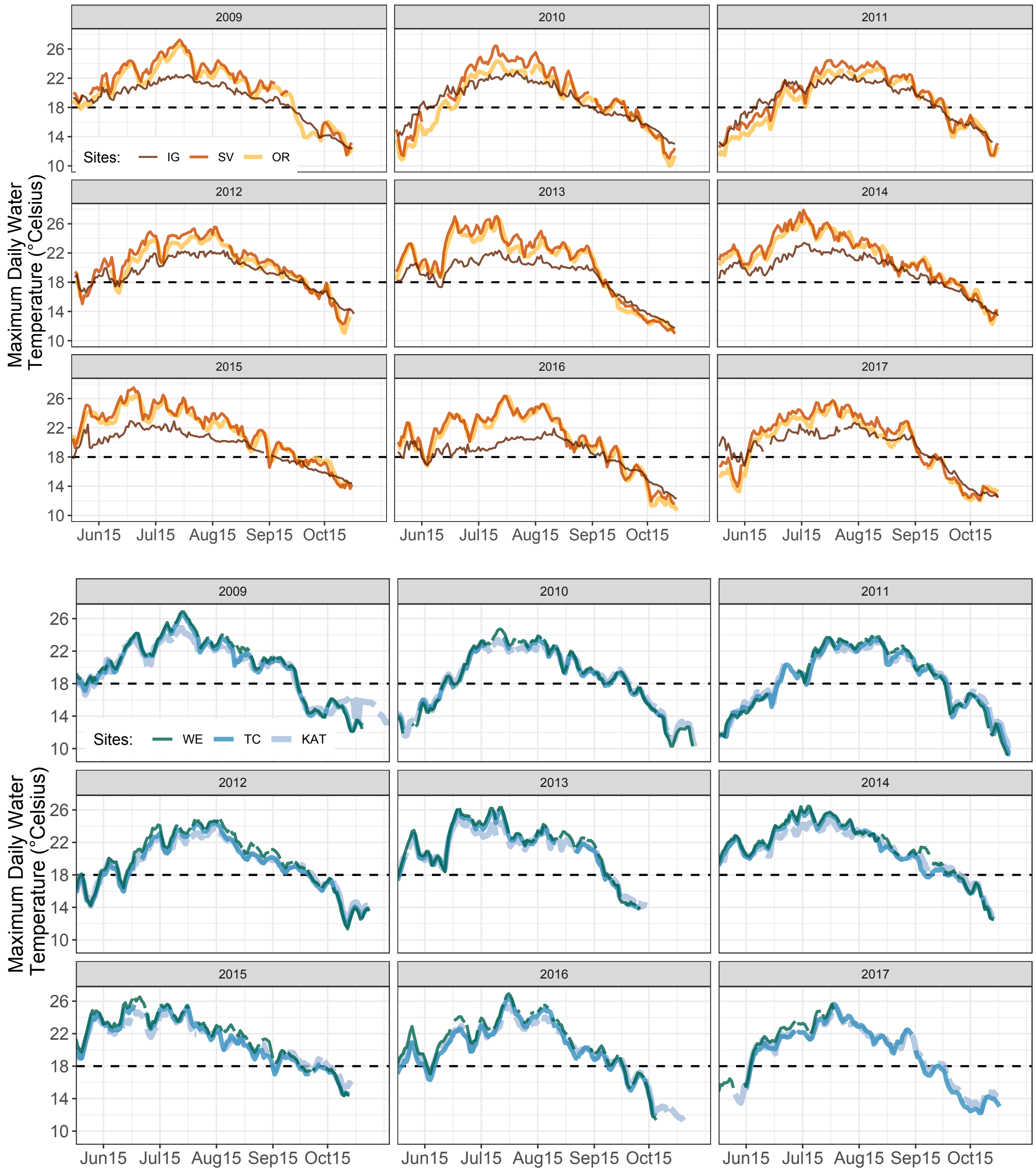


Figure A-3. Maximum daily water temperature (°Celsius) by date at three Mid-Klamath River sites (top panel) and three Lower Klamath River sites (bottom panel) from 2009 through 2017.

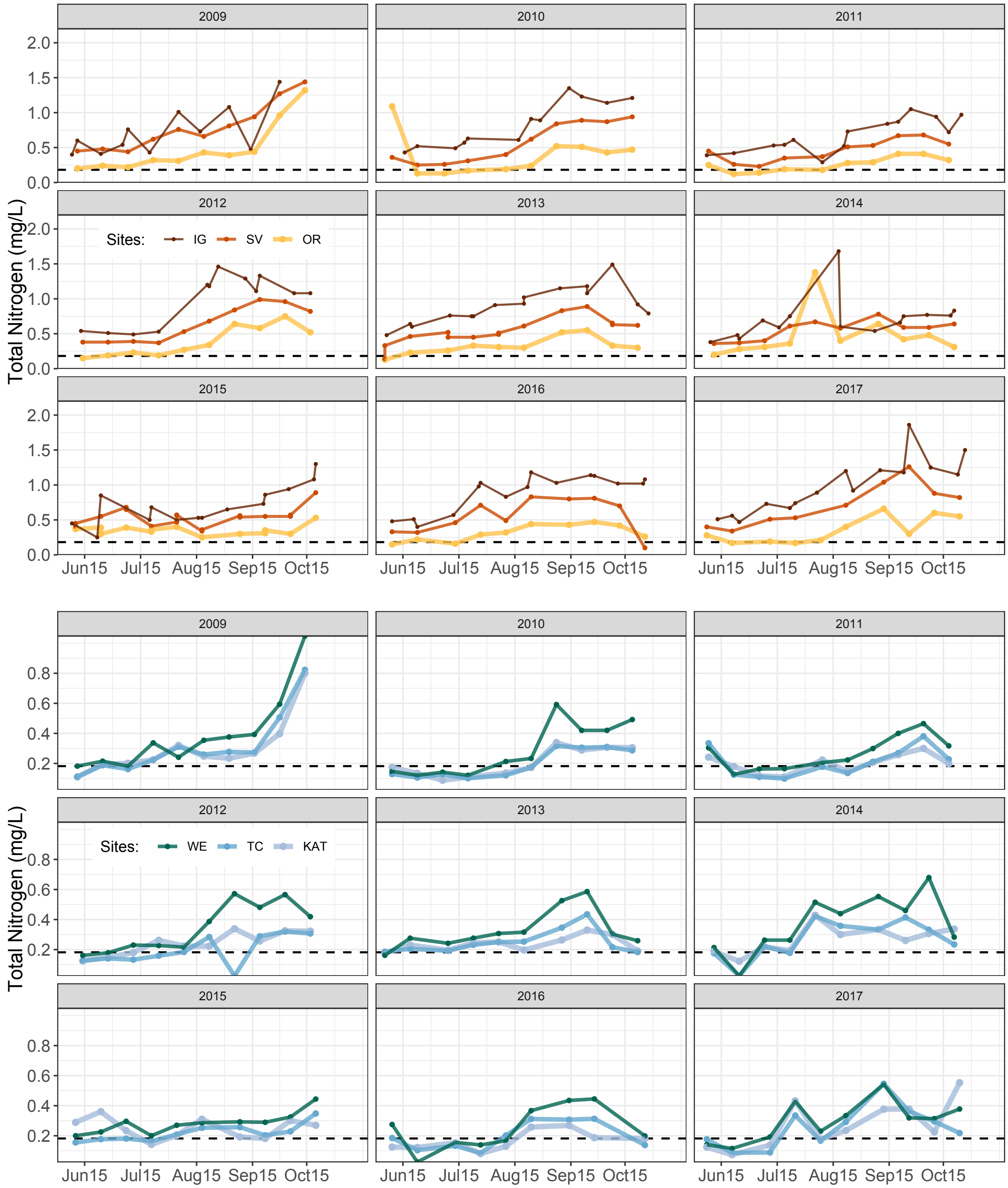


Figure A-4. Total Nitrogen by date at three Mid-Klamath River sites (top panel) and three Lower Klamath River sites (bottom panel) from 2009 through 2017.

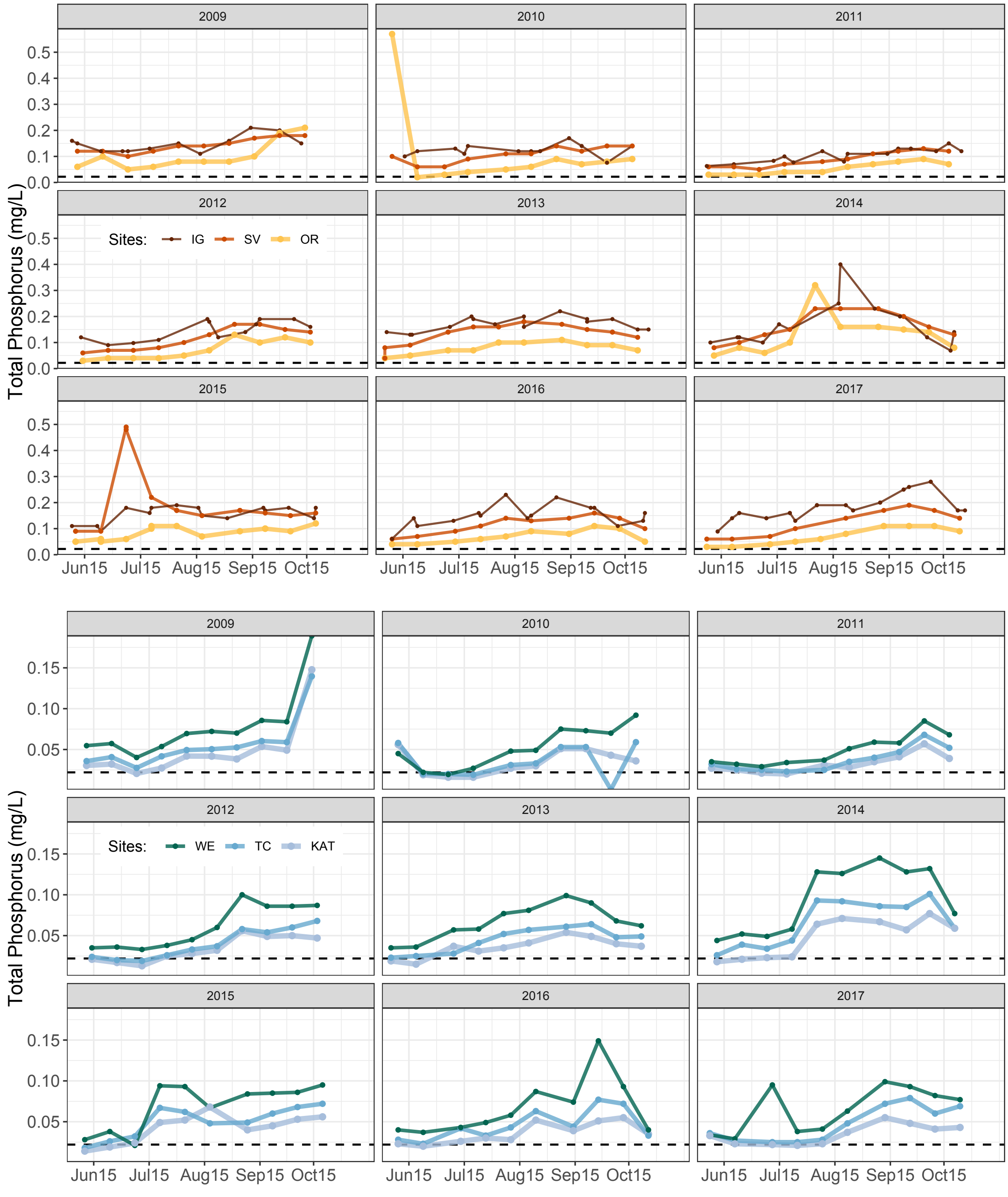


Figure A-5. Total Nitrogen by date at three Mid-Klamath River sites (top panel) and three Lower Klamath River sites (bottom panel) from 2009 through 2017.

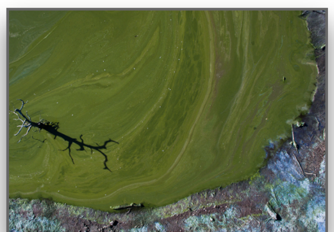
Appendix B: Klamath River Water Quality Flyers

The following pages contain the Mid Klamath and Lower Klamath two page water quality flyers created for 2017.

2017 MID KLAMATH WATER QUALITY

The Mid Klamath River extends from below Iron Gate Dam to below Orleans, California. Water quality here is degraded from dams, upstream water diversions and nutrient runoff from agriculture, and a legacy of mining, logging, and fire suppression throughout the watershed. Microcystin toxin from blue-green algae is a major human health concern. High water temperatures can be bad for fish and other tribal trust species, as can high pH and low dissolved oxygen from excessive algae growth driven by the high nutrients.

Microcystin toxin from blue-green algae in the Mid Klamath was on average 13-times higher than the caution level for the Karuk Tribe and State of California's public health threshold during August–September of 2017.



The algae, which produces microcystin toxin, blooms in the calm, nutrient-rich waters of Copco and Iron Gate reservoirs and is released downstream into the Klamath River.

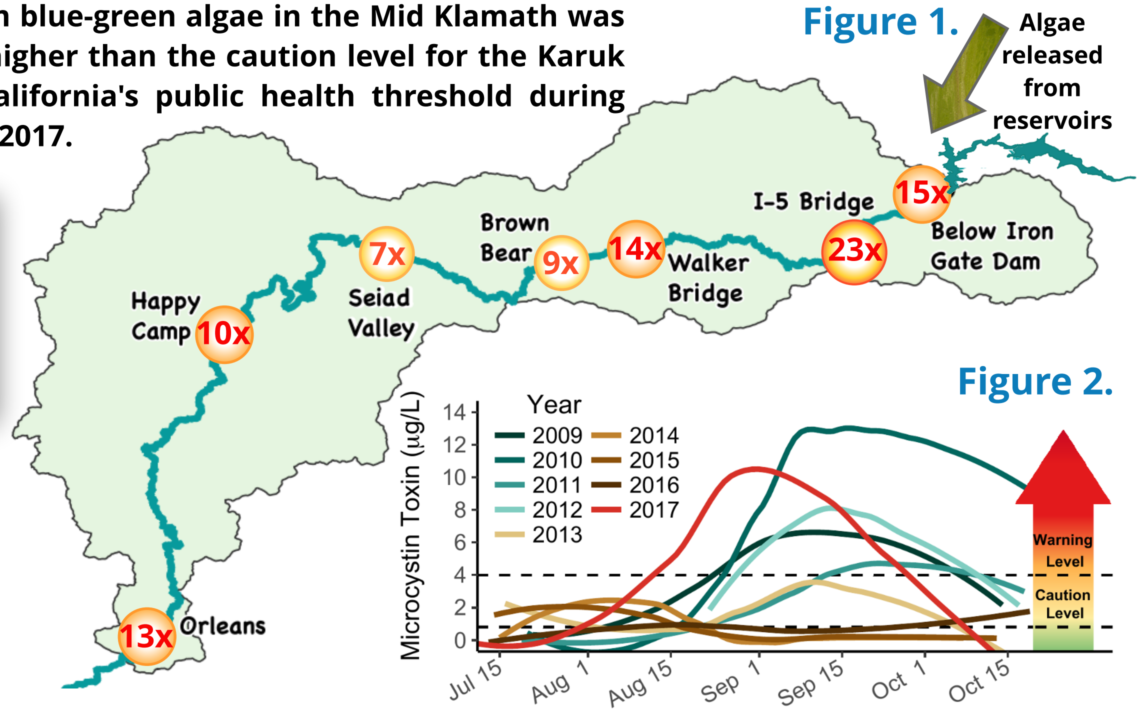
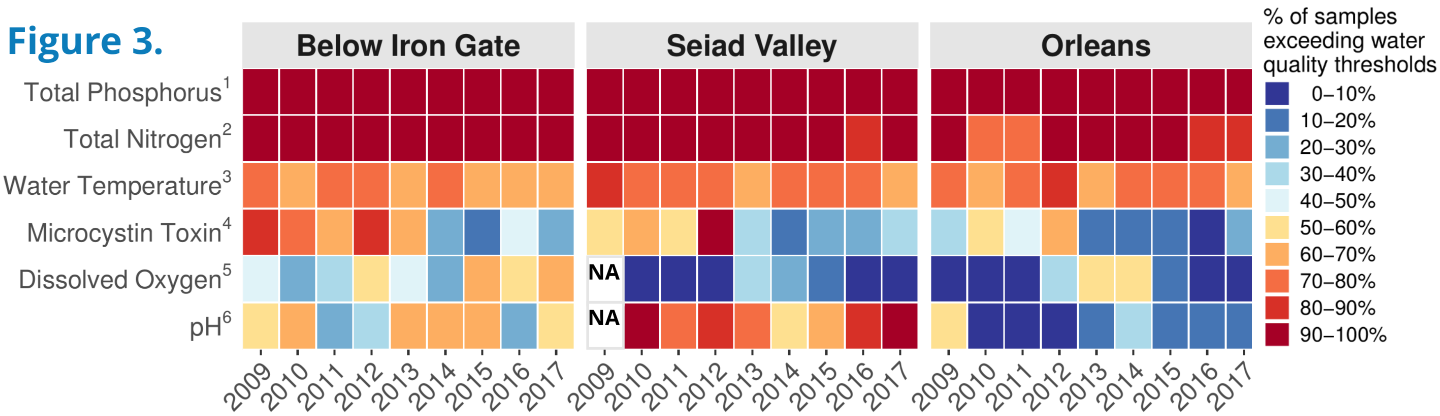


Figure 1. The Mid Klamath Watershed with algae sampling sites named in black. Circles show how many times higher the August–September mean toxin level was than the caution level at each site in 2017.

Figure 2. Seasonal microcystin trends compared among years (colored lines) show that toxins increased in late summer above the caution and warning levels (dashed lines). Note that colored lines represent average toxin levels and some individual samples were much higher.

Figure 3. The percent of samples that exceeded the water quality thresholds in the summer (Jun-Oct) for each of 6 parameters are shown by color for each year at 3 Klamath River sites. Thresholds are defined on the next page.



2017 WATER QUALITY RESULTS

Poor water quality in the Mid Klamath River is a threat to human health and fisheries. Tribal natural resource departments monitor water quality to inform state and federal processes, to observe changing conditions, and to inform the public about the status of the river. Below are the 2017 results.

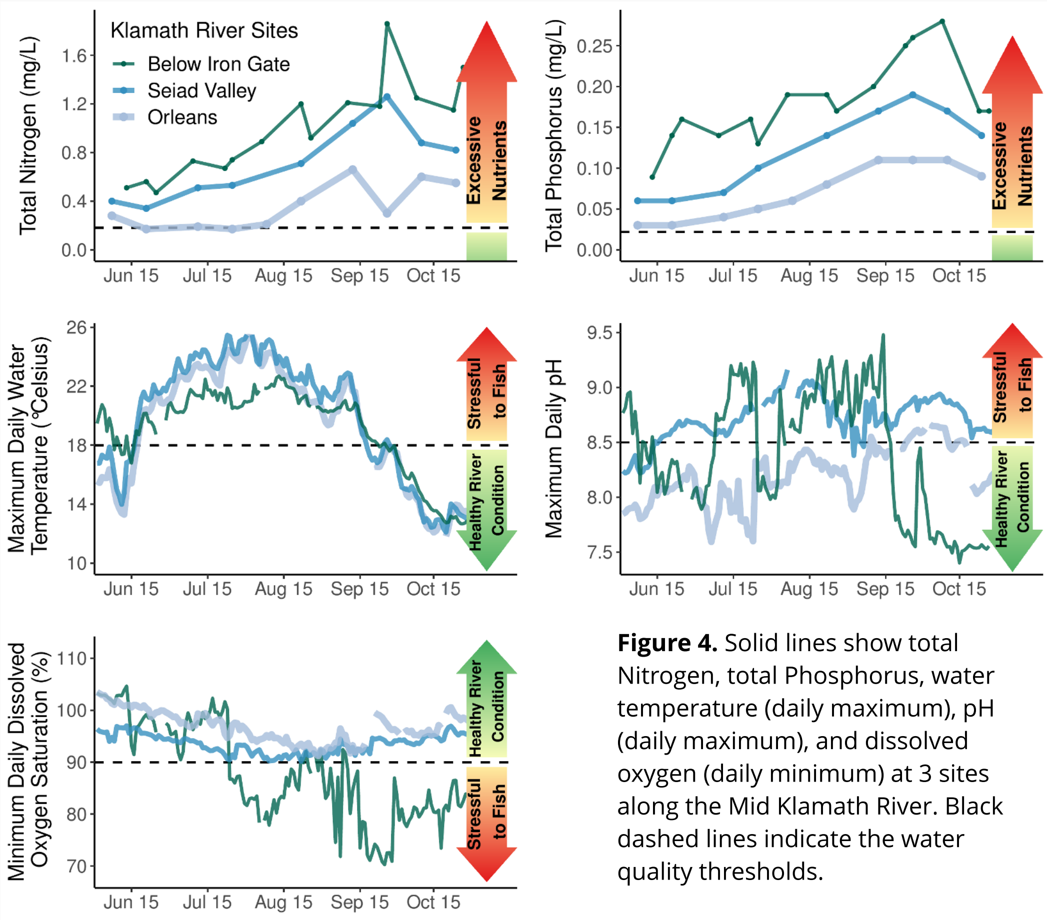


Figure 4. Solid lines show total Nitrogen, total Phosphorus, water temperature (daily maximum), pH (daily maximum), and dissolved oxygen (daily minimum) at 3 sites along the Mid Klamath River. Black dashed lines indicate the water quality thresholds.

Water quality followed similar trends in 2017 as in previous years:

Nutrients were high; most samples exceeded the thresholds for Nitrogen and Phosphorus.

Maximum daily water temperature was above the 18°C threshold from mid-June to mid-September.

Maximum daily pH decreased from Seiad to Orleans, but was more sporadic below Iron Gate.

Minimum daily dissolved oxygen was lowest below Iron Gate Dam and improved at downstream sites.

Microcystin Toxin was higher and present earlier in 2017 than in most previous years.

Stay informed about Klamath water quality!

For current information about blue-green algae blooms and water quality in the Mid-Klamath, check out the **Blue-Green Algae Tracker** at **http://kbmp.net**

The Klamath Tribal Water Quality Consortium created this handout using funding from U.S. EPA region 9. Published November 2018. The full report can be found at www.klamathwaterquality.com

Karuk Tribe

Yurok Tribe

Hoopa Valley Tribe

Quartz Valley Indian Reservation

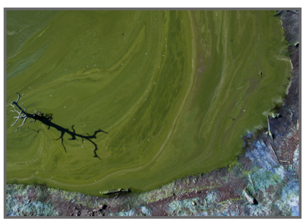
Resighini Rancheria

Water Quality Thresholds are based on Tribal and State standards set for the Klamath River. When seasonal and site-specific thresholds were presented, a single threshold was selected for use in this analysis. **1. Total Phosphorus:** 0.022 mg/L (upper limit); **2. Total Nitrogen:** 0.182 mg/L (upper limit); **3. Water temperature:** 18 °C (upper limit); **4. Microcystin:** 0.8 µg/L (caution level, upper limit); **5. Dissolved oxygen:** 90% (lower limit); **6. pH:** range of 7.0–8.5

2017 LOWER KLAMATH WATER QUALITY

The Lower Klamath River extends from above the confluence of the Trinity River to the Klamath Estuary. Water quality here tends to be better than up-river, but is still degraded from upstream diversions, nutrient runoff from agriculture, and dams. A legacy of mining, logging, and fire suppression throughout the watershed also impacts local water quality. Microcystin toxin from blue-green algae is a major human health concern. High water temperatures can be bad for fish and other tribal trust species, as can high pH and low dissolved oxygen from excessive algae growth driven by the high nutrients.

Algal Toxins in the Lower Klamath River



The blue-green algae that produces microcystin toxin blooms in the nutrient-rich waters of Copco and Iron Gate reservoirs, and is then released into the Klamath River. Microcystin toxin in the Lower Klamath was on average six times higher than the Yurok Tribe's warning level and the State of California's caution level (0.8 µg/L) during August and September of 2017. Young children and pets are at greatest risk of exposure because they often ingest water while swimming and playing in the river.

Figure 1. Seasonal microcystin trends compared among years (colored lines) show that average toxin levels increased in late summer above the caution and warning levels (dashed lines).

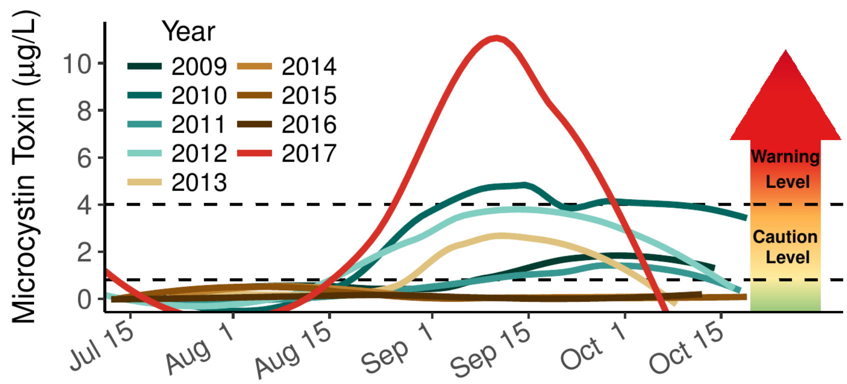
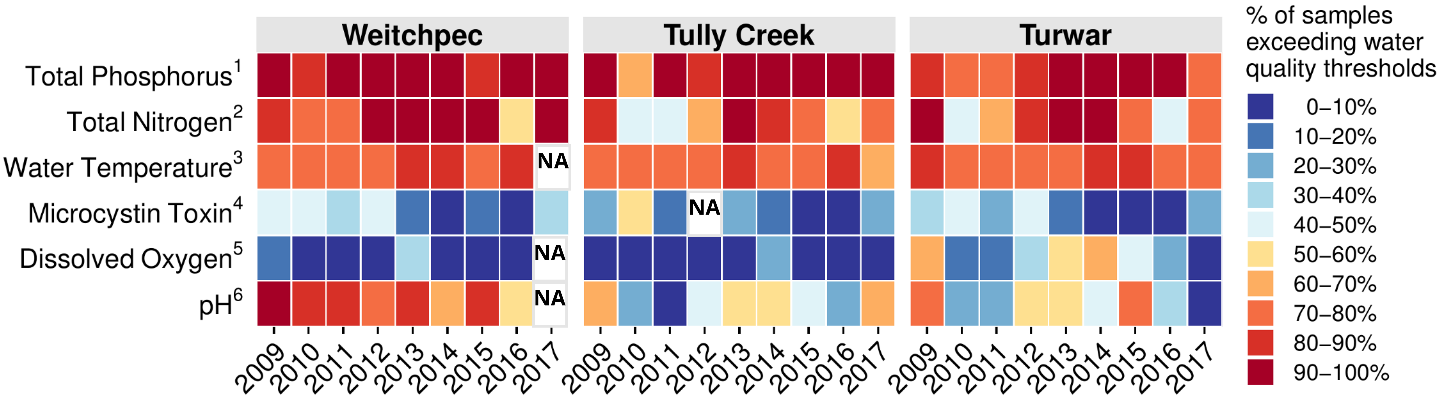


Table 1. Summary of microcystin toxin sample results at Lower Klamath River sites for August–September 2017

Sample Site	River Mile (from Ocean)	Average Microcystin Toxin (µg/L)	Highest Microcystin Toxin (µg/L)	Number of Samples
Weitchpec	43	6.1	30	13
Tully Creek	38	5.5	21	4
Turwar	7	3.9	13	12
Lower Estuary	0.5	4.6	17	4
South Slough	0.2	2.5	9	9

Figure 2. Water Quality Compared to Past Years: Percent of samples that exceeded water quality thresholds in the summer (July–October) by year at 3 Lower Klamath sites



2017 WATER QUALITY RESULTS

Poor water quality in the Lower Klamath River is a threat to human health and fisheries. Tribal natural resource departments monitor water quality to inform state and federal processes, to observe changing conditions, and to inform the public about the status of the river. Below are the 2017 results.

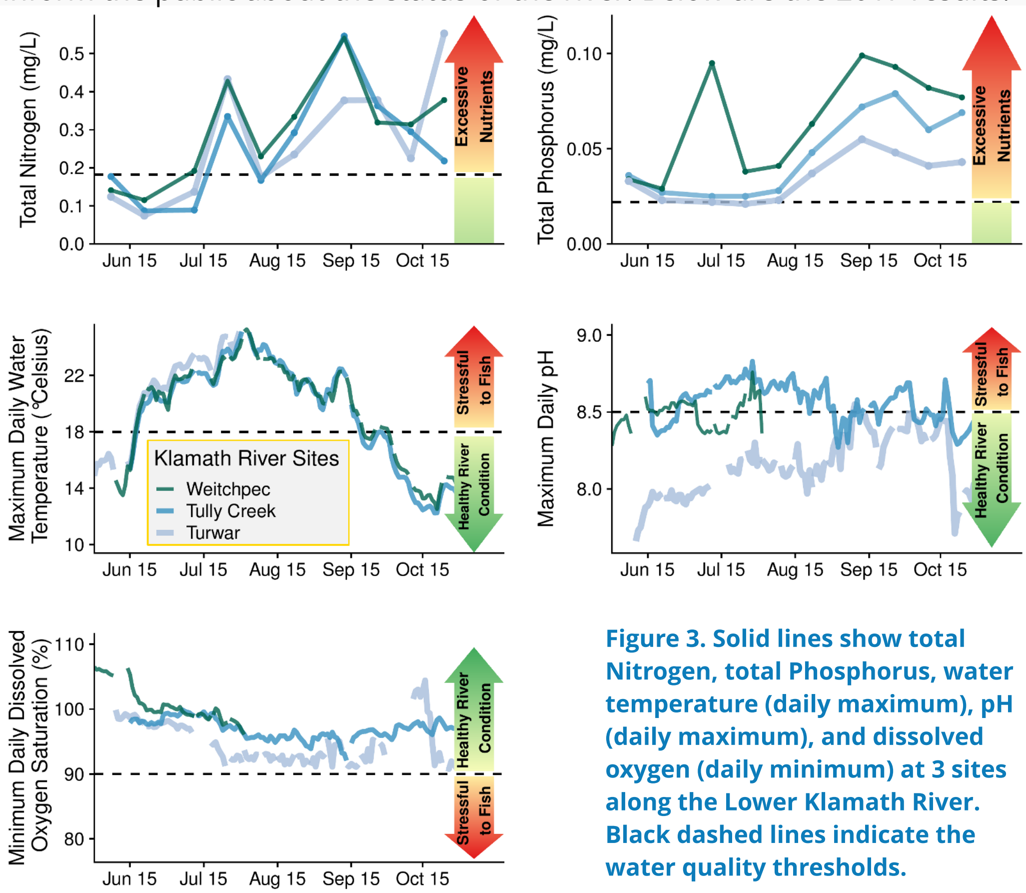


Figure 3. Solid lines show total Nitrogen, total Phosphorus, water temperature (daily maximum), pH (daily maximum), and dissolved oxygen (daily minimum) at 3 sites along the Lower Klamath River. Black dashed lines indicate the water quality thresholds.

Water quality followed similar trends in 2017 as in previous years:

Nutrients generally exceeded water quality thresholds, with highest concentrations in late summer

Maximum daily water temperature was above 18°C from mid-June to mid-September

Maximum daily pH generally decreased in a downstream direction from Weitchpec to Turwar

Minimum daily dissolved oxygen was maintained at higher (good) levels in 2017 than during most previous years

Stay informed about Klamath water quality!

For current information about blue-green algae blooms and water quality in the Lower Klamath, check out the **Blue-Green Algae Tracker** at **http://kbmp.net**

Water Quality Thresholds are based on Tribal and State Water Quality Objectives. When seasonal and site-specific thresholds were presented, a single threshold was selected for use in this analysis. **1. Total Phosphorus**: 0.022 mg/L (upper limit); **2. Total Nitrogen:** 0.182 mg/L (upper limit); **3. Water temperature:** 18 °C (upper limit); **4. Microcystin:** 0.8 µg/L (caution level, upper limit); **5. Dissolved oxygen:** 90% (lower limit); **6. pH:** range of 7.0–8.5

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Karuk Tribe | Yurok Tribe | Hoopa Valley Tribe | Quartz Valley Indian Reservation | Resighini Rancheria