3.4 Phytoplankton and Periphyton

This section focuses on potential effects of the Proposed Project on the phytoplankton and periphyton communities in the Klamath River. For the purposes of this EIR the following terms have the following meanings:

- Phytoplankton: aquatic microscopic organisms, including algae, bacteria, protists, and other single-celled plants, that obtain energy through photosynthesis and float in the water column of still or slowly flowing waters such as lakes or reservoirs.
- Periphyton: aquatic organisms including aquatic plants, algae, and bacteria that live attached to underwater surfaces such as rocks on a riverbed.
- Algae: common name for photosynthesizing organisms that are a component of phytoplankton and/or periphyton (see above definitions) where algae typically include diatoms, green algae, and blue-green algae.
- Blue-green algae: common name for a type of phytoplankton that can produce toxic compounds that have harmful effects on fish, shellfish, mammals, bird, and people. Though blue-green algae are a type of cyanobacteria they are commonly referred to as algae. Cyanobacteria toxins are often referred to as “algal toxins”. For readability, and to reduce confusion, this EIR will primarily refer to cyanobacteria as blue-green algae, with the exception of referencing source material.

In a balanced ecosystem, phytoplankton and periphyton supply base energy for the food web, because they convert energy from the sun (through photosynthesis) into biomass. In addition to sunlight, water and air, phytoplankton and periphyton also rely on nutrients from the water (primarily nitrogen and phosphorus). An excessive nutrient load in the water can allow phytoplankton and periphyton to overwhelm the ecosystem, causing negative impacts to water quality and other environmental resources. In addition to water quality and environmental impacts, blue-green algae can produce toxic compounds that have harmful effects on fish, shellfish, mammals, birds, and people.

The State Water Board received several comments related to blue-green algae during the NOP public scoping process (Appendix A), including comments indicating that dam removal would reduce the incidence of blue-green algae blooms and associated toxins in the Klamath River system. Commenters related numerous instances in which they linked health impacts to water contact in the presence of blue-green algae toxins, and they described having to limit recreation and avoid water contact due to blue-green algae despite the cultural importance of the river. Several commenters also noted that they no longer eat fish from the Klamath River due to concerns about consuming blue-green algae toxins with the fish. Other comments indicated that blue-green algae growth would continue to occur in the Klamath River in the absence of the Lower Klamath Project reservoirs. There were also several comments regarding periphyton, suggesting that dam removal would reduce the prevalence of attached algae in the Klamath River, which could reduce parasite rates in anadromous fish. A detailed summary of comments received during the NOP public scoping process, as well as individual comments, are presented in Appendix A.

Discussion of blue-green algae toxins and their impact on water quality are addressed in Section 3.2 *Water Quality*. Discussion of the relationship between periphyton and fish disease is addressed further with respect to aquatic organisms in Section 3.3.2.3.5 *Disease and Parasites*. Discussion of blue-green algae and its impact on recreation are addressed in Section 3.20 *Recreation*. Discussion of tribal cultural resources impacts of blue-green algae are addressed in Section 3.12 *Historical Resources and Tribal Cultural Resources* and Appendix V to this EIR.

3.4.1 Area of Analysis

The Area of Analysis for phytoplankton and periphyton includes multiple reaches of the Klamath River, as listed below and shown in Figure 3.4-1.

Upper Klamath Basin

- Hydroelectric Reach (upstream end of J.C. Boyle Reservoir to Iron Gate Dam)

Mid-Klamath Basin

- Klamath River from Iron Gate Dam downstream to the confluence with the Salmon River
- Klamath River from the confluence with the Salmon River to the confluence with the Trinity River

Lower Klamath Basin

- Lower Klamath River from the confluence with the Trinity River to the Klamath River Estuary
- Klamath River Estuary
- Pacific Ocean nearshore environment

Note that the portion of the Hydroelectric Reach that extends into Oregon (i.e., from the Oregon-California state line [RM 214.1] to the upstream end of J.C. Boyle Reservoir) is only being considered in this chapter to the extent that conditions in this reach influence phytoplankton and periphyton communities downstream in California.

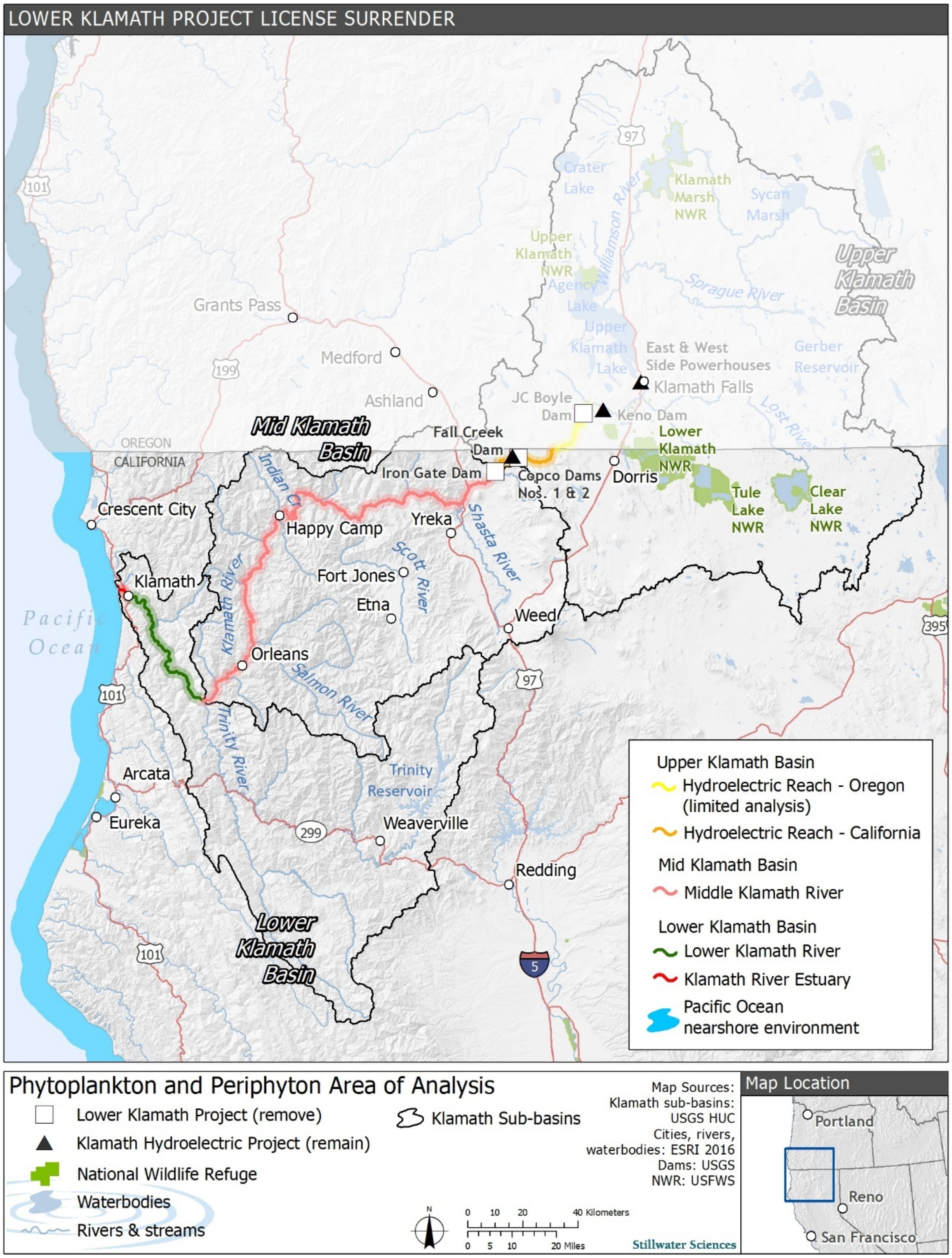

Figure 3.4-1. Klamath River Reaches Included in the Area of Analysis for Phytoplankton and Periphyton.

3.4.2 Environmental Setting

Phytoplankton and periphyton (defined in bullets at the beginning of in Section 3.4) are the two primary groups of algae (i.e., algal communities) in the Area of Analysis. Phytoplankton, including blue-green algae, compose the majority of the algal community in the reservoirs since phytoplankton prefer relatively still water. In the Klamath Basin, blue-green algae frequently reach nuisance levels within Upper Klamath Lake, Copco No. 1 Reservoir, and Iron Gate Reservoir. In addition, blue-green algae can be found in portions of the Klamath River (e.g., backwater eddies and near shore shallows) where blue-green algae cells from upstream lakes and the Lower Klamath Project reservoirs have drifted downstream. These portions of the river can also support nuisance levels of blue-green algae under certain conditions. Typically, most of the riverine portions of the Klamath River are dominated by periphyton, which include diatoms, green algae, fungi, and bacteria that attach to the stream bed and/or other underwater surfaces. Larger aquatic plants may also be present in quiet backwater areas in the Klamath River; however, no known quantitative or species-specific information about these plants has been collected in the phytoplankton and periphyton Area of Analysis. Since no surveys have been conducted to determine the relative distribution or biomass[100] of large aquatic plants in the Klamath River, they are not discussed further in this section. Wetland and riparian habitat, along with associated plant species, are discussed in Section 3.5 *Terrestrial Resources*.

3.4.2.1 Phytoplankton

A number of different groups of organisms contribute to the phytoplankton communities in the Klamath River and mainstem reservoirs, including diatoms, green algae, and blue-green algae. The composition of the phytoplankton communities shifts seasonally in response to changing temperature, light, and nutrient levels. Phytoplankton form the base of the food web in lakes and reservoirs throughout the world; they are consumed by zooplankton, insects, and some small fish, which are fed upon by larger fish, birds, mammals, and humans. Diatoms and green algae are generally considered to be beneficial components of phytoplankton communities based on their important role supplying nutrients to the food web. When phytoplankton communities reach high concentrations in the water column (e.g., greater than 10 to 15 micrograms per liter [ug/L] of water), the species composition often shifts from the more beneficial green algae species to nuisance blue-green algae species. The shift in species composition can happen quickly (i.e., in days) due to blue-green algae's relatively fast reproductive rates.

At high biomass levels, phytoplankton can create nuisance water quality conditions. A primary driver of nuisance conditions is extreme diel (daily) fluctuations in dissolved oxygen and pH due to the process of photosynthesis (the consumption of carbon dioxide and waste production of oxygen) and cellular respiration (the consumption of oxygen and waste production of carbon dioxide). During daylight hours, phytoplankton use sunlight to conduct photosynthesis, increasing the dissolved oxygen concentrations in water. Photosynthesis stops in the evening when sunlight is not available. During the night, cellular respiration consumes dissolved oxygen and results in decreases in dissolved oxygen concentrations in the water column. During both daylight and evening hours, dead and decaying phytoplankton are consumed by aerobic bacteria, using

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[100] The total mass of organisms in a given area or volume.

dissolved oxygen from the water column and at times contributing to decreases in dissolved oxygen levels below those sufficient to support aquatic organisms (e.g., fish). The pH of water fluctuates with daily variations in photosynthesis and respiration. Photosynthesis consumes carbon dioxide in the water, such that when photosynthesis dominates during the day the pH increases. Cellular respiration releases carbon dioxide that, in contact with water, forms carbonic acid, decreasing the pH during the evening. Microbial decomposition of dead phytoplankton can also release free ammonia into the water column as cellular nitrogen is converted into ammonia, especially after a bloom when a high concentration of dead phytoplankton cells is being decomposed. Variations in dissolved oxygen, pH, and ammonia due to phytoplankton are primarily driven by the availability of sunlight and the resulting variations in the amount of photosynthesis and respiration. As more sunlight is available during summer months, there is generally more for photosynthesis at this time of year and a higher potential for larger variations in dissolved oxygen and pH in lakes, reservoirs, and rivers. In addition to dissolved oxygen, pH, and at times ammonia, high concentrations of blue-green algae species, such as *Anabaena flos-aquae* and *Microcystis aeruginosa,* can produce nuisance levels of algal toxins (e.g., anatoxin-a and microcystin) that are harmful to fish, mammals, and humans (see also Section 3.2.2.7 *Chlorophyll-a and Algal Toxins*).

The stable lacustrine[101] environment created by Copco No. 1 and Iron Gate dams, coupled with high nutrient availability and high water temperatures in summer and fall months, provides ideal conditions for phytoplankton growth, especially the growth of blue-green algae species (Figure 3.4-2 and Figure 3.4-3). While cyanobacteria [blue-green algae] can be found in a variety of lake, reservoir, river, and estuarine environments, the cyanobacteria [blue-green algae] species *Anabaena flos-aquae* and *Microcystis aeruginosa* thrive in warm, high nutrient, and stable water column conditions (Konopka and Brock 1978; Kann 2006; Asarian and Kann 2011), where they can out-compete other beneficial algae species such as diatoms and green algae (Visser et al. 2016). While they do not thrive in fast-moving water, diatoms and green algae do not regulate their buoyancy, and thus they rely on mixing in the water column (e.g., from wind, convection, or slow currents) to remain suspended near the water surface where light is available for photosynthesis. In reservoirs with warm water and a stable water column, diatoms and green algae tend to settle out of the water column away from sunlight. Cyanobacteria [blue-green algae] cells contain gas sacs (vesicles[102]), so they can control their buoyancy and remain near the water surface to obtain light for photosynthesis (Walsby et al. 1997). The ability to control their density and position in the water column gives blue-green algae better access to light and they can shade phytoplankton lower in the water column. Thus, blue-green algae are able to outcompete diatoms and/or green algae under lower mixing conditions in reservoirs. *Microcystis aeruginosa* can dominate the phytoplankton community in calm, stable lacustrine conditions, when their ability to float exceeds the rate of turbulent mixing in the water column (Huisman et al. 2004). However, blue-green algae abundance in the phytoplankton community decreases compared to diatoms and green algae when water column mixing in a water body increases (McDonald and Lehman 2013; Visser et al. 2016).

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[101] Pertaining to a lake, reservoir, or other calm water types.

[102] A small bubble-like hollow sac within a cell made of rigid proteins and filled with gas (Walsby 1994).

Figure 3.4-2. Dense summer and fall blue-green algae bloom in Iron Gate Reservoir with higher concentrations of blue-green algae occurring along the shoreline of the reservoir in slower moving water. Photo courtesy of the Karuk Tribe. Source: NMFS 2012.

Figure 3.4-3. Blue-green algae bloom along the Copco No. 1 shoreline on 7/13/2005. Source: Kann and Corum 2006.

As discussed above, blooms of floating algae (i.e., phytoplankton) can have negative impacts on water quality related to daily fluctuations in dissolved oxygen, pH, and nutrients such as ammonia. In the Klamath River, nuisance water quality conditions associated with phytoplankton are dominated by blooms of cyanobacteria [blue-green algae] species for both reservoir (Copco No. 1 and Iron Gate) and river portions of the Klamath River, particularly in the summer months (Asarian and Kann 2011; Gibson 2016). Within the phytoplankton and periphyton Area of Analysis, blue-green algae productivity is locally and seasonally associated with extreme daily fluctuations in dissolved oxygen levels (high during the day and low at night), elevated pH (above 8 s.u.), and free ammonia concentrations. Blue-green algae have a high cellular nitrogen content, so microbial decomposition of dead blue-green algae after a bloom can generate a relatively high amount of free ammonia and result in a further decrease in the water column's pH. Multiple reaches of the Klamath River from the Oregon-California state line to the Klamath River Estuary are included on the Clean Water Act (CWA) Section 303(d) list of water bodies with water quality impairments for water temperature, organic enrichment/dissolved oxygen, nutrients, and microcystin concentration (USEPA 2010) (Table 3.2-3). Organic enrichment and dissolved oxygen depressions are particularly problematic during the summer and fall months when water temperatures are relatively high.

Nuisance and/or noxious algal blooms that occur in the phytoplankton and periphyton Area of Analysis are primarily composed of three species of blue-green algae: *Aphanizomenon flos-aquae*, *Anabaena flos-aquae*, and *Microcystis aeruginosa*. While these blue-green algae species are a natural part of aquatic systems in California, including the Klamath River, environmental conditions that favor the growth and bloom of these blue-green algae species have been created by human modifications to the Klamath River (e.g., dams on the Klamath River that form slow-moving or stagnant water and additional inputs of nutrients above natural conditions). Blooms of these blue-green algae species can cause water quality and human health concerns because these species have been associated with the release of algal toxins (State Water Board et al. 2010, updated 2016).

Aphanizomenon flos-aquae

Aphanizomenon flos-aquae is a filamentous (thread-like), nitrogen-fixing cyanobacteria [blue-green algae] that is common in the Klamath Basin, especially in Upper Klamath Lake where it can comprise more than 90 percent of blue-green algae bloom biovolume (Figure 3.4-4 and Figure 3.4-5; Kann 1997; Eldridge et al. 2012). Nitrogen fixation is a cellular process where nitrogen gas in the air is converted into a biologically useful form of nitrogen for cellular growth. *Aphanizomenon flos-aquae* can thus provide its own source of nitrogen for algal growth, giving it a competitive advantage over non-nitrogen fixing algae species when phosphorus is abundant, but nitrogen is not. *Aphanizomenon flos-aquae* accounted for approximately 39 percent of the total phytoplankton biovolume measured between June and November 2007 at 21 sites in the Klamath Basin from the Upper Klamath Lake to Turwar, including Copco No. 1 and Iron Gate reservoirs (Raymond 2008). In a study of phytoplankton abundance at nine reservoir and river sites in the Hydroelectric Reach (i.e., Klamath River upstream of J.C. Boyle Reservoir to Iron Gate Dam), *Aphanizomenon flos-aquae* made up approximately 26 percent of the total phytoplankton biovolume measured in 106 samples collected during 14 sampling events in January and May through December 2009 (Raymond 2010). While members of the *Aphanizomenon* genus have been shown to produce cylindrospermopsin[103] and several neurotoxins in laboratory cultures, they have not been shown to produce microcystin. Thus, while *Aphanizomenon flos-aquae* is commonly found in the Klamath Basin, it is not likely to be the source of microcystin in the Klamath River (Eldridge et al. 2012). Nitrogen fixation by *Aphanizomenon flos-aquae* can provide a new nitrogen source within lakes and rivers when *Aphanizomenon flos-aquae* cells die and decay releasing fixed nitrogen and other nutrients contained in their cells. The additional nitrogen released can provide nutrients for *Microcystis aeruginosa,* potentially promoting *Microcystis aeruginosa* growth later in the season (discussed further below).

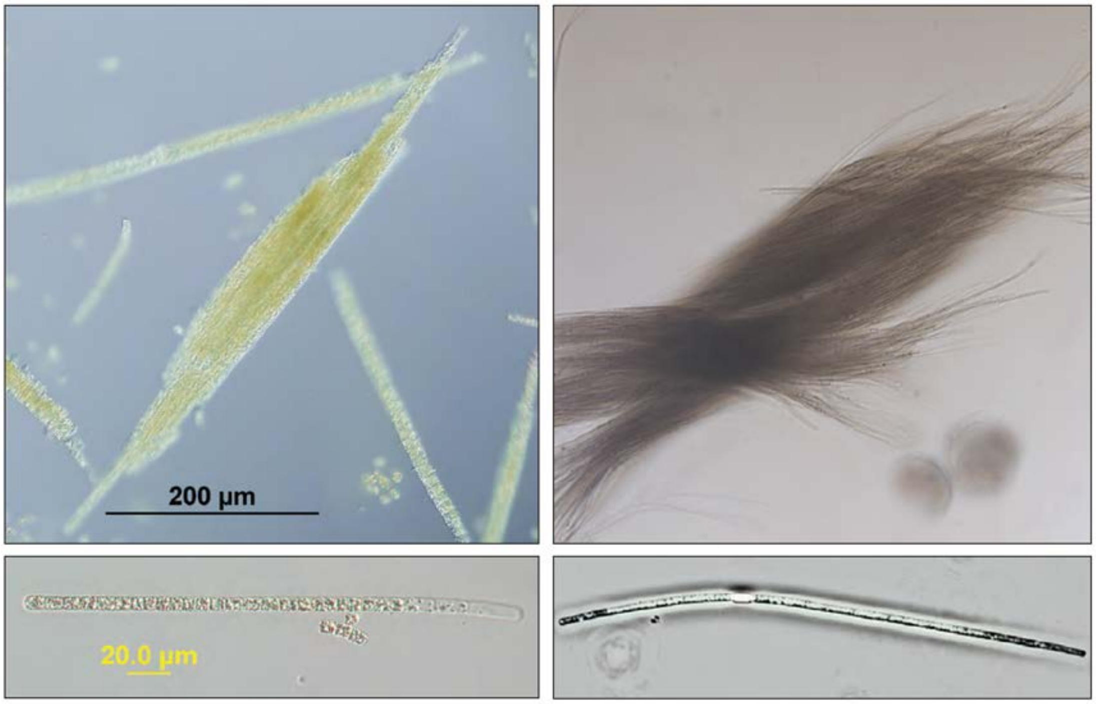

Figure 3.4-4. Microscopic View of *Aphanizomenon flos-aquae* Showing it in Bundles (upper left and right images) and Individual Filaments (lower left and right images). Photographs: Left, Barry H. Rosen; Right, Ann St. Amand. Source: Rosen and St. Amand 2015.

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[103] An algal toxin associated with adverse health effects such as gastrointestinal, liver inflammation and hemorrhage, pneumonia, dermatitis, malaise, and long-term liver failure (Lopez et al. 2008). Cylindrospermopsin were only detected near or less than the method detection limit (<0.05 parts per billion) in the Upper Klamath Lake (Eldridge et al. 2012).

Figure 3.4-5. *Aphanizomenon flos-aquae* bloom. Photograph: Jacob Kann. Source: Rosen and St. Amand 2015.

Anabaena flos-aquae[104]

Anabaena flos-aquae is also a filamentous (thread-like) nitrogen-fixing blue-green algae that occurs in the Klamath Basin (Figure 3.4-6; Kann 1997; Eldridge et al. 2012). Similar to *Aphanizomenon flos-aquae, Anabaena flos-aquae* can provide its own source of nitrogen for growth through nitrogen fixation and thus it has a competitive advantage over non-nitrogen fixing phytoplankton species under high phosphorous and low nitrogen conditions in streams or reservoirs. In phytoplankton sampling between June and November 2007, at 21 sites in the Klamath Basin from the Upper Klamath Lake to Turwar, including Copco No. 1 and Iron Gate reservoirs, *Anabaena flos-aquae* occurrence was low (i.e., less than 10 percent of samples). It was primarily found in Copco No. 1 and Iron Gate reservoirs, but it typically had low biovolumes on the order of 10,000 cubic micrometers per milliliter (um^3/mL) (Raymond 2008). In 2009, *Anabaena flos-aquae* comprised approximately 0.2 percent of the total phytoplankton biovolume measured in 106 samples collected during 14 sampling events at nine reservoir and river sites in the Hydroelectric Reach in January and May through December (Raymond 2010). Photographs of an algae bloom composed of primarily *Anabaena flos-aquae* are not available for the Klamath Basin, since it has not been found in isolation and has occurred at such low biovolumes.

Anabaena flos-aquae can produce several types of toxins, including anatoxin-a and microcystin (Lopez et al. 2008). Anatoxin-a is a neurotoxin which can cause irritation,

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[104] *Anabaena flos-aquae* was recently renamed *Dolichospermum flos-aquae*. However, this EIR continues to use the *Anabaena* name since it was more frequently used in the literature cited and it is still commonly used in descriptions of this species.

muscle twitching, paralysis, and death. It was detected in September 2005 during one sampling event in Iron Gate Reservoir, at levels ranging from 22 to 34 µg/L (T. Mackie, pers. comm., 2005). Additional details about anatoxin-a concentrations measured in the Klamath River are found in Section 3.2.2.7 *Chlorophyll-a and Algal Toxins* and Appendix C – Section C.6 *Chlorophyll-a and Algal Toxins*. While anatoxin-a has been measured in the Klamath Basin, the extent of anatoxin-a production by *Anabaena flos-aquae* in the Area of Analysis for phytoplankton and periphyton is largely unknown due to the limited sampling to date. Toxin production by some strains of *Anabaena flos-aquae* appears to be sporadic, and the circumstances which prompt toxin production are unknown. While *Anabaena flos-aquae* have also been found to produce the algal toxin microcystin (Lopez et al. 2008), it is widely assumed that the severe blooms of *Microcystis aeruginosa* in the Area of Analysis are responsible for the detected concentrations of microcystin rather than *Anabaena flos-aquae* because the measured biovolume of *Anabaena flos-aquae* is typically much less than the *Microcystis aeruginosa* biovolume. The relative proportion of microcystin contributions from *Anabaena flos-aquae* versus *Microcystis aeruginosa* has not been documented for the Klamath Basin.

Figure 3.4-6. Microscopic view of *Anabaena flos-aquae,* recently renamed *Dolichospermum flos-aquae*. Source: Kudela Lab 2018.

<u>Microcystis aeruginosa</u>

Microcystis aeruginosa is a round- or oval-shaped unicellular, colony-forming cyanobacteria [blue-green algae] (Figure 3.4-7 and Figure 3.4-8; Eldridge et al. 2012). *Microcystis aeruginosa* are not capable of nitrogen fixation, unlike *Aphanizomenon flos-aquae* or *Anabaena flos-aquae*, so this species is dependent on ammonia and other nitrogen sources for growth, and the availability of nitrogen in the water column may limit their occurrence in portions of the Klamath Basin (Eldridge et al. 2012). In phytoplankton sampling conducted in Iron Gate and Copco No. 1 reservoir ranging from 2005 through 2010, *Microcystis aeruginosa* accounted for up to approximately 78 percent of the total phytoplankton biovolume in some samples collected at open water reservoir monitoring stations (Raymond 2008, 2009, 2010; Asarian et al. 2011), suggesting favorable habitat conditions in the reservoirs for this species.

Analysis of blue-green algae species present in the Klamath River from the Upper Klamath Lake to Turwar identified Iron Gate Reservoir as the principal source of *Microcystis aeruginosa* to the Klamath River downstream of Iron Gate Dam. Phytoplankton samples were collected either once or twice a month from April to December 2012 at fifteen sites along the Klamath River, including Copco No. 1 and Iron Gate reservoirs. The types of phytoplankton present were identified and genetic analysis (deoxyribonucleic acid [DNA] sequencing) was performed to identify genetic differences between the blue-green algae populations at the sample sites. Blue-green algae bloom populations at sites upstream of J.C. Boyle Dam were predominantly *Aphanizomenon flos-aquae* with some *Anabaena flos-aquae* (*Dolichospermum flos-aquae*) and a small amount of *Microcystis aeruginosa* present, but blue-green algae bloom populations in Copco No. 1 and Iron Gate reservoirs were primarily *Microcystis aeruginosa* and *Aphanizomenon flos-aquae*. *Microcystis aeruginosa* cells were present in low concentrations upstream of Copco No. 1 Reservoir, suggesting the majority of *Microcystis aeruginosa* cells in Copco No. 1 and Iron Gate reservoirs grew in the reservoirs and they were not transported into the reservoirs from upstream. Genetic analysis of the *Microcystis aeruginosa* populations showed Copco No. 1 Reservoir populations were dominated by one genetic type the entire year, but the *Microcystis aeruginosa* populations in Iron Gate Reservoir and immediately downstream of Iron Gate Dam had a simultaneous change in the dominant genetic type in late August. The genetic change was also detected in the *Microcystis aeruginosa* populations in the Klamath River downstream of Iron Gate Dam. The simultaneous timing of the genetic change in Iron Gate Reservoir and downstream *Microcystis aeruginosa* populations, but no corresponding genetic change in Copco No. 1 Reservoir, provides direct evidence that downstream river populations are originating in Iron Gate Reservoir rather than Copco No. 1 Reservoir or locations farther upstream (Otten et al. 2015).

Blooms of *Microcystis aeruginosa* are of particular concern since this species is known to produce the algal toxin microcystin, a hepatotoxin that affects liver function in animals and humans (State Water Board et al. 2010, updated 2016; OEHHA 2012). In humans, exposure to microcystin has been documented to cause abdominal pain, headache, sore throat, vomiting, nausea, dry cough, diarrhea, blistering around the mouth, pneumonia, muscle weakness, and acute liver failure (OEHHA 2012) (see also Section 3.2.2.7 *Chlorophyll-a and Algal Toxins*). Studies suggest that the presence of toxin producing *Microcystis aeruginosa* blooms could result in acute (short-term) and chronic (long-term) effects on fish including increased mortality, reduced fertility, reduced feeding, and habitat avoidance (Interagency Ecological Program 2007; Fetcho 2008, 2009; CH2M Hill 2009; Teh et al. 2010; Kann et al. 2013) (see also Section 3.3.2.3 *Habitat Attributes Expected to be Affected by the Project*).

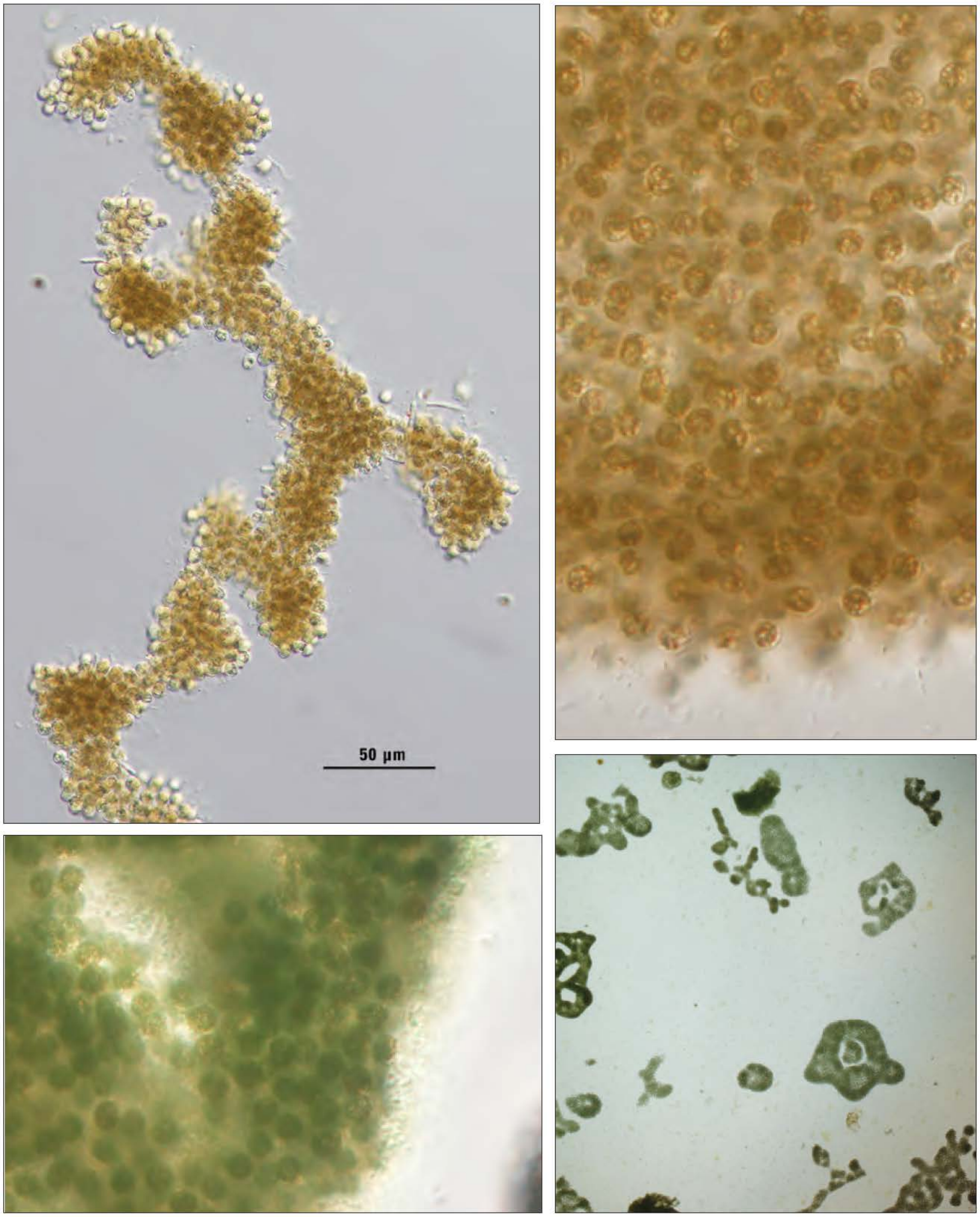

Figure 3.4-7. Microscopic views of *Microcystis aeruginosa*. Photographs: Barry H. Rosen. Source: Rosen and St. Amand 2015.

Figure 3.4-8. Blue-green algae *Microcystis aeruginosa* bloom. Photograph: Susan Corum. Source: Stillwater Sciences et al. 2013.

Algal blooms of nitrogen-fixing *Aphanizomenon flos-aquae* and *Anabaena flos-aquae* early in the year (spring) can supply a new nitrogen source to lakes or reservoirs, potentially promoting *Microcystis aeruginosa* growth later in the year (summer and fall) (FERC 2007; Eldrige et al. 2012; Otten et al. 2015). As blooms of *Aphanizomenon flos-aquae* and *Anabaena flos-aquae* die and decay, fixed nitrogen in their cells is released and becomes a source of nitrogen for *Microcystis aeruginosa*, which cannot fix nitrogen from the atmosphere. Studies of cyanobacteria [blue-green algae] dynamics in 2009 in the Upper Klamath Lake report a low initial *Microcystis aeruginosa* population followed by an increase after a major decline in an *Aphanizomenon flos-aquae* bloom. The *Microcystis aeruginosa* population continued to increase rapidly during a second *Aphanizomenon flos-aquae* bloom, suggesting that these two species can coexist (Eldridge et al. 2012).

Cyanobacteria [Blue-green Algae] Thresholds and Guidelines

Thresholds and guidelines for cyanobacteria [blue-green algae] densities (in cells/mL) and algal toxin concentrations (in µg/L) that are protective of human health have been established and are occasionally updated (see also Section 3.2.3.1 *Thresholds of Significance*). The World Health Organization (WHO) specifies for safe recreational water contact (not drinking water) a cell density of less than 20,000 cells/mL for cyanobacteria [blue-green algae] species and a microcystin concentration of less than 4 µg/L for a relatively low probability of adverse human health effects during recreational water contact (Falconer et al. 1999). The California Cyanobacteria and Harmful Algal Bloom (CCHAB) Network, composed of various entities with expertise, including the State Water Board, the California Department of Public Health (CDPH), the California Environmental Protection Agency Office of Environmental Health and Hazard Assessment (OEHHA), Native American tribes, and reservoir managers has established thresholds and guidance for the cyanobacteria [blue-green algae] cell densities and cyanotoxin [algal toxin] concentrations for the protection of human health in recreational waters. The 2010 CCHAB thresholds (also referred to as the SWRCB/OEHHA Public Health Thresholds or the California Health Thresholds) recommended posting a health advisory warning sign[105] if the *Microcystis aeruginosa* cell density was greater than or equal to 40,000 cells/mL, the potentially toxigenic[106] cyanobacteria [blue-green algae] species cell density was greater than or equal to 100,000 cells/mL, or the microcystin concentration was greater than or equal to 8 ug/L. The 2016 CCHAB thresholds revised the 2010 CCHAB thresholds and specified primary and secondary threshold triggers for posting health advisories for recreational water contact (Table 3.4-1). The 2016 CCHAB thresholds are 4,000 cells/mL for total potentially toxigenic cyanobacteria [blue-green algae] species cell density and 0.8 ug/L for microcystin concentration, which are approximately one to two orders of magnitude less than the 2010 CCHAB thresholds (State Water Board et al. 2010, updated 2016).

Table 3.4-1. 2016 California Cyanobacteria Harmful Algal Bloom (CCHAB) Trigger Levels for Human Health.

Trigger Level	Primary Triggers[1]			Secondary Triggers	
	Total Microcystins (ug/L)	Anatoxin-a (ug/L)	Cylindrospermopsin (ug/L)	Total Potentially Toxigenic Cyanobacteria [Blue-green Algae] Species (cells/mL)	Site Specific Indicators of Cyanobacteria [Blue-green Algae]
Caution Action	0.8	Detection[2]	1	4,000	Blooms, scums, mats, etc.
Warning TIER I	6	20	4	-	-
Danger TIER II	20	90	17	-	-

Source: (State Water Board et al. 2010, updated 2016)

[1] Primary triggers are met when ANY toxin exceeds criteria.

[2] Must use an analytical method that detects less than or equal to 1 ug/L anatoxin-a.

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[105] The advisory signs communicate to the public the potential risk of exposure to algal toxins in the associated waterbody and contain information about how to avoid or minimize the risk. The advisory signs include: “Caution – Harmful algae may be present in this water”; “Warning – Toxins from algae in this water can harm people and kill animals”; “Danger – Toxins from algae in this water can harm people and kill animals” (California Water Quality Monitoring Council 2018).

[106] Potentially toxigenic cyanobacteria [blue-green algae] that have been detected in California include those of the genera *Anabaena*, *Microcystis*, *Aphanizomenon*, *Planktothrix*, and *Gloeotrichia*.

The Hoopa Valley Tribe surface-water objectives are less than 100,000 cells/mL for total potentially toxigenic cyanobacteria [blue-green algae] species for recreational waters, less than 5,000 cells/mL *Microcystis aeruginosa* for drinking water, less than 40,000 cells/mL *Microcystis aeruginosa* for recreational water, and no cyanobacterial [blue-green algae] scums (see also Table 3.2-6). The Hoopa Valley Tribe surface-water objectives for algal toxins specify total microcystins less than 1 ug/L for drinking water and total microcystins less than 8 ug/L for recreational water (HVTEPA 2008). Similarly, the Yurok Tribe guidelines include posting "caution" public health advisories[105] when toxigenic blue-green algae species, *Microcystis aeruginosa*, or microcystin is detected; "warning" public health advisories when toxigenic blue-green algae species are greater than or equal to 100,000 cells/mL, *Microcystis aeruginosa* is greater than or equal to 1,000 cells/mL, or microcystin is greater than or equal to 0.8 ug/L; and "danger" public health advisories when toxigenic blue-green algae species are greater than or equal to 500,000 cells/mL, *Microcystis aeruginosa* is greater than or equal to 5,000 cells/mL, or microcystin is greater than or equal to 4.0 ug/L (see also Table 3.2-10; YTEP 2016).

Frequent exceedances of the cyanobacteria [blue-green algae] density and/or algal toxin concentration thresholds and guidelines have occurred since 2004 in the Lower Klamath Project reservoirs (Kann 2006) and since 2007 in the Middle and Lower Klamath River and the Klamath River Estuary (Chorus and Bartram 1999; Fetcho 2006, 2007, 2008; Kann 2008; Kann and Corum 2009; YTEP 2014, 2015; Genzoli and Kann 2016, 2017; Gibson 2016). The Klamath River from the upstream end of Copco No. 1 Reservoir to the Klamath River's confluence with the Trinity River is included in the CWA Section 303(d) list as impaired for microcystin due to regular exceedances of the established microcystin thresholds and water quality objectives (see also Table 3.2-3, Section 3.2.2.7 *Chlorophyll-a and Algal Toxins,* Potential Impact 3.2-12*,* Appendix C – Section C.6 *Chlorophyll-a and Algal Toxins*). Detailed discussion of phytoplankton communities by reach is presented below in Section 3.4.2.3 *Hydroelectric Reach* through Section 3.4.2.6 *Pacific Ocean nearshore environment*.

3.4.2.2 Periphyton

Periphyton are generally dominated by diatoms and green algae. Cyanobacteria [blue-green algae] can also occur in the periphyton community, but they are typically a small component of the community and do not reach nuisance levels (Asarian et al. 2014, 2015). Like phytoplankton in lakes and reservoirs, periphyton are important components of the base of the food web in riverine systems. Periphyton can also play an important role in riverine water quality, affecting nutrient cycling and resulting in diel (24-hour cycle) fluctuations in dissolved oxygen and pH (Anderson and Carpenter 1998, Kuwabara 1992, Tanner and Anderson 1996). Excessive swings in dissolved oxygen and pH can be stressful to aquatic biota, such that too much periphyton can adversely affect designated beneficial uses related to fish and other aquatic organisms (State Water Board 2001; HVTEPA 2008; North Coast Regional Board 2011). Monitoring at multiple locations along the Middle and Lower Klamath River indicates that dissolved oxygen and pH patterns over a 24-hour period are driven primarily by photosynthesis and respiration of periphyton (Ward and Armstrong 2010, Asarian et al. 2015). The repeatable and consistent diel cycling of dissolved oxygen is characteristic of a stream metabolism that is dominated by periphyton photosynthesis and respiration (Odum 1956). However, free-floating algae transported through the system likely exert some influence on the dissolved oxygen signal in the Klamath River, as does the oxygen demand from decaying organic matter (e.g., bacteria, algae, plant litter) exported from upstream Klamath River reservoirs (PacifiCorp 2006; FERC 2007).

Documented algae species in the Klamath River periphyton community include nuisance filamentous (thread-like) green algae species such as *Cladophora* sp. (FERC 2007), which can form dense mats in some places in the Lower Klamath River. These mats tend to be patchy and occur in lower velocity areas. They are not a dominant feature of the Klamath River, but in some locations they are an important habitat for the polychaete worm (*Manayunkia speciose*) that is the intermediate host of the fish parasites *Ceratomyxa shasta* and *Parvicapsula minibicornis* (Figure 3.4-9). The factors influencing periphyton abundance and community composition are complex and include physical factors such as nutrients, substrate, flow velocity, shading, light availability, and water temperature (Biggs 2000), as well as ecological factors (such as macroinvertebrate grazing) that interact with the physical factors (Power et al. 2008). The Lower Klamath Project dams influence the abundance of periphyton by altering the nutrient availability, riverbed substrate, flow, light availability, and water temperature in the Klamath River (NMFS 2010; NMFS and USFWS 2013; Alexander et al. 2016; Gillett et al. 2016). Analysis and modeling of pre- and post-Klamath Irrigation Project hydrology indicates that operation of the Klamath Irrigation Project upstream of the Lower Klamath Project dams has altered Klamath River flows by increasing flows in October and November, decreasing flows in the late-spring and summer, and decreasing the peak flows (NMFS and USFWS 2013). As a result of upstream Klamath Irrigation Project operations, the Klamath River peak flows downstream of Iron Gate Dam are less frequent, resulting in less frequent high-velocity flows that would scour streambed sediments downstream of the dam. In addition to lower peak flows, the Lower Klamath Project dams trap sediment behind the dams and reduce the availability of fine sediments downstream that can be transported at lower flows, leading to streambed armoring and less frequent scouring events that disturb the streambed. Reduced scouring frequency along with higher fall water temperatures, promote dense growth of periphyton. Additionally, operation of the upstream Klamath Irrigation Project results in flow modifications downstream of the Lower Klamath Project dams that alters the light availability for periphyton on the streambed, with lower flows generally decreasing water depth and increasing light penetration to the streambed for periphyton photosynthesis. These conditions favor proliferation of polychaete worm habitat and subsequent infection of fish by parasites (NMFS 2010; NMFS and USFWS 2013; Alexander et al. 2016) (see also Figure 3.4-8 [parasite life cycle]). Overall, data regarding the distribution, community composition, and biomass of periphyton in the Area of Analysis for phytoplankton and periphyton are limited.

Figure 3.4-9. Lifecycle of *Ceratomyxa shasta*. Source: NMFS 2012.

3.4.2.3 Hydroelectric Reach

Phytoplankton

Phytoplankton dynamics in the Hydroelectric Reach can be influenced by upstream conditions, so the following briefly discusses phytoplankton conditions from the Upper Klamath Lake to the Hydroelectric Reach before detailing the conditions within the Hydroelectric Reach. In the Upper Klamath Lake, the mean total phytoplankton biomass annually increases from relatively low concentrations ranging from less than 5 mg/L wet weight to approximately 15 mg/L wet weight per data collected between 1990 and 1996 in winter and spring (January to May) to peak concentrations ranging from approximately 30 mg/L wet weight to 60 mg/L wet weight per data collected between 1990 and 1996 in summer to fall (June to October), before decreasing to relatively low concentrations again in late fall/early winter (November to December) (Kann 1997). In addition to the seasonal change in total phytoplankton biomass, the phytoplankton community also has an annual seasonal shift from diatom-dominated communities in spring (Kann 1997; ODEQ 2002; Sullivan et al. 2009) to blue-green algae-dominated communities in summer and fall (Eilers et al. 2004; FERC 2007; Eldridge et al 2012). Phytoplankton biovolume in summer and fall is dominated by blue-green algae blooms comprised primarily of *Aphanizomenon flos-aquae*, but also includes *Anabaena flos-aquae* and *Microcystis aeruginosa* (Eilers et al. 2004; FERC 2007; Eldridge et al. 2012). Data from 2009 indicate concentrations of *Microcystis aeruginosa* in the Upper Klamath Lake are typically low during the early part of the calendar year, but concentrations increase later in the year following the decline of large blue-green algae blooms dominated by *Aphanizomenon flos-aquae* (Eldridge et al. 2012). *Microcystis aeruginosa* is believed to be responsible for the production of microcystin in the Upper Klamath Lake, which has exceeded the WHO guidelines for drinking water (1 ug/L) and safe recreational water contact (4 ug/L) with annual peaks in 2007 to 2009 between 1.6 and 24.4 ug/L (VanderKooi et al. 2010; Eldridge et al. 2012).

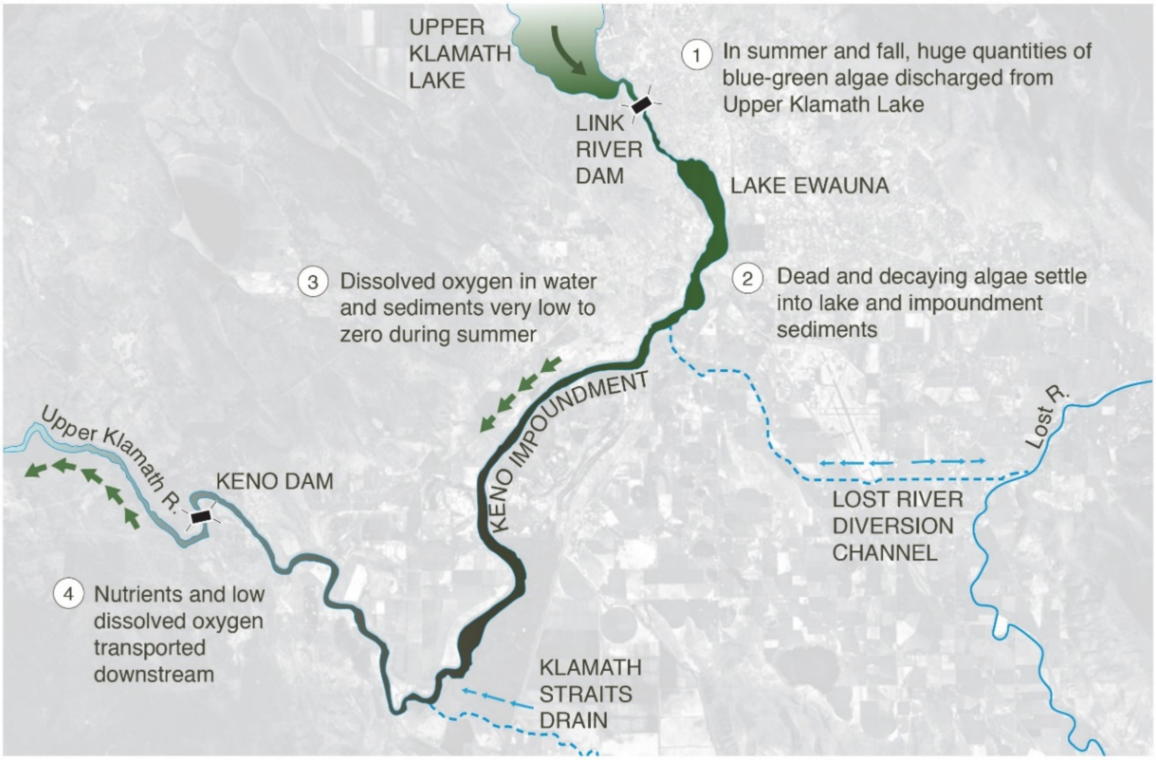

Figure 3.4-10. Blue-green algae transport from the Upper Klamath Lake into the Upper Klamath River. Blue-green algae do not completely die and settle out in the Keno Impoundment, with some blue-green algae exported into the Upper Klamath River downstream of Keno Dam. Source: Stillwater Sciences et al. 2013.

Phytoplankton patterns from the Link River downstream to Keno Dam are driven by blooms that originate in Upper Klamath Lake and are transported into this reach (Figure 3.4-10), with the phytoplankton community varying seasonally and reflecting the community present in the Upper Klamath Lake. In 2008, a total of 141 algae species were identified in the reach from Link River downstream to Keno Dam, with *Aphanizomenon flos-aquae* having the highest average density (61 percent) when present. In spring, 56 percent of the total phytoplankton biovolume was composed of diatoms, with blue-green algae making up only 24 percent the total phytoplankton biovolume. The remainder of the total phytoplankton biovolume was composed of other types of phytoplankton. In summer and fall, the phytoplankton community composition shifted to being primarily comprised of blue-green algae (76 to 80 percent of total phytoplankton biovolume), with diatoms (7 to 15 percent) and other phytoplankton (4 to 10 percent) making up the remainder of the total phytoplankton biovolume (Sullivan et al. 2009). Phytoplankton biovolume generally decreases in the Klamath River with distance downstream of Upper Klamath Lake, with the greatest median decrease in this reach occurring between the Upper Klamath Lake (at Pelican Marina/Fremont Street Bridge) and Link River (Figure 3.4-11; Raymond 2005; Kann and Asarian 2006; Sullivan et al. 2009). In Lake Ewauna and the Keno Impoundment, phytoplankton concentrations are observed to decrease, which is attributed to dead and decaying phytoplankton, especially blue-green algae, settling out of the water column and forming lake and impoundment sediments (Deas and Vaughn 2006; Stillwater Sciences et al. 2013; ODEQ 2017).

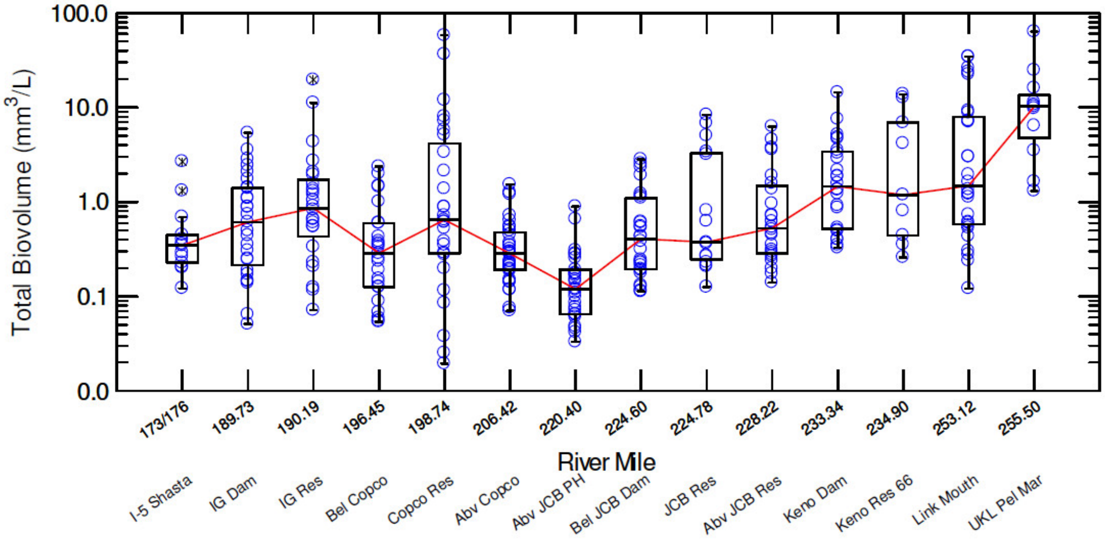

Figure 3.4-11. Total phytoplankton biovolume in mm^3/L from June 1 to September 30 for the years 2001 to 2004. River miles associated with Klamath River features are based on the river miles in 2006 and differ slightly from current river miles in this EIR. Station definitions: UKL Pel Mar = Upper Klamath River at Pelican Marina; Link Mouth = Link River at Mouth; Keno Res 66 = Klamath River at Hwy 66 Keno Bridge; Keno Dam = Keno Dam outflow; Abv JCB Res = Klamath River upstream of J.C. Boyle Reservoir; JCB Res = J.C. Boyle Reservoir at log boom; Bel JCB Dam = Klamath River downstream of J.C. Boyle Dam; Abv JCB PH = Klamath River upstream of the J.C. Boyle Powerhouse; Abv Copco = Klamath River upstream of Shovel Creek; Copco Res = Copco No. 1 Reservoir; Bel Copco = Klamath River downstream of Copco No. 2 Powerhouse; IG Res = Iron Gate Reservoir near dam; IG Dam = Klamath River downstream of Iron Gate Dam; I-5 Shasta = Klamath River at I-5 Rest Area and Klamath River upstream of Shasta River. Source: modified from Kann and Asarian 2006.

Phytoplankton abundance, including abundance of blue-green algae, generally decreases in the Klamath River with distance downstream of Keno Dam to upstream of Copco No. 1 Reservoir (Figure 3.4-11; Kann and Asarian 2006; Kann and Corum 2009; Asarian and Kann 2011; Watercourse Engineering, Inc. 2016). In this reach, turbulent mixing and higher water velocities that constitute unfavorable growing conditions and break apart phytoplankton cells, and cold groundwater-fed springs in the J.C. Boyle Bypass Reach that add flow and cool the river creating less favorable water temperatures for growth, result in decreasing phytoplankton concentrations and associated algal toxins (i.e., microcystin) between Keno Dam and the upstream end of Copco No. 1 Reservoir (see also Section 3.2.2.7 *Chlorophyll-a and Algal Toxins* and Appendix C – Section C.6.1 *Upper Klamath Basin*). Additionally, the proportion of the phytoplankton community composed of diatoms increases relative to blue-green algae between Keno Dam and the upstream end of Copco No. 1 Reservoir (Kann and Asarian 2006).

Measurements of *Microcystis aeruginosa* abundance (measured by biovolume) between 2001 and 2004 also show a decreasing trend from Upper Klamath Lake to upstream of Copco No. 1 Reservoir (Figure 3.4-12). Individual measurements for *Microcystis aeruginosa* taken during this period are represented by circles (o) in Figure 3.4-12, but the circles overlap and appear as a single circle when multiple measurements have the same value (e.g., multiple non-detect results for sites appear as a single circle at zero along the x-axis). Box and whisker features showing the statistical trends (e.g., 25 to 75 percent of measurements occur within the biovolume range encompassed by the box) are shown for most sites, but these box and whisker features cannot be seen for sites with primarily non-detect results for *Microcystis aeruginosa* (i.e., biovolume equal to zero) because they are compressed at the x-axis. While there were eight detections (44 percent of measurements) of *Microcystis aeruginosa* in the Keno Impoundment/Lake Ewauna, no *Microcystis aeruginosa* was detected in 24 samples collected between the Keno Dam outflow and the Klamath River site upstream of J.C. Boyle Reservoir. At sites from J.C. Boyle Reservoir to the Klamath River site upstream of Copco No. 1 Reservoir, there were one to two detections (5 to 15 percent of measurements) per site in the July to October period (Kann 2006).

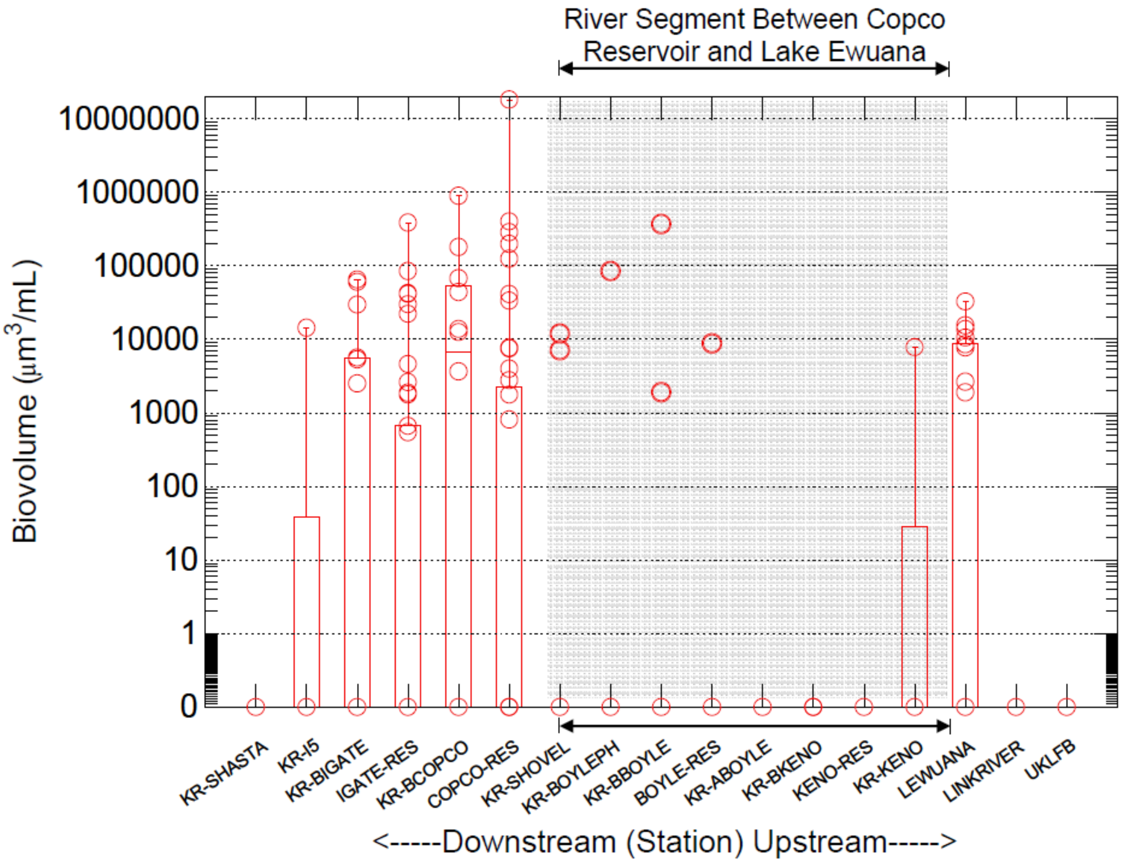

Figure 3.4-12. *Microcystis aeruginosa* biovolume in um^3/mL from July to October for the years 2001 to 2004. No *Microcystis aeruginosa* were detected before July or after October. Station definitions: UKLFB = Upper Klamath Lake at Fremont St. Bridge; LINKRIVER = Link River at mouth; LEWUANA = Lake Ewauna; KR-KENO = Klamath River upstream of Keno Reservoir; KENO-RES = Keno Reservoir; KR-BKENO = Klamath River downstream of Keno Reservoir; KR-ABOYLE = Klamath River upstream of J.C. Boyle Reservoir; BOYLE-RES = J.C. Boyle Reservoir; KR-BBOYLE = Klamath River downstream of J.C. Boyle; KR-BOYLEPH = Klamath River upstream of J.C. Boyle Powerhouse; KR-SHOVEL = Klamath River upstream of Shovel Creek; COPCO-RES = Copco No. 1 Reservoir; KR-BCOPCO = Klamath River downstream of Copco No. 2 Powerhouse; IGATE-RES = Iron Gate Reservoir; KR-BIGATE = Klamath River downstream of Iron Gate Dam; KR-I5 = Klamath River at I-5 Rest Area; KR-SHASTA = Klamath River upstream of Shasta River. Individual measurements are represented by circles (o), with overlapping circles appearing as a single circle when multiple measurements have the same value. Box and whisker features cannot be seen for sites with primarily non-detect results for *Microcystis aeruginosa* (i.e., biovolume equal to zero) because they are compressed at the x-axis. Source: Kann 2006.

The decreasing riverine trend with respect to algal cell concentration in the Hydroelectric Reach is interrupted by large summer and fall blooms of cyanobacteria [blue-green algae] in Copco No. 1 and Iron Gate reservoirs (Kann and Asarian 2006; Raymond 2008, 2009, 2010; Asarian et al. 2009; Asarian and Kann 2011; Otten et al. 2015; Watercourse Engineering, Inc. 2016; Otten and Dreher 2017). In these two reservoirs, a bloom of diatoms generally occurs in spring to early summer, followed by a period of low chlorophyll-*a* concentrations (FERC 2007; Raymond 2008, 2009, 2010; Asarian and Kann 2011) (see also Appendix C – Section C.6.1.1 *Hydroelectric Reach*). Large phytoplankton blooms occur in the reservoirs in mid-summer, dominated by *Aphanizomenon flos-aquae,* which are then followed by a late-summer or early-fall bloom of toxigenic *Microcystis aeruginosa* (Kann 2006; FERC 2007; Raymond 2008, 2009, 2010; Asarian and Kann 2011; Eldridge et al. 2012; Otten et al. 2015; Otten and Dreher 2017). During the late-season *Microcystis aeruginosa* bloom, this species typically constitutes a higher proportion of the overall algal biomass in Copco No. 1 and Iron Gate reservoirs than it does in blooms occurring in Upper Klamath Lake (Kann and Asarian 2006; Raymond 2008, 2009, 2010; Asarian and Kann 2011; Eldrige et al. 2012; Otten et al. 2015). Recent data from August and September 2012 using genetic analysis of the cyanobacteria [blue-green algae] community dynamics further confirms these trends in the Klamath River and its reservoirs. In Upper Klamath Lake in both August and September 2012, *Aphanizomenon flos-aquae* made up more than 75 percent of the blue-green algae population, while *Microcystis aeruginosa* was less than 1 percent. During that same time period, the cyanobacteria [blue-green algae] community composition shifted in Copco No. 1 and Iron Gate reservoirs from greater than approximately 90 percent *Aphanizomenon flos-aquae* and less than approximately 5 percent *Microcystis aeruginosa* (August 2012) to approximately 10 to 45 percent *Aphanizomenon flos-aquae* and approximately 50 to 90 percent *Microcystis aeruginosa* (September 2012). The remaining cyanobacteria [blue-green algae] community in Upper Klamath Lake, Copco No. 1 Reservoir, and Iron Gate Reservoir during this time was primarily comprised of *Anabaena flos-aquae* (*Dolichospermum flos-aquae*) (Otten et al. 2015).

Copco No. 1 and Iron Gate reservoirs provide ideal habitat conditions for the proliferation of large seasonal blooms of *Microcystis aeruginosa*, which subsequently become the source of *Microcystis aeruginosa* to the Middle and Lower Klamath River. This pattern is robust and repeatable in most years. Figure 3.4-2, modified from Kann and Asarian (2007), illustrates the pattern in 2005. At the Klamath River station, just upstream of Copco No. 1 Reservoir (“KRAC” in Figure 3.4-2), *Microcystis aeruginosa* was never detected during multiple summer samplings; however, nitrogen-fixing blue-green algae such as *Aphanizomenon flos-aquae* were detected at KRAC during that period (Kann and Asarian 2007). During the same period, blooms of *Microcystis aeruginosa* within the reservoirs (Copco No. 1 Reservoir stations CR02 and CR01 and Iron Gate Reservoir stations IR03 and IR01) were pronounced. Among all reservoir samplings in 2005, *Microcystis aeruginosa* comprised 20 to 60 percent of sample biovolume and during some periods it was 60 to 100 percent of sample biovolume, particularly in Iron Gate Reservoir. Significant export of the *Microcystis aeruginosa* bloom from Iron Gate Reservoir to downstream reaches of the Klamath River is evident by the relatively high biovolume observed at the river station downstream from Iron Gate Dam (KRBI). Nearly identical patterns were documented for other years, such as 2006 (Kann and Corum 2007), 2008 (Kann and Corum 2009), 2012 (Otten et al. 2015), and 2015 (Watercourse Engineering, Inc. 2016), as well as patterns aggregated over longer time periods such as 2001 to 2004 (Kann 2006), 2005 to 2011 (Asarian and Kann 2011) demonstrating the repeatable nature of this phenomenon.

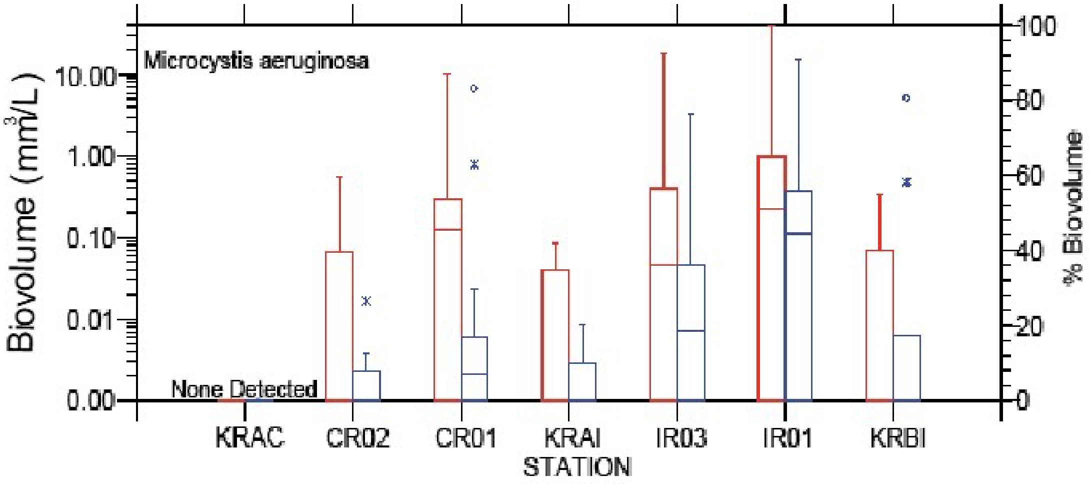

Figure 3.4-13. Biovolume (in red) and percent biovolume (in blue) of *Microcystis aeruginosa* above, within, and downstream from Copco No. 1 and Iron Gate reservoirs during 2005. Station definitions: KRAC = Klamath River upstream of Copco No. 1 Reservoir; CR01 = Copco No. 1 Reservoir Station 1; CR02 = Copco No. 1 Reservoir Station 2; KRAI = Klamath River upstream of Iron Gate Reservoir; IR03 = Iron Gate Reservoir Station 3; IR01 = Iron Gate Reservoir Station 1; KRBI = Klamath River downstream of Iron Gate Reservoir. Source: modified from Kann and Asarian (2007).

As previously noted in Section 3.4.2.1 *Phytoplankton*, genetic analysis of the *Microcystis aeruginosa* in Copco No. 1 Reservoir, Iron Gate Reservoir, and multiple Klamath River sites downstream of Iron Gate Dam also identified Iron Gate Reservoir as the principal source of *Microcystis aeruginosa* to the Klamath River downstream of Iron Gate Dam (Otten et al. 2015). In 2012, measured *Microcystis aeruginosa* at sites in the Klamath River and its reservoirs was comprised of two distinct genetic types (SNP 131-A and SNP 131-G) of *Microcystis aeruginosa.* These two genetic types were either not detected (Upper Klamath Lake) or infrequently detected upstream of Copco No. 1 Reservoir. In Copco No. 1 Reservoir, SNP 131-A was the dominant type (i.e., highest relative proportion) of *Microcystis aeruginosa* throughout the measurement period from June to December 2012. The dominant genetic type varied in Iron Gate Reservoir and downstream Klamath River sites, with a shift from SNP 131-A to SNP 131-G in July and August, followed by another change from SNP 131-G back to SNP 131-A in September (Figure 3.4-14). Both shifts in the dominant genetic type at Iron Gate Reservoir and downstream Klamath River sites occurred simultaneously without a corresponding genetic shift in Copco No. 1 Reservoir. This provides direct evidence that in 2012 downstream populations originated in Iron Gate Reservoir rather than Copco No. 1 Reservoir or further upstream (Otten et al. 2015).

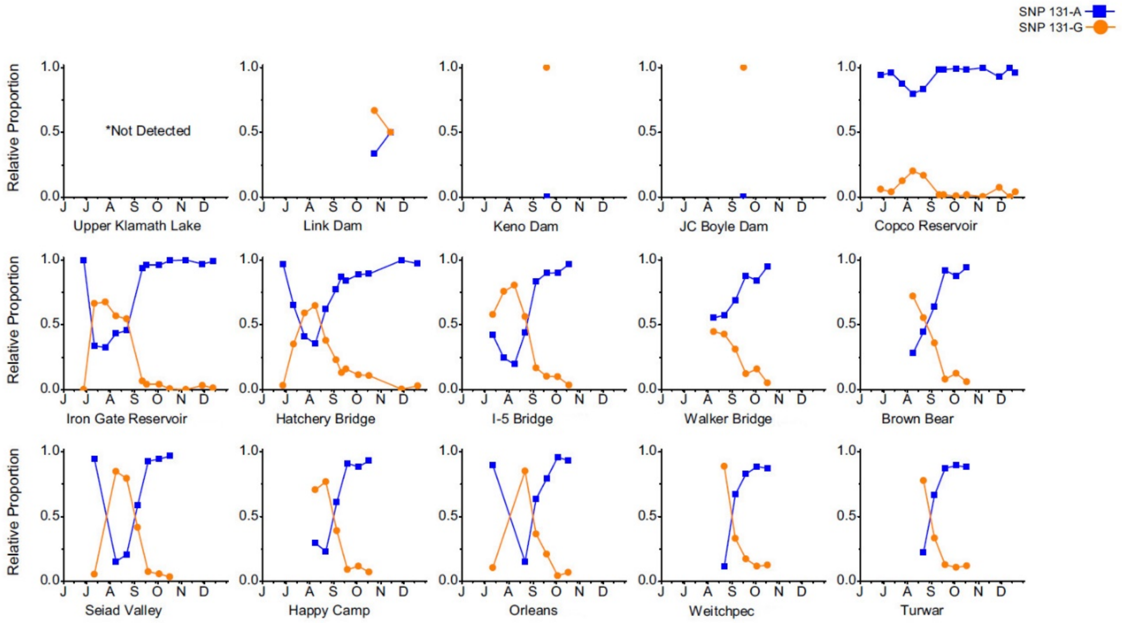

Figure 3.4-14. Relative proportion of the *Microcystis aeruginosa* population comprised of two *Microcystis aeruginosa* genetic types (SNP 131-A and SNP 131-G) at sites in the Klamath River and reservoirs. Relative proportion ranges from 1.0 (100 percent) to 0.0 (0 percent). The month is specified using the first letter of the month starting from June. Source: modified from Otten et al. 2015.

As illustrated Figure 3.4-12 and Figure 3.4-14, the main supply of *Microcystis aeruginosa* was not from sources upstream of Copco No. 1 Reservoir (i.e., Upper Klamath Lake), but instead most likely originated within Iron Gate Reservoir and continued downstream. Although some colonies of *Aphanizomenon flos-aquae* and *Microcystis aeruginosa* are transported into the Hydroelectric Reach from upstream sources, the low detection of *Aphanizomenon flos-aquae* and *Microcystis aeruginosa* at the monitoring sites upstream of Copco No. 1 Reservoir indicate that *Aphanizomenon flos-aquae* and *Microcystis aeruginosa* are primarily generated within Copco No. 1 and Iron Gate reservoirs (Asarian and Kann 2011; Otten et al. 2015). Additionally, the genetic and toxin analyses show that the *Microcystis aeruginosa* populations in Copco No. 1 and Iron Gate reservoirs are genetically distinct, providing evidence that blooms in Iron Gate Reservoir are internally derived and not due to transport of *Microcystis aeruginosa* populations from Copco No. 1 Reservoir or further upstream (Otten et al. 2015).

The documented presence of algal toxins in water and fish tissue in the Hydroelectric Reach corresponds with spatial and temporal patterns in the distribution of blue-green algae blooms within the reach. Recent data indicate that microcystin is undetectable or at very low levels in the Upper Klamath River at the upstream entrance to the Hydroelectric Reach, but microcystin increases through the reach as water is impounded in Copco No. 1 and Iron Gate reservoirs. The reservoirs create ideal growing conditions for toxigenic blue-green algae (calm, stable lacustrine conditions with bioavailable nutrients), regularly resulting in high microcystin concentrations from approximately July through October (Kann and Corum 2006, 2009; Asarian and Kann 2011; Otten et al. 2015; Watercourse Engineering, Inc. 2016; Otten and Dreher 2017). The CCHAB Network, consisting of the State Water Board, CDPH, OEHHA, Native American tribes, and reservoir managers, has primary and secondary cyanotoxin [algal toxin] trigger threshold levels that would result in posting public health advisories[105] for a water body (e.g., lake, reservoir, or river reach), if one or more of the algal toxin threshold levels is exceeded. While microcystin is the algal toxin typically measured in water bodies, the algal toxins anatoxin-a and cylindrospermopsin also have threshold levels which would trigger posting of the water body (see also Section 3.4.2.1 *Phytoplankton*).

Since 2005, high levels of microcystin have prompted the posting of public health advisories around Copco No. 1 and Iron Gate reservoirs, and during certain years along reaches of the Middle and Lower Klamath River downstream from Iron Gate Dam in the late summer months (see Section 3.2.2.7 *Chlorophyll-a and Algal Toxins*, Appendix C – Section C.6.1.1 *Hydroelectric Reach* for more detail). In 2010, the Lower Klamath Project reservoirs and the entire Klamath River downstream from Iron Gate Dam (including the Klamath River Estuary) were posted to protect public health due to elevated blue-green algae cell counts (i.e., *Aphanizomenon flos-aquae, Anabaena flos-aquae,* and *Microcystis aeruginosa*) and algal toxin (i.e., microcystin) concentrations. Public health advisories for both Copco No. 1 and Iron Gate reservoirs were also posted in 2012 (North Coast Regional Board 2012), 2013 (North Coast Regional Board 2013), 2014 (North Coast Regional Board 2014), 2015 (Watercourse Engineering, Inc. 2016), and 2016 (North Coast Regional Board 2016). Measurement of elevated algal toxin (i.e., microcystin) concentrations also prompted a public health advisory in 2017 for Copco No. 1 and Iron Gate reservoirs and reaches of the Klamath River downstream of Iron Gate Dam (North Coast Regional Board 2017). Blue-green algae cell counts and microcystin concentrations greater than CCHAB thresholds for posting public health advisories were also measured in Copco No. 1 and Iron Gate during summer and fall 2018 (E&S Environmental Chemistry, Inc. 2018b). High cell counts and toxin concentrations in the water column can result in bioaccumulation of microcystin in muscle and/or liver tissues of resident (e.g., yellow perch) and anadromous fish (e.g., juvenile hatchery Chinook, adult Chinook salmon, steelhead) and in freshwater mussels (Kann 2008; Kann and Corum 2009; PacifiCorp 2010; Kann et al. 2011; Kann et al. 2013) (see also Section 3.3.2.3 *Habitat Attributes Expected to be Affected by the Project*).

Periphyton

Nuisance blooms of periphyton have not been documented in the riverine portions of the Hydroelectric Reach. In the J.C. Boyle Peaking Reach, it has been noted that periphyton tends to be absent from the margins of the river that are alternately dried and wetted during peaking operations (E. Asarian, pers. comm., 2011).

3.4.2.4 Middle and Lower Klamath River

Phytoplankton

Although both *Aphanizomenon flos-aquae* and *Microcystis aeruginosa* have been observed in the Klamath River just downstream from Iron Gate Dam, and as far downstream as the Klamath River Estuary, this reach of the river is more suitable for the growth of periphyton and does not provide optimal habitat for phytoplankton species that typically thrive in reservoir and lake environments. As discussed above, data collected in 2001 through 2010 suggest that the phytoplankton composition of Klamath River sites immediately downstream from Iron Gate Reservoir is dominated by cyanobacteria [blue-green algae] on a seasonal basis, when large blooms occurring in this reservoir are transported downstream (Kann and Asarian 2006; Asarian and Kann 2011). Additional monitoring from 2013 to 2018 further documents the seasonal abundance of cyanobacteria [blue-green algae] downstream of Iron Gate Dam (E&S Environmental Chemistry, Inc. 2013, 2014, 2015, 2016, 2018a, 2018b). Genetic analysis of *Microcystis aeruginosa* indicates genetic similarities of populations found in Iron Gate Reservoir and downstream river sites, providing further evidence that Iron Gate Reservoir is the source of *Microcystis aeruginosa* populations in the Klamath River downstream of Iron Gate Dam (see Section 3.4.2.3 above; Otten et al. 2015).

In general, turbulent mixing, increased velocity, and tributary dilution result in a gradual decrease in suspended algal materials from the Klamath River water column as the river travels downstream (Armstrong and Ward 2008; Ward and Armstrong 2010) (see also discussion in Appendix C – Section C.2.2.1 *Iron Gate Dam to Salmon River* and Section C.6.2.1 *Iron Gate Dam to Salmon River*). *Microcystis aeruginosa* transported downstream from Copco No. 1 and Iron Gate reservoirs can become trapped and accumulate in calm pools and eddies along the edges of the Middle and Lower Klamath River (Kann and Corum 2006) in some years (e.g., 2007) resulting in pockets of highly concentrated cyanobacteria [blue-green algae] along the river shoreline in greater concentrations than those measured immediately downstream from Iron Gate Dam (Fetcho 2008; Raymond 2008; Kann and Corum 2009; Kann et al. 2010). The spatially and temporally variable nature of blue-green algae blooms along the edges of the Middle and Lower Klamath River makes it difficult to fully assess the distribution and frequency of these events (Kann and Corum 2009). In measurements of the cyanobacteria [blue-green algae] cell density across one transect of the Klamath River, the cyanobacteria [blue-green algae] cell density was substantially higher near the shoreline where turbulent mixing and water velocities were lower (Figure 3.4-15; Kann et al. 2010; Genzoli and Kann 2016, 2017). The presence of blue-green algae along the shoreline is particularly important because the shoreline is where animals (e.g., pets) and humans are most likely come in contact with water and any blue-green algae or algal toxins present in the water, especially during recreational activities (see Section 3.20.2.2 *Klamath River-based Recreation*). At times, accumulations of cyanobacteria [blue-green algae], including *Microcystis aeruginosa,* along shorelines and in protected coves and backwaters in the Middle and Lower Klamath River can result in exceedances to the 2016 CCHAB secondary thresholds for the protection of human health (4,000 cells/mL of all toxin-producing cyanobacteria [blue-green algae] or site specific indicators of cyanobacteria [blue-green algae] like blooms, scums, or mats) and the WHO guidelines for *Microcystis aeruginosa* cell density (20,000 cells/mL for a relatively low probability of adverse human health effects) (Falconer et al. 1999; State Water Board et al. 2010, updated 2016). These thresholds and guidelines have been set for safe recreational water contact (not drinking water) (see also Section 3.4.2.1 *Phytoplankton*)

Despite these localized accumulations of blue-green algae along shorelines and in backwaters, data collected in June through November during 2005 to 2015 indicate that the measured *Microcystis aeruginosa* cell density at river sites in the Middle and Lower Klamath River was usually less than the vast majority of measured *Microcystis aeruginosa* cell densities in Copco No. 1 and Iron Gate reservoir sites (Appendix C, Figure C-49; see also Kann et al. 2010; Kann and Bowman 2012; Genzoli and Kann 2017). While the majority of *Microcystis aeruginosa* cell density measurements at river sites in the Middle and Lower Klamath River were less than the 2010 CCHAB (SWRCB/OEHHA Public Health) threshold of 40,000 cells/mL, the measured *Microcystis aeruginosa* cell densities at river sites frequently exceeded the 2016 CCHAB threshold of 4,000 cells/mL (Genzoli and Kann 2017). The measured *Microcystis aeruginosa* cell density at river sites in the Middle and Lower Klamath River in June through November during 2005 to 2015 was typically less than the higher WHO guidelines (20,000 cells/mL), but measurements of *Microcystis aeruginosa* cell density from the Klamath River I-5 Rest Area (RM 181.8) to Orleans (RM 58.9) reached 20,024 to 35,784 cells/mL in late July/early August 2015, with the maximum occurring at Seiad Valley (RM 132.7) (Watercourse Engineering, Inc. 2016).

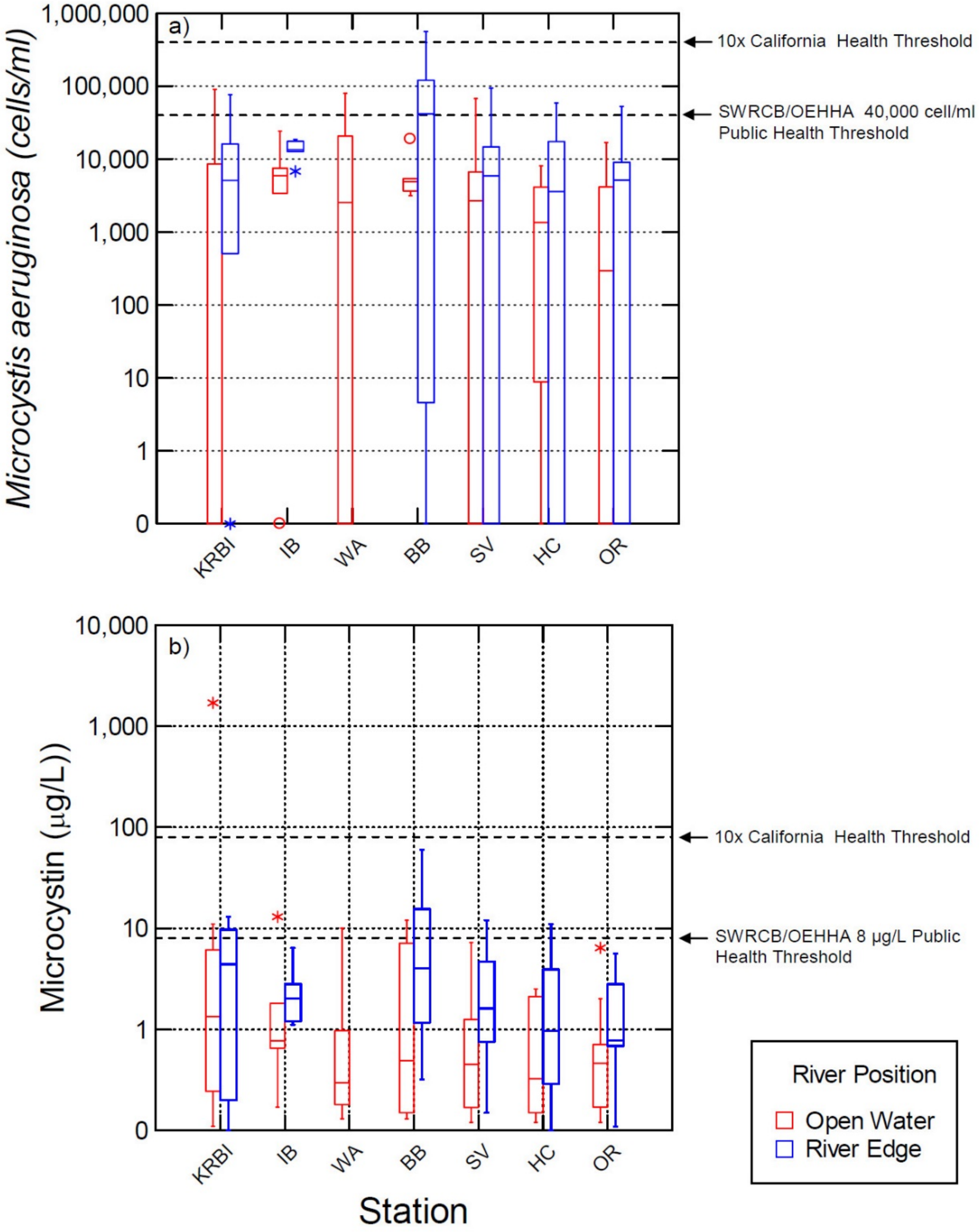

Figure 3.4-15. *Microcystis aeruginosa* density and microcystin concentration variations between open water and along the river edge in the Klamath River. Station locations on the Klamath River: KRBI = Klamath River downstream of Iron Gate Dam; IB = I-5 Bridge; WA = Walker Bridge; BB = Brown Bear River Access just east of Horse Creek; SV = Seiad Valley; HC = Happy Camp; and OR = Orleans. Thresholds listed are those that were applicable when study was published and do not reflect current thresholds. Current threshold is 0.8 ug/l as discussed in Section 3.4.2.1 *Phytoplankton*. Source: Kann et al. 2010.

Algal toxins (e.g., microcystin, anatoxin-a) are a critical concern in the Klamath River downstream from Iron Gate Dam, because they can remain viable along the low-velocity margins of the river where little mixing occurs (Kann and Corum 2009; Genzoli and Kann 2016, 2017). During cyanobacteria [blue-green algae] growth, most toxins are contained within the cells of the cyanobacteria [blue-green algae]. However, once cyanobacteria [blue-green algae] die and decay, its cells break apart (lyse) and toxins are released (Falconer et al. 1999). Microcystin is the primary algal toxin concern in the Klamath River downstream of Iron Gate Dam, because microcystin is extremely stable and resists common chemical breakdown such as hydrolysis, oxidation, or photolysis (i.e., photochemical degradation by sunlight) under conditions found in most natural water bodies. The time it takes for half of the microcystin to break down (i.e., half-life) under typical ambient conditions is 10 weeks (OEHHA 2009), so microcystin concentrations can continue to increase over multiple weeks in the areas of the Klamath River with limited mixing as blue-green algae continue to die, decay, and release microcystin. Even after boiling, microcystin can persist in water, indicating that cooking is not sufficient to destroy microcystin (Chorus and Bartram 1999; OEHHA 2009). Anatoxin-a, the other blue-green algae toxin that has been detected in the Klamath River downstream of Iron Gate Dam (see Appendix C – Section C.6.2 *Mid- and Lower Klamath Basin*), is much less stable than microcystin, with a half-life of 1 to 10 hours in natural light under typical ambient conditions. Anatoxin-a has been found to persist up to 21 days at low pH (4 s.u.) or up to several months in the absence of sunlight (USEPA 2015).

Concentrations of microcystin in the Klamath River downstream from Iron Gate Dam are typically 1 to 3 orders of magnitude lower than observed in Copco No. 1 and Iron Gate reservoirs (Appendix C, Figure C-49; see also Raymond 2008; Kann et al. 2010; Kann and Bowman 2012). However, the lowest 2016 CCHAB threshold (0.8 ug/L), the 2010 CCHAB (SWRCB/OEHHA Public Health) threshold (8 ug/L), the WHO guideline (4 ug/L), the Hoopa Valley Tribe recreational water objective (8 ug/L), and the lowest Yurok Tribe guideline (detection) for exposure to microcystin have each been exceeded downstream from Iron Gate Dam on numerous occasions (Kann 2004; Kann and Corum 2009; Kann et al. 2010; Fetcho 2011; Kann and Bowman 2012; Watercourse Engineering, Inc. 2012, 2013, 2014, 2015, 2016; KTWQC 2016), including late-summer/early-fall *Microcystis aeruginosa* blooms in September 2007, 2009, 2010, 2011, 2012, 2013, and 2016 from Iron Gate Dam (RM 193.1) to the mouth of the Klamath River (RM 0.5). Overall, the data indicate that while Middle and Lower Klamath River microcystin exceedances do occur, they are far less in number than exceedances in Copco No. 1 and Iron Gate reservoirs (Appendix C, Figure C-49; see also Raymond 2008; Kann et al. 2010; Kann and Bowman 2012). Data from 2007 also indicate that microcystin can bioaccumulate in juvenile salmonids reared in Iron Gate Hatchery (see Section 3.3.2.3 *Habitat Attributes Expected to be Affected by the Proposed Project* for more details; Kann 2008), potentially resulting in earlier hatching; disruption of development, growth, immune status, and cardiac function; damage to the liver, kidney, and gills; and death (OEHHA 2009).

Overall, the literature and studies to date overwhelmingly support the conclusion that blue-green algae blooms in Iron Gate Reservoir are the primary source of *Microcystis aeruginosa* detected seasonally in the Klamath River downstream from the Hydroelectric Reach. Additionally, Copco No. 1 Reservoir may also contribute to *Microcystis aeruginosa* populations in these reaches. Measured data along with the persistence of microcystin in the environment indicate that microcystin concentrations downstream of J.C. Boyle are typically below detectable concentrations with only infrequent measurements, so blue-green algae blooms in both Copco No. 1 and Iron Gate reservoirs provide the primary source of the seasonally detected microcystin in the Klamath River downstream from the Hydroelectric Reach rather than transport of microcystin from upstream of Copco No. 1 through the reservoirs and into the Middle or Lower Klamath River. The relatively high turbulence and velocity of the Middle and Lower Klamath River makes it poor habitat for blue-green algae species to thrive in most reaches, although colonies of *Microcystis aeruginosa* can be transported into the river from Iron Gate Reservoir and potentially Copco No. 1 Reservoir and accumulate, and in some cases, may persist in the localized pools and edges of the river. That Copco No. 1 and Iron Gate reservoirs receive excessive nutrients and potentially a small amount of viable blue-green algae cells transported from upstream of the Hydroelectric Reach, while well documented, does not diminish the fundamental role of Copco No. 1 Reservoir and especially Iron Gate Reservoir, in fostering excessive growth of *Microcystis aeruginosa,* the production of high concentrations of microcystin, and the downstream transport of both, to the Middle and Lower Klamath River.

Periphyton

Periphyton sampling in the Klamath River downstream from Iron Gate Dam reveals distinct longitudinal and seasonal patterns in species composition. In a single survey undertaken downstream of Iron Gate Dam between September 1 and 2, 2004, Eilers (2005) documented relatively high periphyton coverage (near 80 percent) on stream rocks and periphyton chlorophyll-*a* content (near 50 micrograms per square centimeter [ug/cm^2]) immediately downstream from Iron Gate Dam ([RM 193.1]). Several miles downstream, near the Collier Rest Area at the I-5 bridge (RM 182.1), periphyton coverage (near 10 percent) on stream rocks was relatively low. Downstream from the Collier Rest Area, both periphyton coverage and chlorophyll-*a* content increased gradually to peak levels near the confluence with the Salmon River (RM 66). While periphyton biomass was generally found to be low to moderate during the survey (with the exception of the site immediately downstream from Iron Gate Dam), it is believed that increased discharge (i.e., a doubling of flow from approximately 600 cfs around August 15 to approximately 1,200 cfs near the end of August, and decreasing to approximately 800 cfs by September 1, the start of the survey) may have dislodged filamentous algae that had proliferated under the previous lower flow regime (Eilers 2005; FERC 2007).

Analysis of periphyton data collected between 2004 and 2013 indicates that attached diatoms represent the highest percentage of total periphyton biomass in the Middle and Lower Klamath River, but variations in the periphyton community occur in specific reaches and time periods (Asarian et al. 2014, 2015). During June through October, periphyton communities[107] occurring from Iron Gate Dam (RM 193.1) to RM 160 tend to exhibit the highest percentage of species tolerant of degraded dissolved oxygen conditions, bacteria capable of obtaining energy from organic nitrogen-containing compounds as well as from photosynthesis, and free-floating, un-attached algae species, including cyanobacteria [blue-green algae] *Aphanizomenon flos-aquae* and *Microcystis aeruginosa* that are part of the periphyton assemblage (Asarian et al. 2014). The periphyton community established between Seiad Valley (RM 132.7) and Happy

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[107] A periphyton community is comprised of all the species of algae found when sampling a section of the streambed, including both attached periphyton species and free-floating, un-attached algae species that may be associated with the attached periphyton species.

Camp (RM 108.3), shows strong seasonal trends, with a high diatom, low cyanobacteria [blue-green algae] community dominant until June, followed by a community that is more tolerant of low dissolved oxygen concentrations and exhibits higher cyanobacteria [blue-green algae] biomass during August through October (Asarian et al. 2014). Nitrogen-fixing species are not present directly downstream from Iron Gate Dam, but begin to appear by Seiad Valley and then make up an increasing percentage of periphyton biomass at sites farther downstream (Asarian et al. 2010; E. Asarian, pers. comm. 2011; Asarian et al. 2014, 2015). There is also seasonal variation evident in the periphyton community from Happy Camp (RM 108.3) to the Klamath River Estuary (RM 2), with the majority of periphyton falling into the high diatom, low blue-green algae community in May and June, then transitioning in July to a periphyton community comprised primarily of nitrogen-fixing diatom and blue-green algae species (i.e., species that can use nitrogen from the atmosphere). The three main nitrogen-fixing diatoms in the periphyton community beginning in July and continuing through October are *Epithemia sorex*, *Epithemia turgida*, and *Rhopalodia gibba,* which all contain cells of cyanobacteria [blue-green algae] that live inside the diatom cells to help the diatoms fix nitrogen. The main nitrogen-fixing cyanobacteria [blue-green algae] species in the periphyton community from July to October is *Calothrix* sp., a species of cyanobacteria [blue-green algae] that grows as pronounced tapering filaments (i.e., threads) attached to the streambed and rocks (Asarian et al. 2014, 2015). The nitrogen-fixing diatom and blue-green algae periphyton community dominates in the Lower Klamath River between August and October, which coincides with very low levels of inorganic nitrogen (ammonia and nitrate) concentrations in water samples (Asarian et al. 2010, 2014, 2015).

Variations in periphyton communities in the Middle and Lower Klamath River are influenced by both nutrient concentrations and flow conditions. The overall longitudinal pattern in periphyton communities described above is driven by changes in nutrient concentrations in the Middle and Lower Klamath River. Nutrient concentrations tend to decrease in a downstream direction due to nutrient retention dynamics (e.g., nutrients being used and retained in biomass) along the Middle and Lower Klamath River and dilution, as tributaries with lower nutrient concentrations flow into the Klamath River (Asarian and Kann 2013). As nutrient concentrations decrease and less nutrients are available in the water for periphyton growth, the percentage of nitrogen-fixing periphyton in the periphyton community increases, because those species are able to overcome the nitrogen limitations in the Middle and Lower Klamath River waters by using nitrogen from the atmosphere. While nutrient concentrations decrease from upstream to downstream, the overall periphyton biomass tends to increase due to these nitrogen-fixing periphyton species (Asarian et al. 2015; Gillet et al. 2016). Variations in the periphyton community during the year correspond to changes in flow in the Klamath River, with higher flow associated with a lower abundance of nitrogen-fixing periphyton. These variations are most pronounced in late summer (after July) and at locations in the Lower Klamath River (Gillet et al. 2016). As an example, the percent of the periphyton community comprised of nitrogen-fixing periphyton at the Turwar Klamath River site decreased from approximately 80 percent at flows less than approximately 3,000 cfs, to approximately 20 percent at flows greater than 10,000 cfs (Gillet et al. 2016).

Cladophora sp. have been noted to dominate the periphyton community at a Shasta River (tributary) site, where this species made up 50 percent of the periphyton community by biovolume; however, *Cladophora* sp. were not documented at any of the other tributary or mainstem Klamath River sites surveyed between September 1 and 2, 2004 (Eilers 2005). The abundance of *Cladophora* sp. in the Klamath River found in

Eilers (2005) was likely influenced by a release from Iron Gate Dam that increased the flow in the Klamath River one week prior to the study from approximately 700 cfs to 1,100 cfs for several days before decreasing to approximately 900 cfs. The increased flow may have dislodged *Cladophora* sp. and other periphyton, resulting in lower abundances than would have occurred before that release. As discussed previously (Section 3.4.2.2 *Periphyton*), *Cladophora* sp. provide suitable habitat for the polychaete worm that is the intermediate host for fish parasites. However, data regarding *Cladophora* biomass are limited, making it difficult to determine the primary factors that control the biomass and distribution of these species (E. Asarian, pers. comm., 2011). While periphyton has been studied in the Klamath River and *Cladophora* sp. has been detected in those studies, the methods used for the sampling was not designed to adequately characterize filamentous algae like *Cladophora* sp. (Asarian et al. 2014, 2015).

3.4.2.5 Klamath River Estuary

The algal community in the Klamath River Estuary is dominated by phytoplankton, although it does exhibit relatively greater amounts of periphyton in the upper portion of the estuary where conditions are more riverine. The presence of brackish water influences the types of phytoplankton and periphyton present in different areas of the estuary. Similar to the Lower Klamath River, the Klamath River Estuary phytoplankton community is composed primarily of diatoms and blue-green algae (Fetcho 2007, 2008, 2009). Phytoplankton densities are more frequently lower in the estuary than those measured concurrently in the Lower Klamath River, but phytoplankton cell densities are occasionally higher in the estuary than measured upstream. Between 2010 and 2015 when *Microcystis aeruginosa* was concurrently detected at the Klamath River Estuary and Turwar (i.e., the Lower Klamath River site upstream of the estuary), *Microcystis aeruginosa* was lower in the estuary than at the upstream site in 57 percent (12 of 21) of measurements. However, *Microcystis aeruginosa* was higher in the estuary than upstream in 43 percent (9 of 21) of measurements, so there is not always a decreasing trend in *Microcystis aeruginosa* cell densities between the Lower Klamath River and the Klamath River Estuary (Gibson 2016).

Phytoplankton sampling of the lower estuary surface by the Yurok Tribe since 2005 has indicated that blue-green algae concentrations peak annually between August and October (Fetcho 2006, 2007, 2008, 2009, 2011; Sinnott 2011, 2012; Hanington and Torso 2013; Hanington and Stawasz 2014; Hanington and Cooper-Carouseli 2014; Gibson 2016). Concentrations of *Microcystis aeruginosa* measured between 2010 and 2015 further support that trend, with annual peaks occurring primarily between August and October (Figure 3.4-16; Gibson 2016).

Blue-green algae concentrations, especially *Microcystis aeruginosa*, in the Klamath River Estuary have exceeded 2010 CCHAB, 2016 CCHAB, WHO, and Yurok Tribe blue-green algae thresholds and guidelines multiple times since 2005 (Fetcho 2006, 2007, 2008, 2009, 2011; Sinnott 2011, 2012; Hanington and Torso 2013; Hanington and Stawasz 2014; Hanington and Cooper-Carouseli 2014; Gibson 2016). On one occasion in September 2005, blue-green algae cell density exceeded the WHO guidelines for low risk recreational use (20,000 cells/mL), with instances of elevated levels of *Microcystis aeruginosa* corresponding to elevated levels measured at upstream locations in the Lower Klamath River (Fetcho 2006, 2008). In September 2007, estuary *Microcystis aeruginosa* cell density twice exceeded the then-current Yurok Tribe posting action level

(40,000 cells/mL). Yurok Tribe posting guidelines have been revised since 2007 and a caution posting currently occurs after detection of *Microcystis aeruginosa* cells (see Section 3.2.3.1 *Thresholds of Significance* and 3.4.2.1 *Phytoplankton*). In 2010 to 2014, *Microcystis aeruginosa* was detected every year, with *Microcystis aeruginosa* cell densities greater than the 2016 CCHAB threshold of 4,000 cells/mL total potentially toxigenic cyanobacteria [blue-green algae] at least once every year (Figure 3.4-16). However, *Microcystis aeruginosa* was not detected in surface samples of the Klamath River Estuary during 2015, even though it was detected upstream in the Lower Klamath River (Gibson 2016).

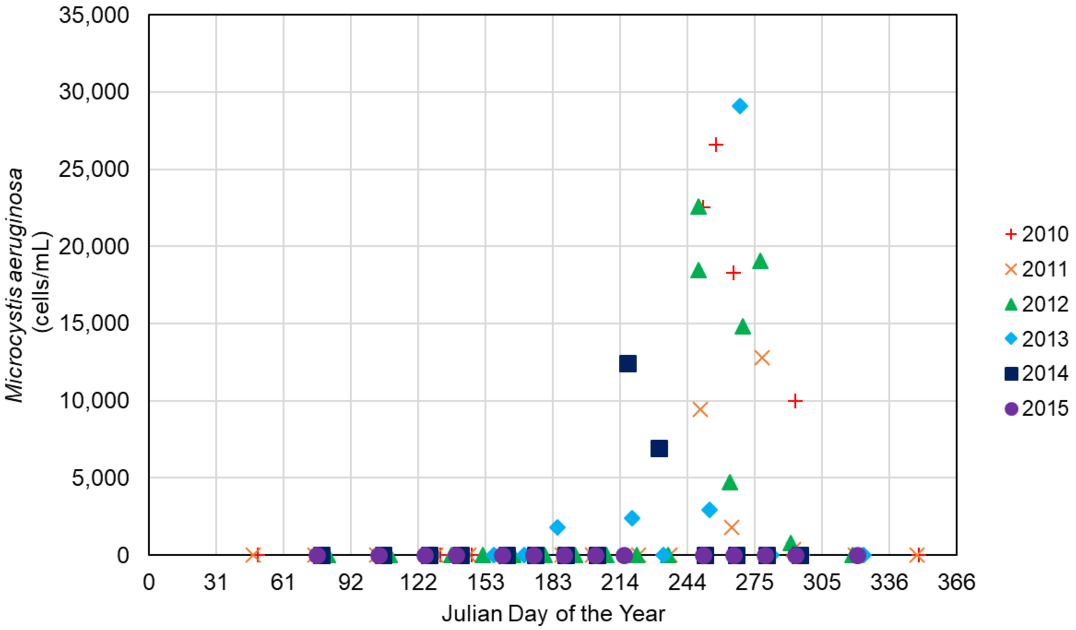

Figure 3.4-16. *Microcystis aeruginosa* cell density in the Klamath River Estuary between 2010 and 2015. Source: adapted from Gibson 2016.

Although periphyton data for the estuary are unavailable, in part due to the difficulty of sampling in deeper areas, abundant periphyton cover has been documented in the south slough (Hiner 2006).

3.4.2.6 Pacific Ocean Nearshore Environment

The algal community of the nearshore Pacific Ocean is dominated by marine algae, including attached red and brown seaweeds, as well as many marine planktonic species. The freshwater algae discussed in Section 3.4.2 *Phytoplankton* are not expected to thrive in the turbulent, saline marine environment, but they may be carried into the ocean with the current and survive for limited periods. Toxins can also be washed into the ocean, but they are expected to be rapidly diluted. There have been no reports of problems relating to freshwater algal toxins in the Pacific Ocean near the mouth of the Klamath River. However, microcystin has been reported as the cause for numerous deaths of sea otters, a federally-listed species, in the vicinity of Monterey Bay, California. Miller et al. (2010) presented evidence that microcystin produced by *Microcystis aeruginosa* in freshwater streams and lakes flowed out into the Pacific Ocean nearshore environment in Monterey Bay, California, and bioaccumulated in marine invertebrates (e.g., clams) that are a sea otter food source. Sea otter deaths due to microcystin exposure were attributed to consumption of microcystin contaminated marine invertebrates, rather than direct exposure to microcystin in freshwater, because most sea otters that died from microcystin were recovered near embayments, harbors, or river mouths. Further, sea otters do not venture into rivers to feed (Miller et al. 2010).

3.4.3 Significance Criteria

For purposes of this EIR, impacts of the Proposed Project related to phytoplankton and/or periphyton would be significant if they were to result in the following:

- An increase in the spatial extent, temporal duration, toxicity, or concentration of nuisance and/or noxious phytoplankton blooms. The nuisance and/or noxious phytoplankton blooms in the Area of Analysis are comprised of the blue-green algae species *Aphanizomenon flos-aquae*, *Anabaena flos-aquae*, and *Microcystis aeruginosa*.
- An increase in the spatial extent, temporal duration, or biomass of nuisance periphyton species that results in new or further impairment of designated beneficial uses (Table 3.2-2). The nuisance periphyton species in the Area of Analysis is *Cladophora* sp.

For this EIR's phytoplankton and periphyton analysis, short-term is defined as the period during pre-dam removal activities, reservoir drawdown, dam removal, and associated sediment flushing events that could transport sediment-associated nutrients, which could influence phytoplankton or periphyton growth. This period corresponds to pre-dam removal years 1 and 2, dam removal year 1, dam removal year 2, and post-dam removal year 1 (Table 2.7-1). Long-term is defined as occurring after post-dam removal year 1 (i.e., greater than three years after dam removal begins).

3.4.4 Impact Analysis Approach

Existing information regarding blue-green algae blooms in the Area of Analysis for phytoplankton and periphyton suggests that several critical factors affect the frequency and toxicity of blue-green algae blooms in the Lower Klamath Project reservoirs: water temperature, light levels (FERC 2007), flow rates (Kann 2006; Asarian and Kann 2013), nutrient availability/ratios (Chorus and Bartram 1999; Fetcho 2008; Moisander et al. 2009, Asarian and Kann 2011), and wind-induced turbulence and mixing.

The assessment of the effects of the Proposed Project on phytoplankton and periphyton, especially toxic blue-green algae blooms, in the Klamath River reaches in the Area of Analysis is based on the expected effects of dam removal on water temperature, light availability, hydrodynamic conditions (water movement), nutrient availability, streambed scour conditions, and transport of blue-green algae cells in the reservoirs downstream of the dams. Existing model output and empirical data describing the expected effects of dam removal on water quality (see Section 3.2.4 *Impact Analysis Approach*) provide the basis for the anticipated effects on water temperature, suspended sediment concentrations, and nutrients. In combination with existing literature regarding the biology and ecology of blue-green algae species, the water temperature and nutrient information is used to determine whether the Proposed Project would alter the spatial extent of optimal habitat in the Area of Analysis for blue-green algae or periphyton.

Suspended sediment concentrations were used to evaluate the relative magnitude and timing of potential sediment-associated nutrients available in the river during transport of reservoir sediment deposits under the Proposed Project. Light availability that would alter photosynthesis and growth for phytoplankton and periphyton also was qualitatively assessed from expected suspended sediment concentrations, with light availability, photosynthesis, and growth potential decreasing as suspended sediment concentrations increase.

The following specific metrics are evaluated:

- The extent to which monthly mean and maximum water temperatures would be within the range of 64 to 77°F or exceed 82°F;
- Total suspended sediment and nutrient concentrations; and,
- The presence or absence of lacustrine (i.e., lake- or reservoir-like) conditions.

The water temperature range of 64 to 77ºF has been selected because the algal toxin content in cyanobacteria [blue-green algae] cells is the highest within this range and the algal toxin content decreases at water temperatures greater than 82ºF (Van Der Westhuizen and Eloff 1985; Chorus and Bartram 1999; State Water Board et al. 2010, updated 2016). Suspended sediment and nutrient concentration data are based on output from the SRH-1D model and the California Klamath River TMDLs model, respectively (see Section 3.2.4 *Impact Analysis Approach* and Appendix D for descriptions of these numeric models).

The potential effects of the Proposed Project on periphyton growth were evaluated using information about nutrients in the Klamath River presented in Asarian et al. (2010), which quantified nutrient loads and nutrient retention (seasonal removal and/or release) rates in reaches of the Klamath River. Asarian et al. (2010) estimated daily nutrient concentrations from measurements occurring monthly or more frequently using five different methods, including two constant flow-weighted-mean concentration methods, a linear interpolation method, and two regression methods. Nutrient loads (metric tons/day) for each surface inflow and outflow of individual reaches of the Klamath River and its tributaries were then estimated using the daily estimated nutrient concentrations (mg/L) and the daily mean flows (cfs). See Asarian et al. (2010) for further explanation of the method details, including equations. Table 3.4-2 presents five nutrient load estimates for each reach based on the five different methods of estimating the daily nutrient concentrations and highlights how the mean daily nutrient load estimate is similar regardless of the method used to estimate the daily nutrient concentration. A nutrient mass balance on individual reaches of the Klamath River assumes mass is never destroyed (i.e., conserved) and the nutrient mass that stays in a river reach (e.g., via uptake by periphyton, aquatic plants, or bacteria, burial in streambed sediments, sediment sorption) is equal to the nutrient mass that enters a river reach (e.g., nutrient mass from the mainstem Klamath River plus any nutrients from an incoming tributary in that reach) minus the nutrient mass exiting a river reach (e.g., transported to downstream reaches, lost to atmosphere) (Asarian et al. 2010).

Table 3.4-2. Daily Mean Nutrient Loads at Mainstem Klamath River and Major Tributary Sites Calculated Using the Five Different Methods to Estimate Daily Nutrient Concentrations. Source: Asarian et al. (2010).

Parameter	Site	River Mile	Mean Daily Load (metric tons/day)				
			Method 1[a]	Method 2[b]	Method 3[c]	Method 4[d]	Method 5[e]
Total Phosphorus	KR downstream of Keno	237.1	0.4475	0.4513	0.4969	0.5209	0.5004
	KR upstream of Copco No. 1	211.2	0.4717	0.4814	0.5210	0.4986	0.4969
	KR downstream of Iron Gate Dam	192.7	0.4227	0.4392	0.4656	0.4647	0.4656
	KR at Walker	158.7	0.5131	0.5351	0.5311	0.5372	0.5361
	KR at Seiad Valley	131.5	0.4546	0.4989	0.4905	0.4818	0.4827
	KR at Orleans	59.6	0.4678	0.5018	0.4954	0.5016	0.4973
	KR upstream of confluence with Trinity River	43.5	0.3776	0.4330	0.4351	0.4231	0.4302
	KR downstream of confluence with Trinity River	42.6	0.4454	0.4644	0.4711	0.4623	0.4616
	KR Turwar	5.9	0.4312	0.4427	0.4560	0.4385	0.4515
	Shasta River	179.5	0.0312	0.0313	0.0315	0.0317	0.0316
	Scott River	145.1	0.0146	0.0124	0.0092	0.0081	0.0075
	Salmon River	66.3	0.0105	0.0108	0.0105	0.0122	0.0115
	Trinity River	43.3	0.0551	0.0370	0.0390	0.0364	0.0366

Parameter	Site	River Mile	Mean Daily Load (metric tons/day)				
			Method 1 [a]	Method 2 [b]	Method 3 [c]	Method 4 [d]	Method 5 [e]
Total Nitrogen	KR downstream of Keno	237.1	3.8323	4.2694	4.8199	4.8448	4.7893
	KR upstream of Copco No. 1	211.2	4.7357	4.8690	4.4496	4.3721	4.3260
	KR downstream of Iron Gate Dam	192.7	3.2693	3.3356	2.8999	2.9139	2.8961
	KR at Walker	158.7	2.9650	3.0403	3.0890	3.0670	3.0585
	KR at Seiad Valley	131.5	2.6942	2.9729	2.8540	2.7857	2.8295
	KR at Orleans	59.6	2.4052	2.6056	2.5633	2.5992	2.5723
	KR upstream of confluence with Trinity River	43.5	2.1048	2.2819	2.3388	2.2290	2.3104
	KR downstream of confluence with Trinity River	42.6	2.4566	2.5135	2.5667	2.4359	2.4804
	KR Turwar	5.9	2.6533	2.7568	2.7448	2.6937	2.7513
	Shasta River	179.5	0.0917	0.0829	0.0834	0.0874	0.0848
	Scott River	145.1	0.1269	0.1273	0.1301	0.1450	0.1308
	Salmon River	66.3	0.1000	0.0926	0.0987	0.1008	0.0925
	Trinity River	43.3	0.5404	0.3651	0.3694	0.2170	0.2173

[a] Constant flow-weighted-mean concentration (flow-weighted average of concentration from sampled days multiplied by the mean flow over the entire period).

[b] Constant flow-weighted-mean concentration within low and high-flow strata (above and below the mean flow for the entire period).

[c] Linear interpolation of concentrations between sampling dates (used in Asarian and Kann [2006]).

[d] Regression without residual (observed minus predicted values) interpolation.

[e] Regression with residual interpolation to incorporate relationships between concentration, flow and season, as well as adjacent sample points.

Anticipated changes in water quality (i.e., water temperature, suspended sediment concentrations, and nutrients) between conditions under the Proposed Project and existing conditions during the growth season (i.e., summer and early fall) in the reaches where the Lower Klamath Project reservoirs are located and at various in-river locations within the phytoplankton and periphyton Area of Analysis are also used to evaluate Proposed Project-induced changes on other phytoplankton (e.g., diatoms) and periphyton.

This analysis will then inform comparison of phytoplankton and periphyton conditions under the Proposed Project with the existing condition described above. To the extent that there is an increase in the periphyton as defined in the significance criteria, the analysis will consider whether these changes would affect a new or further impairment of designated beneficial uses.

3.4.5 Potential Impacts and Mitigation

3.4.5.1 Phytoplankton

Potential Impact 3.4-1 Short-term increase in growth of nuisance and/or noxious phytoplankton blooms due to increases in sediment-associated nutrients from release of sediments currently trapped behind the Lower Klamath Project dams. Under the Proposed Project, J.C. Boyle Reservoir would be removed in Oregon and Iron Gate, Copco No. 1, and Copco No. 2 reservoirs would be removed in California, and sediment accumulated behind each dam would be released and transported downstream through the Klamath River and into the Pacific Ocean (see Section 3.2.5.2 *Suspended Sediments* and Potential Impacts 3.11-5 and 3.11-6). By calendar year 2020, the total amount of sediment expected to have been deposited behind J.C. Boyle, Copco No. 1, Copco No. 2, and Iron Gate dams is approximately 15.1 million cubic yards (Table 2.7-10), with modeling indicating that reservoir drawdown would erode and transport between 36 and 57 percent of the reservoir sediment (between 5.4 and 8.6 million cubic yards) downstream through the Klamath River (Table 2.7-11). Large quantities of sediment would remain in place after dam removal, primarily on areas above the active channel of the Klamath River and these remaining reservoir sediments would dry out, decrease in thickness, and stabilize within the historical reservoir footprints (see Section 2.7.3 *Reservoir Sediment Deposits and Erosion During Drawdown* for more details). Reservoir sediments consist primarily of fine and sand sediments (see Table 2.7-9) with the fine sediments mostly an accumulation of silt-size particles of organic material from dead and decaying algae and silt-size inorganic particles of rock (USBR 2012). Sediment-associated nutrients that have accumulated in the sediment deposits are primarily from dead algae and are typically bound to the fine sediments (Deas 2008, Downs et al. 2010, USBR 2012).

Short-term increases in sediment-associated nutrients could occur in the Hydroelectric Reach, Middle and Lower Klamath River, and the Klamath River Estuary due to the release of sediments currently trapped behind the dams (see Potential Impact 3.2-7). While there would be a short-term increase in sediment-associated nutrients, minimal deposition of fine suspended sediments, including the associated nutrients, would occur in the river channel and the estuary (Stillwater Sciences 2008; USBR 2012). Thus, the short-term increase in nutrients would be limited to the time period when sediment deposits are being transported through the Klamath River. The reservoir drawdown and release of these nutrients would occur during winter months when the rates of phytoplankton growth and reproduction, which require nutrients, are relatively low. As a result, the ability of phytoplankton to use sediment-associated nutrients mobilized during reservoir drawdown would be low and the Proposed Project would not be likely to stimulate an increase in phytoplankton growth or reproduction. Sediment released during reservoir drawdown under the Proposed Project also would increase suspended sediment concentrations and water turbidity (Potential Impact 3.2-3), limiting light availability for phytoplankton photosynthesis and further reducing the potential for additional phytoplankton growth and reproduction.

Further, by mid- to late-spring when phytoplankton would have begun to bloom in the calm Lower Klamath Project reservoir habitat, reservoir drawdown would be complete and the riverine concentration of suspended sediments (see Potential Impact 3.2-3) and the additional sediment-associated nutrients (see Potential Impact 3.2-7) would be low. The minimal deposition of fine suspended sediments, including associated nutrients, in the river channel and the estuary (Stillwater Sciences 2008; USBR 2012) could provide nutrients for phytoplankton growth. However, because higher velocity river conditions would replace the slower-moving reservoir habitat in the Hydroelectric Reach after drawdown, there would be limited suitable habitat for phytoplankton growth and reproduction, regardless of any sediment-associated nutrients that may be deposited in the river channel or the estuary during drawdown. Phytoplankton, especially cyanobacteria [blue-green algae], growth is highest in stable water column conditions (Konopka and Brock 1978; Kann 2006; Asarian and Kann 2011) and the abundance of cyanobacteria [blue-green algae] decreases compared to other phytoplankton (e.g., diatoms and green algae) when mixing in a water body increases (McDonald and Lehman 2013; Visser et al. 2016). The lack of suitable habitat in the Hydroelectric Reach in mid- to late-spring would limit phytoplankton growth and reproduction, even with any sediment-associated nutrients that may be present. Furthermore, the reaches of the Hydroelectric Reach where the reservoirs are located would no longer transport high concentrations of nuisance and/or noxious phytoplankton species from phytoplankton blooms in the reservoirs into the Middle and Lower Klamath River and the Klamath River Estuary under the Proposed Project (Potential Impact 3.4-2), so phytoplankton growth and reproduction also would be limited in these reaches, even with any sediment-associated nutrients.

Additional movement of reservoir sediment deposits not mobilized during drawdown in dam removal year 2 may occur during winter high flows in post-dam removal year 1, resulting in additional transport of sediment-associated nutrients. However, nuisance and/or noxious phytoplankton blooms would not be stimulated by these nutrients, since they would occur during winter months when growth, reproduction, and nutrient transformation rates would be low, suspended sediment during transport of sediment-associated nutrients would limit light availability for phytoplankton growth, and calm, slow-moving habitat for phytoplankton would be limited. Winter high flows during post-dam removal year 1 would be likely to transport some sediments from remaining reservoir sediment deposits, although this would be limited due to revegetation of the reservoir footprints (Potential Impact 3.2-3) and the reasons identified above (e.g., limited light and faster-moving water) that would generally limit potential phytoplankton growth during winter flows. Thus, there would be minimal deposition of fine sediments and associated nutrients in the river channel and the estuary and negligible stimulation of phytoplankton growth later in post-dam removal year 1 in associated with sediment export related to the Proposed Project.

For the reasons stated above, phytoplankton growth and reproduction would not be increased by mobilization of sediment-associated nutrients during dam removal year 2 (i.e., reservoir drawdown) and post-dam removal year 1. Accordingly, the Proposed Project would not increase the spatial extent, temporal duration, toxicity, or concentration of nuisance and/or noxious phytoplankton blooms in the Hydroelectric Reach, Middle and Lower Klamath River, or the Klamath River Estuary, and there would be no short-term impact.

Significance

No significant impact

Potential Impact 3.4-2 Alterations in the spatial extent, temporal duration, transport, or concentration of nuisance and/or noxious phytoplankton blooms and concentrations of algal toxins due to dam removal and elimination of reservoir habitat.

Hydroelectric Reach

The removal of the Lower Klamath Project dams and reservoirs, particularly the larger Copco No. 1 and Iron Gate reservoirs, would decrease or eliminate support for excessive growth of blue-green algae (i.e., blooms) over the long term by eliminating large areas of quiescent habitat where these phytoplankton species currently thrive. In the nutrient-rich Klamath River system, the elevated water temperatures and increased light levels that occur during the summer and early fall result in seasonal blue-green algae blooms in the phytoplankton and periphyton Area of Analysis, and especially the Hydroelectric Reach (Section 3.4.2.3 *Hydroelectric Reach*). In addition to Copco No. 1 and Iron Gate reservoirs, riverine reaches downstream of the reservoirs generally experience high abundance of *Microcystis aeruginosa*, with the highest cell densities and microcystin toxin concentrations occurring directly downstream of Iron Gate Reservoir (see Section 3.2.2.7 *Chlorophyll-a and Algal Toxins*, Section 3.4.2.4 *Middle and Lower Klamath River*, and Appendix C – C.6.2 *Mid- and Lower Klamath Basin*). Available data strongly indicate that the reservoirs provide ideal conditions for blue-green algae blooms and serve as a source of blue-green algae cells and their toxins (e.g., microcystin) to downstream areas. While cyanobacteria [blue-green algae] can occur in riverine and estuarine environments (Christian et al. 1986, Lehman et al. 2005, Lehman et al. 2008), the rate of turbulent mixing in the water column relative to the flotation velocity of cyanobacteria [blue-green algae] is a critical factor controlling the size of cyanobacteria [blue-green algae] blooms (Huisman et al. 2004). Numerous studies in water bodies around the world have documented how blue-green algae tend to dominate the phytoplankton community in environments with low turbulent mixing (e.g., lakes, reservoirs). However blue-green algae abundance compared to other phytoplankton (e.g., diatoms and green algae) decreases as water column mixing increases because the net growth rate of blue-green algae decreases as they are mixed into the deeper water column where there is greater light variation and less overall light availability for photosynthesis. In addition to less overall light availability, Mitrovic et al. (2003) reports that the variation in light availability cyanobacteria [blue-green algae] would experience in a turbulent river mixing environment would reduce *Microcystis aeruginosa* and *Anabaena* growth compared to other phytoplankton species (e.g., diatoms and green algae). Under turbulent mixing conditions, cyanobacteria [blue-green algae] also face more competition from other phytoplankton that can remain suspended in the water column, compete for available light, and increase their net growth rate relative to cyanobacteria [blue-green algae] (Visser et al. 2016).

The Proposed Project would dramatically decrease the amount of optimal (i.e., calm, slow-moving reservoir) habitat available for the growth of nuisance and/or noxious phytoplankton species in the Hydroelectric Reach, resulting in a corresponding decrease in phytoplankton blooms compared to under existing conditions. After reservoir drawdown finishes, the calm, slow-moving reservoir habitat would be replaced by higher velocity riverine conditions, with limited suitable habitat for phytoplankton growth and reproduction. Higher mixing conditions would especially decrease blue-green algae abundance, since the increases in mixing would decrease the overall light availability for growth and reproduction compared to calm conditions where these organisms can remain exclusively near the water surface. Diatoms and green algae tend to grow better in turbulent river conditions than calm lake conditions, so blue-green algae also would be out-competed by these other phytoplankton. The lack of suitable habitat would substantially reduce seasonal phytoplankton bloom occurrence, especially blue-green algae blooms, and the associated production of algal toxins that are potentially harmful to animals and humans and impair designated beneficial uses. While the nutrients currently entering the Hydroelectric Reach may continue to be available to organisms in the Klamath River following dam removal, phytoplankton, especially blue-green algae, would be limited in their ability to use those nutrients for growth and reproduction without calm reservoir habitat. Cyanobacteria [blue-green algae] do not dominate under the current nutrient conditions in the turbulently mixing Klamath River downstream of J.C. Boyle Reservoir and upstream of Copco No. 1 Reservoir (Kann and Asarian 2006), so blue-green algae also would not be expected to dominate in the new turbulently mixed river reaches formed when Copco No. 1 and Iron Gate dams are removed. Under the Proposed Project, reductions in nuisance and/or noxious phytoplankton blooms, due to the elimination of the reservoirs in the Hydroelectric Reach, would be beneficial.

Drawdown of the reservoirs would begin in winter and would be largely complete by March/April (i.e., the beginning of the growth season) of dam removal year 2, so complete elimination of the reservoir environment would occur by the end of dam removal year 2 under the Proposed Project. Thus, the reductions in nuisance and/or noxious phytoplankton blooms would also occur by the end of dam removal year 2 in the Hydroelectric Reach and this would be a short-term benefit as well as a long-term benefit.

Middle and Lower Klamath River

Under the Proposed Project, nuisance and/or noxious phytoplankton blooms and concentrations of algal toxins would be expected to decrease in the Middle and Lower Klamath River, because the removal of Copco No. 1 and Iron Gate reservoirs would eliminate the primary source of Microcystis aeruginosa in the Middle and Lower Klamath River downstream of Iron Gate Dam. Existing data indicate blue-green algae (e.g., Microcystis aeruginosa) and associated algal toxins (e.g., microcystin) in the Middle and Lower Klamath River downstream of Iron Gate Dam do not result from transport of blue-green algae or algal toxins from upstream sources (i.e., Upper Klamath Lake), but originate from large seasonal blue-green algae blooms in Iron Gate and potentially Copco No. 1 reservoirs (see Section 3.4.2.3 *Hydroelectric Reach*, Section 3.4.2.4 *Middle and Lower Klamath River*, and Appendix C – *Section* C.6 *Chlorophyll-a and Algal Toxins*). Large seasonal blue-green algae blooms occurring upstream of the Area of Analysis are removed from the Upper Klamath River by upstream processes (e.g., settling in Keno Reservoir, microbial degradation) as well as dilution from tributaries in the Hydroelectric Reach and natural groundwater springs occurring in the J.C. Boyle Bypass Reach (see Section 3.2.2.3 *Suspended Sediments* and Appendix C – Section C.2.1.1 *Hydroelectric Reach*). *Microcystis aeruginosa* are typically not detected immediately upstream of Copco No. 1, but measurements of *Microcystis aeruginosa* taken at sampling locations in Copco No. 1 and Iron Gate reservoirs on the same day as the upstream measurements did occasionally detect large blooms of *Microcystis aeruginosa*, supporting the conclusion *Microcystis aeruginosa* blooms are primarily originating in those reservoirs. *Microcystis aeruginosa* was detected in only 2 of 17 measurements at the Klamath River station just upstream of Copco No. 1 Reservoir near the confluence with Shovel Creek ("KRAC" monitoring location in Figure 3.4-2) from 2001 to 2004 (Kann and Asarian 2006) and no detections were reported in data from 2005 (Kann and Asarian 2007), 2006 (Kann and Corum 2007), 2007 (Kann 2007), and 2008 (Kann and Corum 2009). However, three detections of *Microcystis aeruginosa* (in

79 measurements) were reported upstream of Copco No. 1 Reservoir near the confluence with Shovel Creek in a compilation of data from 2005 to 2010, with two measurements in 2007 and one measurement in 2008 (Asarian and Kann 2011). Those three measurements of *Microcystis aeruginosa* occurred in October or November after *Microcystis aeruginosa* had peaked in Copco No. 1 and Iron Gate reservoirs. Furthermore, genetic analysis of cyanobacteria [blue-green algae] populations in Copco No. 1 and Iron Gate reservoirs indicate the cyanobacteria [blue-green algae] found in the Middle and Lower Klamath River are similar to those found in Iron Gate Reservoir and not due to transport of cyanobacteria [blue-green algae] populations from Copco No. 1 Reservoir or farther upstream (Otten et al. 2015).

Microcystin trends in the Hydroelectric Reach and Middle and Lower Klamath River (see Appendix C, Figures C-52 and C-53 for details) also support the conclusion that microcystin detected downstream of Iron Gate Dam is not the result of transport from upstream sources (i.e., Upper Klamath Lake), but originates from large seasonal blue-green algae blooms in Iron Gate and potentially Copco No. 1 reservoirs. Microcystin toxin rarely persists in the Upper Klamath River under current conditions due to upstream removal mechanisms. Adsorption onto both suspended and streambed sediments (e.g., clay particles), breakdown by sunlight (i.e., photodegradation), and microbial degradation are several key microcystin removal mechanisms in natural freshwater and marine environments (Schmidt et al. 2014). Measured microcystin concentrations within Copco No. 1 and Iron Gate reservoirs have annually exceeded the CCHAB threshold 0.8 ug/L total microcystin between 2009 and 2018, with peak concentrations often exceeding 10 ug/L total microcystin multiple times per year and exceeding 100 ug/L total microcystin in both reservoirs between 2014 and 2017 (Watercourse Engineering Inc. 2011a, 2011b, 2012, 2013, 2014, 2015, 2016; E&S Environmental Chemistry, Inc. 2013, 2014, 2015, 2016, 2018a, 2018b). While microcystin was greater than the 2016 CCHAB threshold in Copco No. 1 and Iron Gate reservoirs, in the Klamath River upstream of Copco No. 1 microcystin was typically below detectable concentrations with infrequent measurements above the 2016 CCHAB threshold of 0.8 ug/L total microcystin (see also Figure 3.4-13; Kann and Asarian 2006, 2007; Kann 2007; Kann and Corum 2007, 2009; Watercourse Engineering Inc. 2011a, 2011b, 2012, 2013, 2014, 2015, 2016; Otten et al. 2015). The frequency of higher microcystin measured in Copco No. 1 and Iron Gate reservoirs than upstream of Copco No. 1 Reservoir strongly supports data that *Microcystis aeruginosa* blooms within the reservoirs are the source of microcystin in the two reservoirs and in the Klamath River downstream of Iron Gate Dam rather than microcystin being transported into the reservoirs from upstream.

Under the Proposed Project, turbulence and higher velocities would occur in the Hydroelectric Reach where the calm, slow-moving waters of Copco No. 1 and Iron Gate reservoirs currently exist, and these conditions would potentially provide additional removal of *Microcystis aeruginosa* from upstream sources, which would also reduce associated microcystin concentrations. The calm, slow-moving reservoir habitat that supports seasonal nuisance and/or noxious phytoplankton blooms in the Hydroelectric Reach would be eliminated and the available data suggests that large blooms of *Microcystis aeruginosa* from upstream would not be transported through the Hydroelectric Reach into the Middle Klamath River and further downstream reaches. Therefore, the overall occurrence of nuisance and/or noxious phytoplankton blooms and associated toxins in the Middle and Lower Klamath River would be substantially reduced or eliminated. Drawdown of the reservoirs would begin in winter and would be largely complete by March/April (i.e., the beginning of the growth season) of dam removal year 2, so complete elimination of the reservoir environment would occur by the end of dam removal year 2 under the Proposed Project. Thus, the reductions in nuisance and/or noxious phytoplankton blooms transported downstream from the reservoirs would also occur by the end of dam removal year 2 and this would be a short-term benefit as well as a long-term benefit.

Long-term increases in annual total nutrient levels would occur in the Middle and Lower Klamath River due to the lack of continued interception of nutrients by the Lower Klamath Project dams (Potential Impact 3.2-8). However, possible summer and fall increases in nutrient concentrations following Lower Klamath Project dam removal (see Section 3.2.5.3 *Nutrients*), particularly directly downstream from Iron Gate Dam, would not substantially contribute to blue-green algae blooms downstream from the dam, due to the lack of the suitable habitat conditions required for extensive phytoplankton growth in the Klamath River (see discussion above under the Hydroelectric Reach). Some phytoplankton growth may still occur after dam removal in calm, slow-moving habitats along shorelines and protected coves and backwaters during low-flow periods in the Middle and Lower Klamath River, but these habitats already support growth of blue-green algae, including *Microcystis aeruginosa*, that results in occasional exceedances of 2016 CCHAB secondary thresholds and WHO guidelines (Falconer et al. 1999; Kann et al. 2010; State Water Board et al. 2010, updated 2016; Genzoli and Kann 2016, 2017). While total nutrient transport into the Middle and Lower Klamath River after dam removal would slightly increase under the Proposed Project, *Microcystis aeruginosa* cell density and microcystin concentrations in Middle and Lower Klamath River after dam removal are expected to decrease due to reduced transport of *Microcystis aeruginosa* and microcystin from the Hydroelectric Reach into the Middle and Lower Klamath River. Therefore, the slight increase in nutrient availability is not expected to support nuisance phytoplankton growth or blooms that exceed current levels.

This analysis suggests that the Proposed Project would have a positive effect on aquatic resources in the Klamath River downstream from Iron Gate Dam in the long term based on reductions in downstream transport and concentrations of phytoplankton and microcystin toxins to this area. Overall, under the Proposed Project, long-term reductions in nuisance and/or noxious phytoplankton blooms in the reservoirs in the Hydroelectric Reach would reduce or eliminate the transport of nuisance and/or noxious phytoplankton species, blooms of these phytoplankton species, and concentrations of algal toxins (e.g., microcystin) into the Middle and Lower Klamath River and would be beneficial.

Klamath River Estuary

Information relating current conditions of phytoplankton biomass, population dynamics, and nutrient limitation to phytoplankton growth in the Klamath River Estuary is limited even though blue-green algae cell concentrations are monitored monthly to bi-weekly during much of the year (Fetcho 2006, 2007, 2008, 2011; Sinnott 2011, 2012; Hanington and Torso 2013; Hanington and Stawasz 2014; Hanington and Cooper-Carouseli 2014; Gibson 2016). Consequently, it is difficult to determine the potential long-term effects that the Proposed Project would have on phytoplankton in the Klamath River Estuary. Existing information indicates that instances of elevated levels of *Microcystis aeruginosa* in the Klamath River Estuary correspond with elevated levels measured at upstream locations in the Lower Klamath River (see Section 3.4.2.5 *Klamath River Estuary*). Removal of the Lower Klamath Project would reduce or eliminate elevated

Microcystis aeruginosa levels in the Lower Klamath River (see discussion in the prior section), so levels in the Klamath River Estuary are also likely to be reduced or potentially eliminated. Klamath River tributaries may influence Klamath River Estuary cyanobacteria [blue-green algae] conditions; however, infrequent detections of low cyanobacteria [blue-green algae] concentrations and associated algal toxins at the mouth of major Klamath River tributaries downstream of Iron Gate Dam (e.g., Scott River) suggest that tributaries are a lesser influence on cyanobacteria [blue-green algae] concentrations in the Klamath River Estuary compared with the mainstem Klamath River (Kann et al. 2010).

As detailed for the Middle and Lower Klamath River, small increases in nutrient transport from the upper watershed could occur over the long term because of dam removal (Potential Impact 3.2-8). The potential nutrient increase to the Klamath River Estuary would be smaller than in the Middle and Lower Klamath River, with the Yurok Tribe analysis modeling an increase of approximately 0.15 mg/L or less total nitrogen and an increase of approximately 0.01 mg/L or less total phosphorus (see Figure 3.2-19). The Yurok Tribe analysis' estimate of nutrient increases conservatively includes assumptions that would tend to over-estimate the potential change, since it does not take into account other possible factors that may decrease nutrients upstream of Copco No. 1 Reservoir under the Proposed Project, such as TMDL implementation or elimination of peaking flows from hydropower operations. If reductions in nutrients do occur upstream of Copco No. 1 Reservoir, then there would be an even smaller long-term increase in nutrients to the Klamath River Estuary (Asarian et al. 2010).

Estimated long-term increases in nutrients to the Klamath River Estuary are less than or within current annual and inter-annual variations in nutrients, suggesting the additional nutrients would not stimulate an increase in phytoplankton growth beyond current conditions in the Klamath River Estuary. In the Klamath River Estuary between 2010 and 2014, the annual variation between maximum and minimum total nitrogen ranged from 0.28 to 0.55 mg/L, with a 0.13 to 0.18 mg/L variation in peak total nitrogen between years. The annual variation between maximum and minimum total phosphorus ranged from 0.03 to 0.15 mg/L, with a 0.01 to 0.12 mg/L variation in peak total phosphorus between years from 2010 to 2014 (Sinnott 2011b, 2012b; Hanington and Torso 2013; Hanington and Stawasz 2014; Hanington and Cooper-Carouseli 2014).

Some additional growth of nuisance and/or noxious phytoplankton species could occur in the Klamath River Estuary during summer and fall low-flow periods due to the previously mentioned small increase in nutrients. The relative increase in phosphorus would be particularly small such that the prevalence of nitrogen-fixing blue green algae species (i.e., *Aphanizomenon flos-aquae* and *Anabaena flos-aquae*) would be unlikely to change relative to existing conditions. Nitrogen availability in the water is relatively more important for *Microcystis aeruginosa* because it does not fix nitrogen from the air (Eldridge et al. 2012). Although nitrogen would also increase in the estuary water, *Microcystis aeruginosa* cell density and microcystin concentrations are likely to be the same or less than current conditions due to the lack of downstream transport of seasonal blooms of this species from Copco No. 1 and Iron Gate reservoirs. Under the Proposed Project, long-term reductions in nuisance and/or noxious phytoplankton blooms in the Hydroelectric Reach and the reduction or elimination of transport of phytoplankton cells and their associated toxins into the estuary would be beneficial for the Klamath River Estuary.

Pacific Ocean nearshore environment
The Pacific Ocean nearshore environment is not a suitable habitat for the freshwater phytoplankton species of concern (i.e., *Aphanizomenon flos-aquae*, *Anabaena flos-aquae*, *Microcystis aeruginosa*) therefore the Proposed Project would have no impact on these species. Further, nutrient increases in the Pacific Ocean nearshore environment due to the lack of continued interception by the Lower Klamath Project dams would be considerably less than the background supply of nutrients from coastal upwelling (Bruland et al. 2001; Bograd et al. 2009), so the nutrient increase is not expected to affect marine phytoplankton blooms.

Significance
Beneficial for the Hydroelectric Reach, Middle and Lower Klamath River, and Klamath River Estuary in the short term and long term

No significant impact for the Pacific Ocean nearshore environment in the short term and long term

3.4.5.2 Periphyton

Potential Impact 3.4-3 Short-term increase in growth of nuisance periphyton species due to increases in sediment-associated nutrients from release of sediments currently trapped behind the Lower Klamath Project dams.
Under the Proposed Project J.C. Boyle Reservoir would be removed in Oregon and Iron Gate, Copco No. 1, and Copco No. 2 reservoirs would be removed in California, releasing sediment accumulated behind each dam and transporting the sediment downstream through the Klamath River and into the Pacific Ocean (see 3.2.5.2 *Suspended Sediments* and 3.11.4 *Impact Analysis Approach).* Modeling indicates reservoir drawdown eroding and transporting between 5.4 and 8.6 million cubic yards of reservoir sediment downstream through the Klamath River (Table 2.7-11). Large quantities of sediment would remain in place after dam removal, primarily on areas above the active channel of the Klamath River and these remaining reservoir sediments would dry out, decrease in thickness, and stabilize in place within the historical reservoir footprints (see Section 2.7.3 *Reservoir Sediment Deposits and Erosion During Drawdown* for more details). Reservoir sediments consist primarily of fine and sand sediments (see Table 2.7-9) with the fine sediments mostly an accumulation of silt-size particles of organic material from dead and decaying algae and silt-size inorganic particles of rock (USBR 2012). Sediment-associated nutrients that have accumulated in the sediment deposits are primarily from dead algae and typically bound to the fine sediments (Deas 2008; Downs et al. 2010; USBR 2012).

In the short term, through winter and early to mid-spring of dam removal year 2 (Table 2.7-1), periphyton growth would be unlikely to be stimulated by sediment-associated nutrients or conversion of the reservoir areas to free-flowing streams and elimination of hydropower peaking operations. Short-term increases in sediment-associated nutrients would occur in the Hydroelectric Reach, Middle and Lower Klamath River, and the Klamath River Estuary due to the release of sediments currently trapped behind the dams (see Potential Impact 3.2-7). However, reservoir drawdown would occur during winter months when rates of periphyton growth and reproduction, which require nutrients, are relatively low due to less light availability for photosynthesis and lower water temperatures. As a result, the ability of periphyton to use sediment-associated nutrients would be limited and there would not be an increase in periphyton growth or reproduction during this period, even though additional nutrients would be available due to the release of sediments trapped behind the Lower Klamath Project dams. Light limitation from high concentrations of suspended sediments in the water (Potential Impact 3.2-3) would also reduce any potential for nuisance levels of periphyton growth during reservoir drawdown.

Additionally, high river flows during the winter drawdown period and late spring storm events would result in greater sediment movement and scouring under the Proposed Project (Potential Impacts 3.11-5 and 3.11-6), which would greatly limit, if not eliminate, the area of the streambed that periphyton can thrive during this period. At individual monitoring sites in the Klamath River, higher flow consistently corresponds to lower total periphyton biovolume, especially at sites with a larger variation in flows. After natural high flows due to storms, periphyton is reduced to a thin layer of scour-resistant diatoms, since some diatom species are well suited to withstand higher flows (Asarian et al. 2015). Three studies analyzed the flows required to mobilize the streambed downstream of Iron Gate Dam from the Klamath River confluence with Bogus Creek (RM 192.6) to either its confluence with the Shasta River (RM 179.5) or Blue Creek (RM 16.2) (dependent on study). An analysis of those studies indicates that under current conditions, flows between 5,000 to 8,700 cfs would move surface fine sediments on 20 to 30 percent of the streambed (i.e., surface flushing), flows between 8,700 and 11,250 cfs would move in-filled fine sediment between streambed cobbles (i.e., deep flushing), and flows between 11,250 to 15,000 cfs would move individual cobbles (i.e., armor disturbance) (Hillemeier et al. 2017). Modeling indicates that during drawdown flow downstream of Iron Gate Dam would exceed the minimum surface flushing flows for approximately one week to over one month between January and April under wet, above normal, and normal water year types, while flow would exceed the minimum armor disturbance flows for approximately one day to one week between January and February under wet and above normal water year types. Mobilization of the streambed during drawdown flows would also be expected to scour periphyton attached to the streambed sediments. This effect is particularly important for periphyton during winter because high drawdown or natural flows that move larger sediments like gravels and cobbles would limit and potentially eliminate short-term establishment of periphyton along the streambed and other underwater surfaces. This reduction in the area periphyton can establish and grow due to these high flows in winter and spring would result in decreases in the overall periphyton abundance in the river, further inhibiting uptake of sediment-associated nutrients by periphyton for growth as those nutrients are transported through the Klamath River.

Additional movement of reservoir sediment deposits not removed during drawdown in dam removal year 2 may occur during winter high flows in post-dam removal year 1 resulting in more transport of sediment-associated nutrients. However, growth of nuisance periphyton species would not be stimulated by these nutrients since they would be transported through the Klamath River during winter months when growth, reproduction, and nutrient transformation rates would be low, high flows may scour the streambed and reduce periphyton abundance, and suspended sediment during transport of sediment-associated nutrients would limit light availability for periphyton growth. Similar to conditions during reservoir drawdown, winter high flows that transport suspended sediments would result in minimal deposition of fine sediments, so minimal sediment-associated nutrients would deposit and be available to stimulate periphyton growth later in the year.

As the periphyton growth would be unaffected by mobilization of sediment-associated nutrients during dam removal year 2 (reservoir drawdown) and post-dam removal year 1, the Proposed Project would not increase the spatial extent, temporal duration, or biomass of nuisance periphyton species to the degree that new or further impairment of designated beneficial uses would occur in the Hydroelectric Reach, Middle and Lower Klamath River, or the Klamath River Estuary due to transport of sediment-associated nutrients from release of reservoir sediment deposits from behind the Lower Klamath Project dams, and there would be no short-term impact.

Significance

No significant impact

Potential Impact 3.4-4 Alterations in growth of nuisance periphyton species in the Hydroelectric Reach due to increased nutrients and available low-gradient channel margin habitat formed by conversion of the reservoir areas to a free-flowing river and the elimination of hydropower peaking operations.

Periphyton growth in low-gradient channel margin areas in the Hydroelectric Reach could increase on a seasonal basis following dam removal because removal of the reservoirs and elimination of hydropower operations in the J.C. Boyle Peaking Reach would provide additional low-gradient habitat suitable for periphyton assemblages. Dam removal, construction, and restoration activities in dam removal year 2 and sediment transport and scour during winter post-dam removal year 1 may reduce periphyton abundance and growth, but, overall, periphyton would be expected to begin colonizing the newly created suitable habitat within the short term and this colonization and growth of periphyton would continue in the long term.

The particular periphyton species that could occupy these areas are unknown (E. Asarian, pers. comm., 2011), but analysis of periphyton species downstream of Iron Gate Dam indicates the types of periphyton assemblages that could occur in the free-flowing Hydroelectric Reach under the Proposed Project (Asarian et al. 2015). The exact periphyton assemblage would be dependent primarily on nutrient availability and seasonal flow variations (Gillet et al. 2016).

Under the Proposed Project, there would be less artificial diel temperature variation during summer and early fall in the J.C. Boyle Peaking Reach from the Oregon-California state line to Copco No. 1 Reservoir (see also Potential Impact 3.2-1). While J.C. Boyle retains relatively little nutrients under existing conditions (see Appendix C, Section C.3.1.1 *Hydroelectric Reach*), nutrients could increase slightly if J.C. Boyle Dam is removed. However, less diel temperature variations and a slight decrease in the maximum water temperature in this reach are not anticipated to affect periphyton colonization. Additionally, the generally high gradient and velocity in the J.C. Boyle Peaking Reach does not currently support excessive periphyton mats and it is not anticipated that this reach would support excessive periphyton mats if J.C. Boyle Dam were to be removed and hydropower peaking flows were to cease. In the short term and long term, increases in periphyton biomass from elimination of peaking flows along with the change in water temperatures are expected to be limited in the Hydroelectric Reach from the Oregon-California state line to Copco No. 1 Reservoir and any potential increase in periphyton would not result in new or further impairment of designated beneficial uses. Thus, there would be a less than significant impact of the Proposed Project on periphyton colonization in this reach.

Further downstream, in the lower-gradient portions of the Hydroelectric Reach, from Copco No. 1 Reservoir to Iron Gate Dam, long-term heavy colonization of periphyton mats in the Hydroelectric Reach is unlikely as potential increases in periphyton growth could be disrupted by increased flow variability during storm flow under the Proposed Project (see also Potential Impact 3.6-3) and more frequent river bed sediment movement (see also Potential Impact 3.11-5). Removal of the Lower Klamath Project dams and reservoirs, particularly Copco No. 1 and Iron Gate reservoirs, would produce slightly higher peak flows and more flow variations because modeling indicates the Lower Klamath Project provides a slight attenuation (1.1 to 6.9 percent) of peak flood flows (USBR 2012) and storm flow variations from tributaries entering the Hydroelectric Reach are dampened by the reservoirs. Additionally, upstream fine and sand sediments currently trapped by the Lower Klamath Project reservoirs, particularly Copco No. 1 and Iron Gate reservoirs, would be transported and deposited along the Hydroelectric Reach streambed, so the flow necessary to mobilize the streambed in the existing riverine sections of the Hydroelectric Reach would be less than existing conditions. Together these processes (i.e., higher peak flows, more flow variations, and lower flow needed to move sediments) would result in more frequent sediment transport in the Hydroelectric Reach, which may result in increased scouring of periphyton during winter and spring storm events compared to existing conditions and a lower overall biomass later in the growth season (FERC 2007; North Coast Regional Board 2010, Appendix 2).

However, the overall effect of the Proposed Project would likely be to increase periphyton in the margins of low gradient portions of Copco No. 1 and Iron Gate reservoir footprints due to the creation of new, previously uncolonized low gradient river channels. While there is considerable uncertainty, there is the potential under the Proposed Project that nuisance periphyton species could be part of the periphyton assemblages that grow in the margins of these new low gradient river channels. The nuisance periphyton species would potentially provide habitat for the polychaete worm (*Manayunkia speciose*) that is the intermediate host of the fish parasites *Ceratomyxa shasta* and *Parvicapsula minibicornis,* so the short-term and the long-term increase in growth of nuisance periphyton species due to increases in available habitat along channel margin areas of the Hydroelectric Reach within the Copco No. 1 and Iron Gate reservoir footprints also would potentially result in a new or further impairment of designated beneficial uses, and would therefore be a significant impact.

The above analysis represents a conservative assessment of the effects of the Proposed Project on short-term and long-term growth of nuisance periphyton species. The response of periphyton in the Klamath River is subject to many competing processes that could either accelerate or hinder periphyton growth and potential increases in nuisance periphyton species (i.e., *Cladophora* sp.) extent, duration, and biomass. In the long term, improvements (i.e., reductions in periphyton biomass) are expected from several processes such as scour, and in-stream nutrient retention processes, but periphyton biomass reductions could be diminished by processes such as reduced nutrient retention from the loss of the reservoirs or climate change. While the growth of nuisance periphyton species along channel margin areas is not expected to contribute algal toxins that would impair water quality, the degree to which designated beneficial uses would be impaired due to an increase in nuisance periphyton species (i.e., *Cladophora* sp.) in the newly formed low-gradient channel margin areas of the Hydroelectric Reach is not fully understood. The implications of potential changes in periphyton biomass and community composition on dissolved oxygen and the spread of fish disease are described in Section 3.2.5.4 *Dissolved Oxygen* and Section 3.3.5.5 *Fish Disease and Parasites*, respectively.

Periphyton are a natural component of river ecology and they are an important element of aquatic food webs. The establishment and growth of periphyton, including nuisance periphyton species, along the margins of the newly created low gradient river channel is a natural process. While processes that influence periphyton establishment and growth have been identified (e.g., light availability, nutrient availability, water temperature, seasonal flow variations, sediment transport), variations in these processes within the Hydroelectric Reach of the Klamath River after dam removal would not completely prevent the potential for growth of nuisance periphyton species along the margins of the newly created low gradient river channels. In the reservoir areas of the Hydroelectric Reach that would become the newly created low gradient habitat, there is no periphyton since it is not suitable habitat. No mitigation measure would completely eliminate the potential for establishment and growth of periphyton or specifically nuisance periphyton within these areas. As such, there are no mitigation measures that can be proposed to significantly avoid or minimize this impact and reduce the impact to less than significant.

<u>Significance</u>

No significant impact for the Hydroelectric Reach from the Oregon-California state line to Copco No. 1 Reservoir in the long term

Significant and unavoidable for the Hydroelectric Reach from Copco No. 1 Reservoir to Iron Gate Dam in the long term

Potential Impact 3.4-5 Alterations in biomass of nuisance periphyton species due to increased nutrients from upstream dam removal and conversion of the reservoir areas to a free-flowing river.

Middle and Lower Klamath River

As described in Section 3.4.2.4 *Middle and Lower Klamath River*, seasonal periphyton growth under existing conditions is relatively high in the Middle and Lower Klamath river (Eilers 2005). Under the Proposed Project, the Lower Klamath Project dams would no longer trap and store annual upstream nutrient inputs nor create the conditions where nutrients stored in reservoir sediments would be seasonally released downstream resulting in an anticipated overall less-than-significant long-term increase in absolute nutrient concentrations (see Section 3.2.5.3 *Nutrients*, Potential Impact 3.2-8 for more details).

The long-term increase in Total Nitrogen (TN) and Total Phosphorus (TP) are not expected to result in a significant biostimulatory effect on periphyton growth because nutrients do not appear to be limiting periphyton growth in the Klamath River from Iron Gate Dam (RM 193.1) to approximately Seiad Valley (RM 132.7) (and potentially farther downstream), N-fixing periphyton are abundant in the Lower Klamath River, and the increase in TP is minimal. While existing data regarding TN:TP ratios in the Klamath River suggest the potential for N-limitation (TN:TP <10), with some periods of co-limitation by N and P (see also Section 3.2.2.4 *Nutrients* and Appendix C – Section C.3.2 *Mid- and Lower Klamath Basin*), concentrations of both nutrients are high enough in the river from Iron Gate Dam to approximately Seiad Valley (and potentially further downstream) that periphyton growth is currently nutrient saturated. Nutrients are not likely to be limiting periphyton growth in this portion of the Klamath River (FERC 2007;

HVTEPA 2008; Asarian et al. 2010, 2014, 2015; Gillet et al. 2016) and additional upstream nutrients would not alter periphyton conditions in this reach. While there would be long-term increases in nutrients due to dam removal, seasonal (i.e., fall) downstream releases of nutrients stored in reservoir sediments would also be eliminated by removing the reservoirs and the overall magnitude of the long-term increases in nutrients available to stimulate periphyton growth downstream of the reservoirs would be less during fall. In the lower reaches of the Klamath River (i.e., downstream of approximately Seiad Valley), where inorganic nitrogen concentrations are low, N-fixing periphyton species currently dominate the periphyton communities (Asarian et al. 2010, 2014, 2015; Gillet et al. 2016). Since N-fixing species can fix their own nitrogen from the atmosphere, increases in TN due to dam removal may alter the composition of the periphyton community and shift the location where N-fixing species begin to dominate farther downstream in the Lower Klamath River (Asarian et al. 2010). However, the Proposed Project would be accompanied by only relatively minor increases in TP, so it is not expected to significantly increase periphyton biomass in these reaches.

In addition to the effects of changes in nutrient concentrations, periphyton community composition and biomass may be affected by light levels and substrate stability. As discussed for the Hydroelectric Reach (Potential Impact 3.4-4), potential increases in periphyton growth could be counteracted by increased flow variability during storm flow (see also Potential Impact 3.6-3) and by more frequent river sediment movement (Potential Impact 3.11-5). Removal of the Lower Klamath Project dams and reservoirs would produce more flow variations because modeling indicates the Lower Klamath Project dams provide a slight attenuation (1.1 to 6.9 percent) of peak flood flows (USBR 2012) and storm flow variations from tributaries entering the Hydroelectric Reach are dampened by the reservoirs. Additionally, upstream fine and sand sediments currently trapped by the Lower Klamath Project reservoirs would be transported and deposited downstream, so the flow necessary to mobilize the streambed would be less than under existing conditions. Together these processes would potentially increase scour of periphyton during winter and spring storm events following dam removal compared to existing conditions (FERC 2007; North Coast Regional Board 2010, Appendix 2). The magnitude of the effect of bed turnover and scouring on periphyton would decrease with distance downstream, with increased scour occurring from Iron Gate Dam to approximately the Shasta River (RM 179.5). TMDL model results suggest that increased scouring may somewhat limit long-term periphyton biomass following dam removal (North Coast Regional Board 2010, Appendix 2). Overall, these processes would reduce periphyton growth downstream from Iron Gate Dam.

Because of these many competing factors, some that may favor enhanced periphyton growth downstream from Iron Gate Dam (i.e., increasing nutrient transport and recycling), and some that counteract this response (i.e., increasing uptake and retention of nutrients by periphyton in the Hydroelectric Reach, increasing frequency and intensity of scouring events, eliminating seasonal nutrient releases from reservoir sediments), it is likely that long-term increases in periphyton growth in the Middle and Lower Klamath River, should they occur, would not be sufficient to result in an overall increase in the growth, extent, duration, or biomass of nuisance periphyton species, and would therefore be less than significant.

Klamath River Estuary

As discussed for the Middle and Lower Klamath River, periphyton growth in the Klamath River Estuary could be affected by increased nutrient availability following dam removal.

Long-term increases in nutrients in the Klamath River Estuary would be relatively small due to tributary dilution and nutrient retention in the 190 river miles between Iron Gate Dam and the Klamath River Estuary, with the Yurok Tribe analysis modeling reporting a potential increase of approximately 0.15 mg/L or less total nitrogen and approximately 0.01 mg/L or less total phosphorus in the Klamath River Estuary (see Figure 3.2-19; Asarian et al. 2010). The Yurok Tribe analysis' estimate of nutrient increases conservatively includes assumptions that would tend to over-estimate the potential change since it does not consider other possible factors that may decrease nutrients under the Proposed Project, such as full TMDL implementation or elimination of peaking flows from hydropower operations upstream of Copco No. 1 Reservoir. There would be an even smaller long-term increase in nutrients to the Klamath River Estuary, if these other factors occur (Asarian et al. 2010).

Estimated long-term increases in nutrients to the Klamath River Estuary are less than or within current annual and inter-annual variations in nutrients, suggesting the long-term increases in nutrients would not result in an increase in periphyton growth beyond the range occurring under existing conditions. In the Klamath River Estuary between 2010 and 2014, the annual variation between maximum and minimum total nitrogen ranged from 0.28 to 0.55 mg/L, with a 0.13 to 0.18 mg/L variation in peak total nitrogen between years. The annual variation between maximum and minimum total phosphorus ranged from 0.03 to 0.15 mg/L, with a 0.01 to 0.12 mg/L variation in peak total phosphorus between years from 2010 to 2014 (Sinnott 2011b, 2012b; Hanington and Torso 2013; Hanington and Stawasz 2014; Hanington and Cooper-Carouseli 2014). These annual variations are less than the estimated long-term increases in total nitrogen (i.e., 0.15 mg/L or less) and total phosphorus (i.e., 0.01 mg/L or less) and the inter-annual variations in peak nutrient concentrations are within the estimated long-term increases in nutrient concentrations. Variations in the growth of periphyton that rely on nitrogen in the water for growth (i.e., non-nitrogen fixing species like *Cladophora* sp.) would be expected to be within the range of existing conditions since the estimated long-term increase in nitrogen is within the range of total nitrogen variations under existing conditions. Additionally, nitrogen-fixing species that can fix their own nitrogen from the atmosphere dominate the periphyton communities in the lower reaches of the Klamath River where inorganic nitrogen concentrations are low (Asarian et al. 2010, 2014, 2015; Gillet et al. 2016) and these species also likely dominate the periphyton community in the estuary. Increases in total nitrogen due to dam removal are not likely to significantly increase periphyton biomass of these species in the Klamath River Estuary, since additional nitrogen could be obtained from the atmosphere by these periphyton, regardless of nutrient inputs. Some variation in periphyton growth could occur in the Klamath River Estuary due to the long-term increase in phosphorus. However, the estimated long-term increase in phosphorus is on the low end of natural variations in phosphorus in the Klamath River Estuary, so the growth and abundance of periphyton species, including nuisance periphyton species, in the estuary would likely remain within the current annual variation in periphyton growth.

Overall, the biological significance of potential increases in periphyton biomass in the Klamath River Estuary and its influence on designated beneficial uses is unknown due to uncertainty regarding the magnitude of increase in biomass required to generate a significant reduction in habitat quality for aquatic resources (North Coast Regional Board 2010, Appendix 2). Nonetheless, for the reasons described above, under the Proposed Project long-term increases in the growth of nuisance periphyton species in the Klamath

Estuary would be a less-than-significant impact since they would be within the range of existing conditions.

Significance
No significant impact for the Middle and Lower Klamath River and the Klamath River Estuary

3.4.6 References

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