Aquatic Ecosystem Sciences LLC

TECHNICAL MEMORANDUM

Microcystis aeruginosa Occurrence in the Klamath River System of Southern Oregon and Northern California

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INTRODUCTION

Toxic blooms of the cyanobacteria *Microcystis aeruginosa* (MSAE) were documented in Copco and Irongate Reservoirs (the lowermost projects of PacifiCorp's Klamath Hydropower Project--KHP) in 2004 and 2005 (Kann 2005). The first documented toxic bloom occurred in Copco Reservoir on September 29th 2004 when 1.9 million cells/ml of MSAE were associated with a microcystin toxin concentration of 482 μg/L. Microcystin is a potent hepatotoxin capable of causing chronic liver damage and acting as a tumor promoter (Carmichael 1995; Chorus et al. 1999; Chorus 2001). Copco and Iron Gate Reservoir data clearly showed the occurrence of large and widespread blooms of MSAE and microcystin toxin levels in 2005 (Kann 2005: shown here in Fig 1). During the July-September period, cell density and toxin levels exceeded the World Health Organization (WHO) Moderate Probability of Adverse Health Effect Level (MPAHEL) often by 10-100's of times; likewise, the Tolerable Daily Intake (TDI—see Kann [2005] for description) was also commonly exceeded by more than 10-100 times throughout the July-September period (Fig. 1).

These data also showed that during the same sample dates when in-reservoir data (the boxes in Fig. 1a and 1b) showed substantial MSAE cell density and toxin concentration, the Klamath River directly above the reservoirs (station KRAC) showed non-detects for both parameters (red circles in Fig. 1a and 1b). Comparatively, the station directly below the reservoirs (station KRBI) exhibited positive MSAE concentrations during this same period (Fig. 1).

From these empirical observations and given the extremely high concentrations of both MSAE density and microcystin toxin in the reservoirs in 2005, it appears that both reservoirs provided ideal growing conditions for MSAE relative to the Klamath River directly upstream (Kann 2005 and Fig. 2 below).

Partly in response to statements by PacifiCorp that MSAE is already frequent and abundant in the system upstream from Copco and Iron Gate (e.g., see response by PacifiCorp [Appendix I with added comment by Kann] to a letter submitted to FERC by California State Water Resources Board [Appendix 2II), and that the reservoirs only reflect this upstream abundance, the Yurok Tribe Environmental and Fisheries Programs contracted with Aquatic Ecosystem Sciences to use available data to evaluate MSAE longitudinal trends in the Klamath River.

The purpose of this technical memorandum is to provide a brief summary of MSAE in the Klamath River System using the following data sets: Klamath Tribes data from Upper Klamath Lake (1990-1997), PacifiCorp data from the outlet of UKL to the Klamath River at I5 (2001-2004), Karuk Tribe/CA State Water Resources Board (SWRB) data for the Copco Iron Gate reservoir system (2005), and Yurok Tribe/US Fish and Wildlife Service (USFWS) data from below Iron Gate Reservoir to the Klamath River estuary (2005).

DATA EVALUATION and TRENDS

Klamath Tribes Upper Klamath Lake (UKL) Data

The Klamath Tribes collected biweekly phytoplankton samples from a variety of stations in UKL and Agency Lake from 1990-1997 (Fig. 3). These data are shown in electronic Appendix E1 and

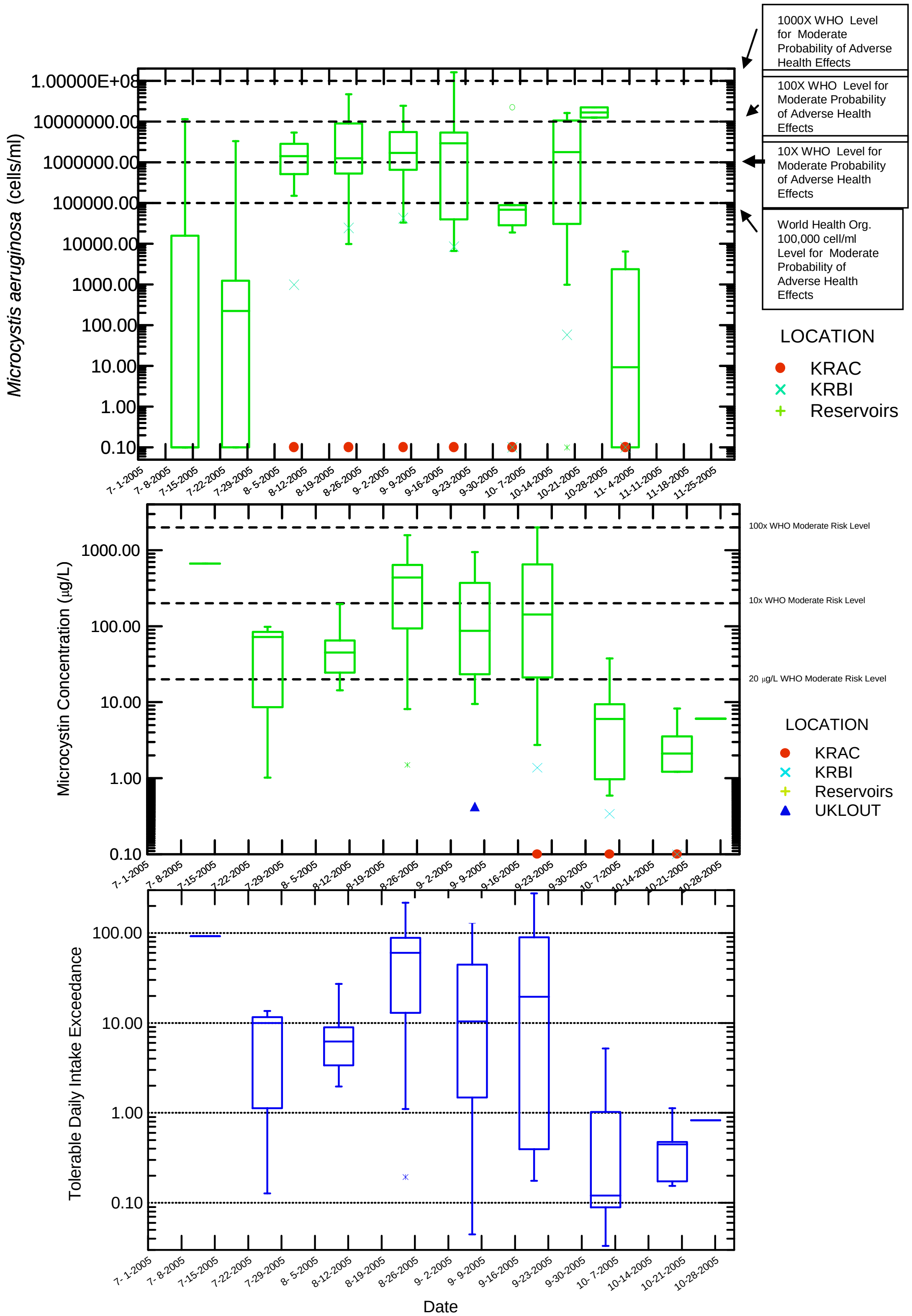

Figure 1. Karuk Tribe/SWRB *Microcystis aeruginosa* cell density (a), microcystin concentration (b), and TDI for all reservoir stations combined (c) in Copco and Irongate Reservoirs, July-October, 2005. Note y-axis is log scaled and for graphing purposes all values have 0.1added to them; Reservoirs=Copco and Iron Gate, KRAC=Klamath R. above Copco Reservoir, KRBI=Klamath R. below Iron Gate Reservoir, UKOUT=UKL outlet (sampled on one occasion). From Kann (2005).

Figure 2. Photos of the Klamath River Station KRAC and an MSAE bloom occurring near the confluence of Jenny Creek in Iron Gate Reservoir, 2005.

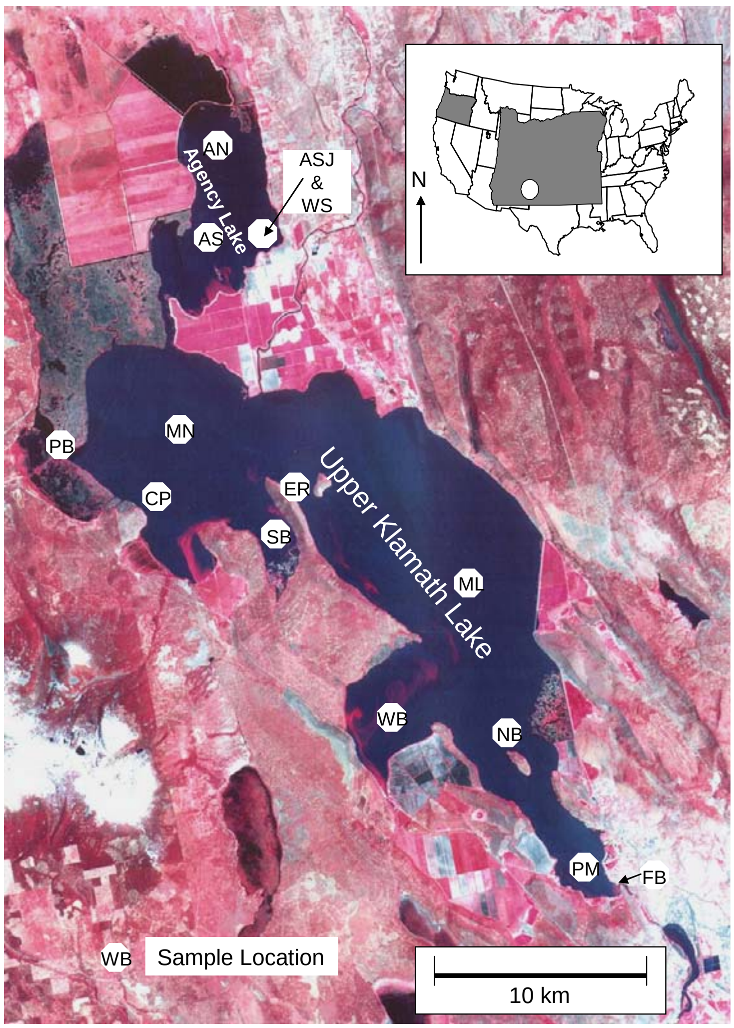

Figure 3. Sample station location for Upper Klamath and Agency Lake phytoplankton collections made by the Klamath Tribes between 1990 and 1997.

sample methods are outlined in Kann (1998). Because MSAE cell density was not reported for the UKL data set, MSAE colony density was also evaluated so that a common measurement unit could be compared among the UKL, PacifiCorp, and Karuk data sets. UKL samples represent an integrated water column sample generally ranging between 2-3 meters. MSAE biovolume and colony density values were converted from a per liter basis to a per mL basis to facilitate comparison among data sets. These data show that MSAE is clearly present in UKL and Agency Lakes (Figures 4a and 5a).

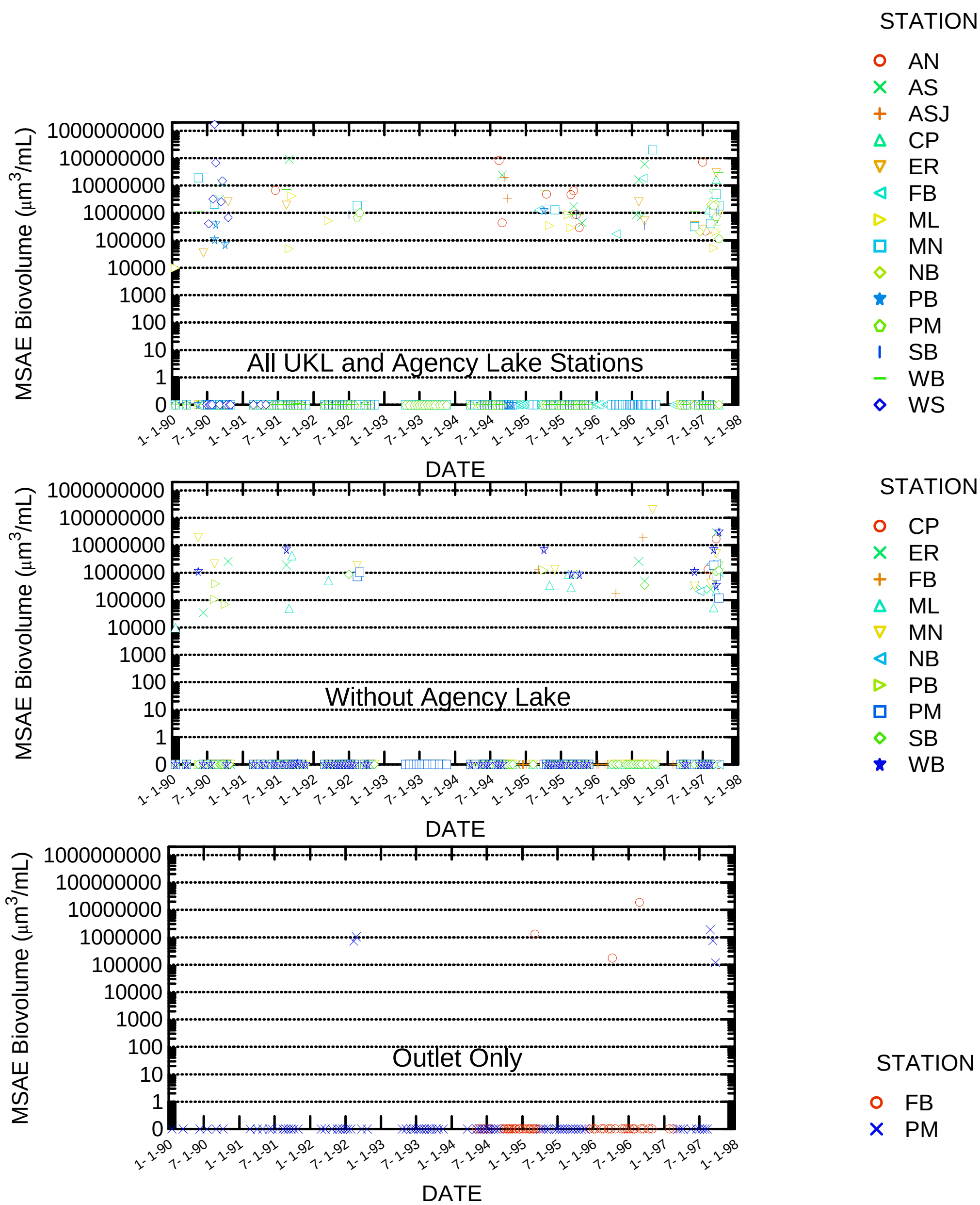

Figure 4. Klamath Tribes *Microcystis aeruginosa* biovolume at all UKL and Agency Lake stations (a), at UKL stations only (b), and for outlet stations only (c), 1990-1997. Note y-axis is log scaled and for graphing purposes all values have 0.1 added to them.

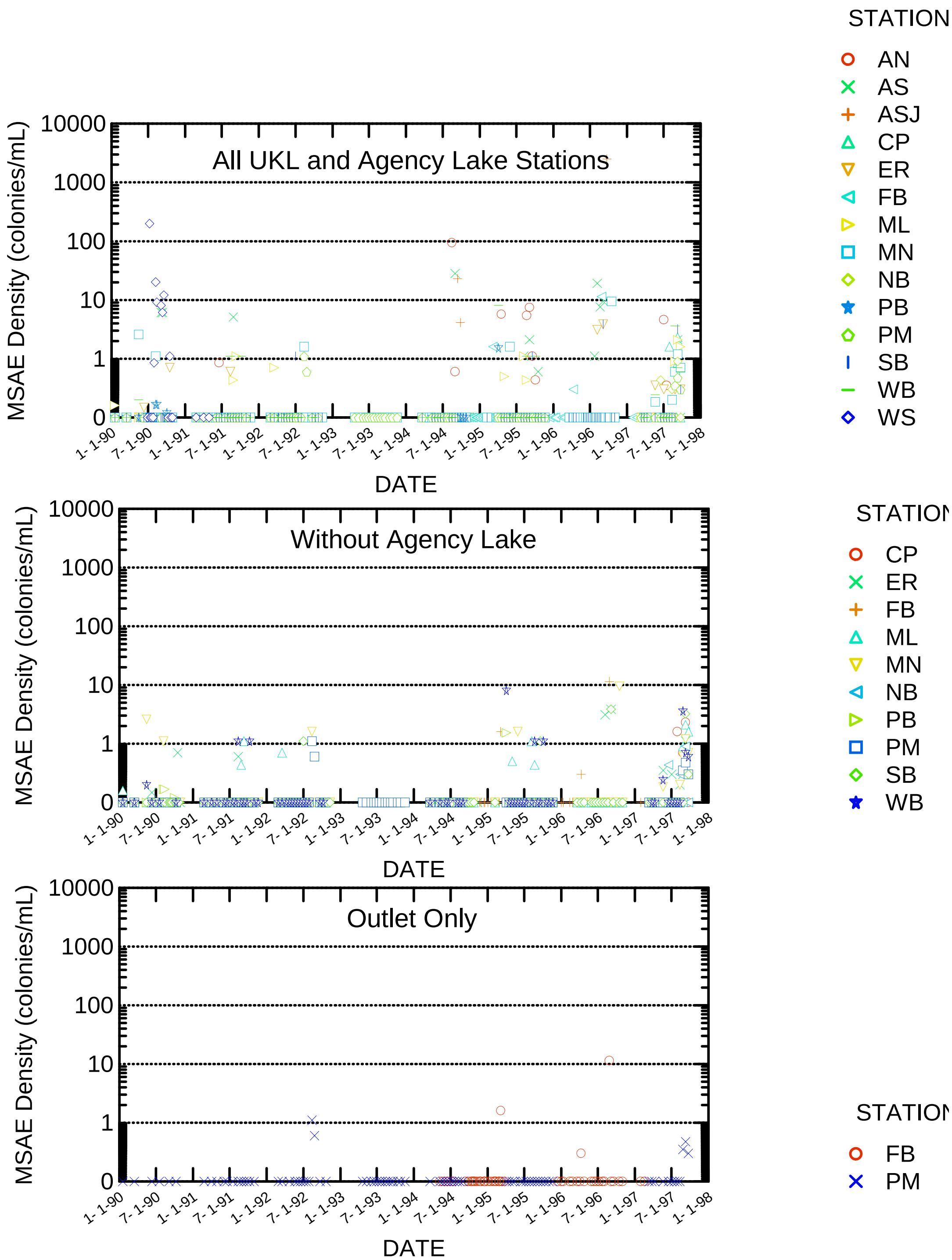

Figure 5. Klamath Tribes *Microcystis aeruginosa* colony density at all UKL and Agency Lake stations (a), at UKL stations only (b), and for outlet stations only (c), 1990-1997. Note y-axis is log scaled and for graphing purposes all values have 0.1 added to them.

However, many of the high biomass and high colony density occurrences were found in Agency Lake, and when these stations (AN, AS, ASJ, and WS) are excluded, maximum values drop substantially (Figures 4b and 5b). In fact, colony density values were rarely greater than10 colonies/mL for UKL only (Figure 5b), and exceeded 1 colony per/mL only 13 in 537 samples, or 2.4% of sample collections during the July-October period over 8 years (Table 1). The percent of all UKL samples where MSAE was detected in this period was 12.8% (Table 1). Given the dominance in UKL by another cyanobacterial species, *Aphanizomenon flos-aquae,* this is not unexpected.

Moreover, because a relevant question is the amount of MSAE leaving UKL and entering the Klamath River (via the Link River), Figure 5c shows MSAE only at PM (Pelican Marina) and FB (Fremont Bridge), stations near the outlet of UKL (Figure 3). It is clear from this figure that there were very few instances when MSAE density exceeded 1 colony/mL, and over the 8-year period there was only 1 incidence in 77 sample collections (1.3%) during July-October when these stations exceeded 1 colony/mL.

Table 1. *Microcystis aeruginosa* (MSAE) occurrence in Upper Klamath Lake (UKL) and Agency Lake phytoplankton samples collected July-October, 1990-1997[1]. The July-October period was chosen because this corresponds to MSAE occurrences downstream.

Sample Station Description	Total # of Samples Collected 1990-1997	Total # of Samples with MSAE	% of Samples with MSAE	Total # of Samples with MSAE > 1 colony/mL	% of Samples with MSAE > 1 colony/mL
All UKL and Agency L. Sample Stations	685	100	14.6%	35	5.1%
UKL Stations Only	537	69	12.8%	13	2.4%
Outlet Stations Only (PM and FB)	77	9	11.7%	1	1.3%

[1]Data collected by the Klamath Tribes; methodology described in Kann (1998).

MSAE clearly exists in UKL and Agency Lakes and is known to form periodic blooms in both systems, but particularly in Agency Lake (e.g., a toxic algae advisory was issued for Agency Lake by the OR Dept. of Human Services in August of 1996). However, despite the initial appearance of frequent and abundant MSAE occurrence in UKL, when data are filtered by excluding Agency Lake and by evaluating only what is leaving UKL and entering the Klamath River system, both occurrences and density were relatively low (generally< 1 colony/mL).

PacifiCorp Klamath River Data

Between 2001-2004 PacifiCorp collected ~monthly phytoplankton samples from stations beginning at the outlet of UKL and ending where the Klamath River crosses I5 (Figure 6). These data are shown in electronic Appendix E2 and sample methods are outlined in Raymond (2005).Station descriptions are shown in Table 2 along with years sampled and graph station code used in subsequent figures. The only station directly below UKL with significant sampling frequency over several years was Link River at Mouth (KR25312), UKL at Fremont Bridge was only sampled 2x in 2002, Lake Ewauna was sampled on only one date in 2003, and KR at Keno Bridge was sampled 4x in 2003 (Table 2). A longitudinal comparison of stations (particularly those with multiple years of data; Table 2, Figures 7 and 8) shows a similar trend to those noted for the UKL (Figure 5c above) and Karuk (Figure 1 above) data sets.

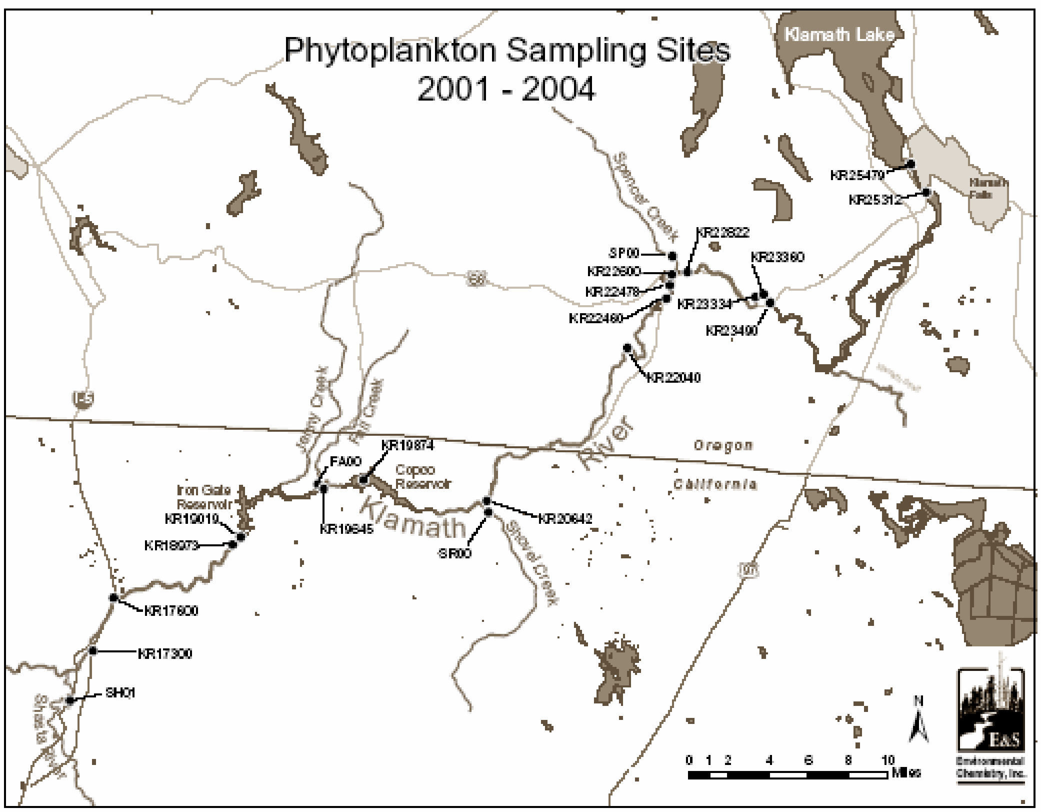

Figure 6. PacifiCorp phytoplankton samples collected in the vicinity of the Klamath Hydroelectric Project, 2001-2004 (Figure excerpted from Raymond (2005); E & S Environmental Chemistry, Inc Technical Memorandum: Methods and Data for PacifiCorp Phytoplankton Sampling in the Klamath River System, 2001-2005.

Table 2. *Microcystis aeruginosa* (MSAE) occurrence in PacifiCorp phytoplankton samples collected July-October in the vicinity of the Klamath Hydroelectric Project, 2001-2004[1]. The July-October interval is shown here because *Microcystis aeruginosa* was not detected in any samples earlier than July or later than October.

PacifiCorp Site ID	River Mile	Site Name	Graph Station Code	Total # of samples collected	Years Sampled	Total # of samples with MSAE	% of samples with MSAE	Total # of MSAE samples > 10,000 cells/ml
KR17300	173.00	Klamath River above Shasta River	KR-SHASTA	4	2002	0	0%	0
KR17600	176.00	Klamath River at I-5 Rest Area	KR-I5	3	2004	1	33%	0
KR18973	189.73	Iron Gate dam Outflow	KR-BIGATE	15	2001-2004	6	40%	0
KR19019	190.19	Iron Gate reservoir near dam	IGATE-RES	41	2001-2004	12	29%	2
KR19645	196.45	Copco 2 dam Outflow	KR-BCOPCO	12	2002-2004	7	58%	2
KR19874	198.74	Copco reservoir	COPCO-RES	43	2001-2004	13	30%	5
KR20642	206.42	Klamath River upstream of Shovel Creek	KR-SHOVEL	17	2001-2004	2	12%	0
KR22040	220.40	Klamath River upstream of J.C. Boyle Powerhouse	KR-BOYLEPH	13	2002-2004	1	8%	1
KR22460	224.60	Klamath River below J.C. Boyle dam	KR-BBOYLE	13	2001-2004	2	15%	1
KR22478	224.78	J.C. Boyle reservoir at Log Boom	BOYLE-RES	20	2001-2003	1	5%	0
KR22822	228.22	Klamath River above J.C. Boyle reservoir	KR-ABOYLE	12	2002-2004	0	0%	0
KR23334	233.34	Keno dam Outflow	KR-BKENO	12	2002-2004	0	0%	0
KR23360	233.60	Keno reservoir at Log Boom	KENO-RES	7	2001	0	0%	0
KR23490	234.90	Klamath River at Keno Bridge (Hwy 66)	KR-KENO	4	2003	1	25%	0
L. Ewauna	[2]	Lake Ewauna	LEWAUNA	18	2003	8	44%	0
KR25312	253.12	Link River at Mouth	LINKRIVER	19	2002-2004	0	0%	0
KR25479	254.79	Upper Klamath Lake at Fremont St Bridge	UKLFB	2	2002	0	0%	0

[1]Pacificorp data and methods obtained from E & S Environmental Chemistry, Inc Technical Memorandum: Methods and Data for PacifiCorp Phytoplankton Sampling in the Klamath River System, 2001-2005

[2]Specific station location not provided for Lake Ewauna (all data collected on one date-- August 20, 2003).

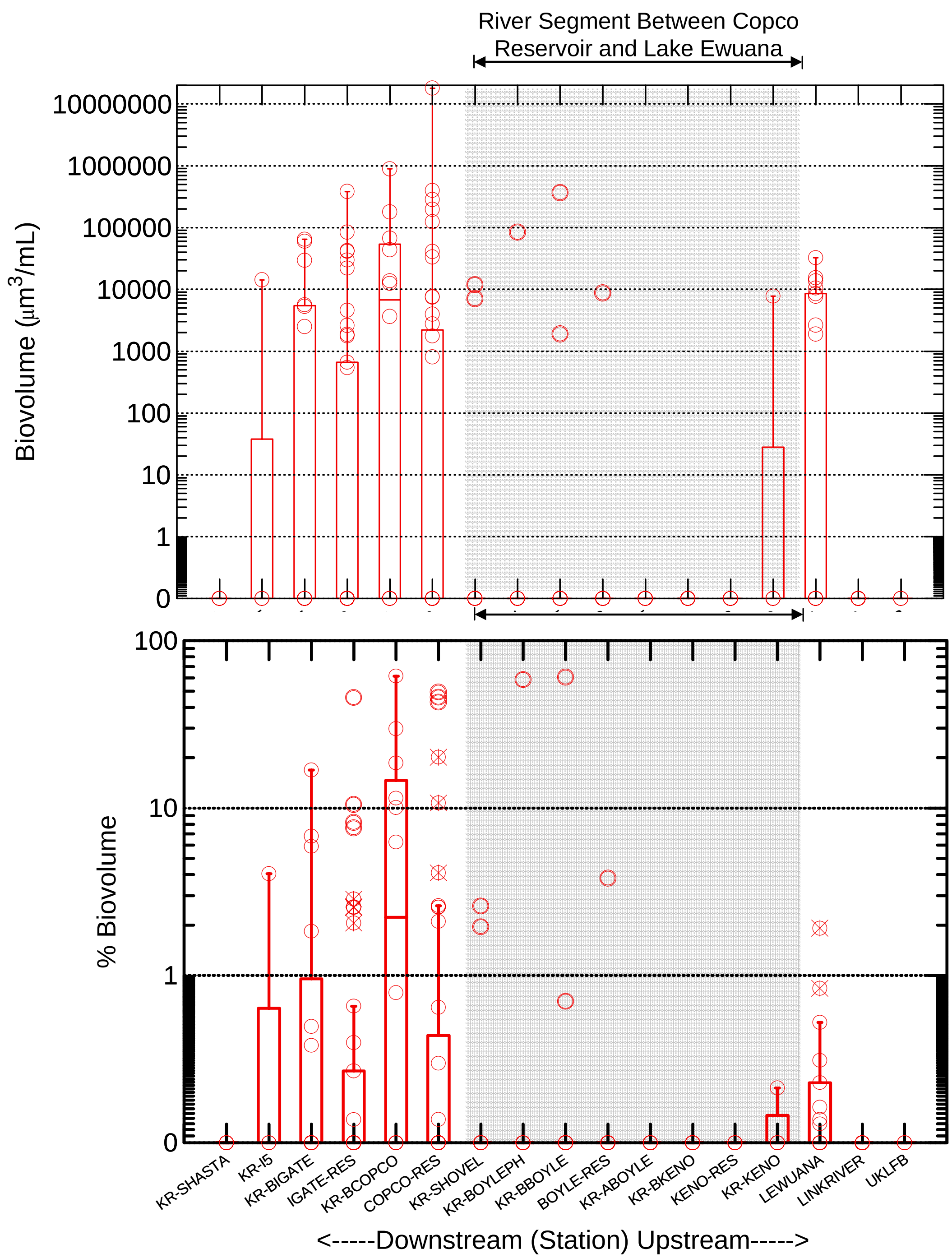

Figure 7. PacifiCorp MSAE biovolume (a) and percent biovolume (b) trends in the vicinity of the Klamath Hydroelectric Project, 2001-2004.

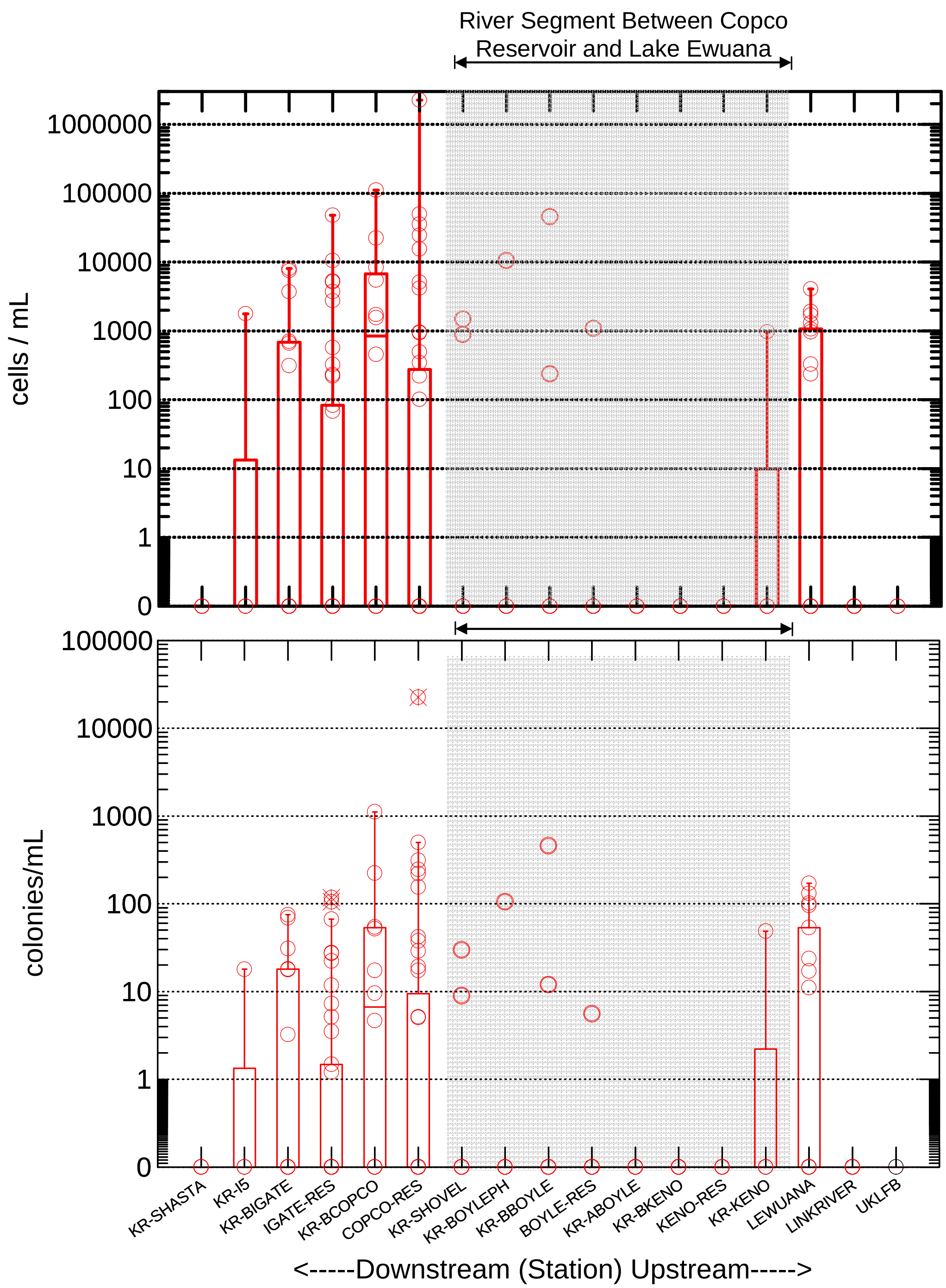

Figure 8. PacifiCorp MSAE cell density (a) and colony density (b) trends in the vicinity of the Klamath Hydroelectric Project, 2001-2004. Cell density is computed by dividing the biovolume by 8 μm^3 - the cell size factor utilized by Aquatic Analysts to compute biovolume (Jim Sweet, pers. comm.).

Similar to the trend of low to no MSAE leaving UKL between 1990-1997 (Figure 5c), PacifiCorp data near the outlet of UKL (Link River at Mouth) showed no detection of MSAE in 19 samples (0%) collected between July-October, 2002-2004 (Table 2, Figures 7 and 8). MSAE was detected in Lake Ewauna and KR at Keno Bridge in 2003, with maximum colony density at ~200 colonies/mL in Lake Ewauna (Figure 8). As noted in Table 2, no location information was provided for this station, and all data were collected on only one date.

Moving downstream, there was no MSAE detected in 24 combined samples collected at the Keno Dam Outflow and the above J.C. Boyle Reservoir stations (Table 2; Figure 8). In the system including Boyle reservoir, below Boyle and the Boyle Powerhouse there were several positive detections (5-15% of measurements; Table 2) indicating possible re-growth of MSAE in the J.C. Boyle Reservoir environment.

In the Klamath river upstream of Shovel Creek (KR-Shovel, which is equivalent to KRAC of the Karuk study—see above Figure 1) only 2 in 17 measurements (12%) showed positive detection for MSAE in the 2001-2004 July-October period, with a maximum of 30 colonies/mL (Figure 8b).

In the Copco/Irongate portion of the KHP system the incidence and magnitude of MSAE clearly increases compared to upstream Klamath River stations (shaded area of Figures 7 and 8). In the reservoirs proper (COPCO-RES and IGATE-RES) and in the river directly below them (KR-BCOPCO and KR-BIGATE), the percent of samples with positive MSAE ranged between 29% and 58% (Table 2). Reservoir samples represent variable depths (sometimes representing a 10m integrated sample or a specific depth such as 0.1m, 0.5m, or 8m), such that a buoyant species like MSAE would be expected to be lower in density at deeper depths. Nonetheless, the Copco/Irongate reservoir system showed significant prevalence of MSAE, especially relative to Klamath River stations directly above the reservoirs. Colony density commonly approached 100 colonies/mL and exceeded 1000 colonies/mL on several occasions (Figure 8b). Furthermore, the only stations exhibiting cell densities greater than 10,000 cells/mL anywhere in the system were the reservoir stations or the river directly below them (Table 2).

Two PacifiCorp samples taken, one in 2003 (see max value of ~18 million cell/mL or ~20,000 colonies/mL for COPCO-RES in Figure 8) and one in 2005 (max ~ 6.6 million cells/mL; data not shown) are from additional (non-routine) samples that were taken from concentrated areas of localized algal blooms at the water surface (see Electronic Appendix E2). These data indicate the potential for extreme surface blooms of MSAE in the reservoirs, and are similar to values measured in the Karuk study (see Figure 1 above).

Similar to the Karuk 2005 data set and the Klamath Tribes UKL data set, the PacifiCorp data set described here shows low incidence and magnitude of MSAE leaving UKL (e.g., compare Link River with UKL outflow) and in the Klamath River above Copco Reservoir (e.g., compare KR-SHOVEL with KRAC), and high incidence and magnitude in Copco and Irongate Reservoirs.

Karuk/SWRB Copco/Iron Gate Reservoir System Data

Although shown above in Figure 1, Karuk Tribe/SWRB data are described in additional detail here. During the 2005 sample season, samples were collected biweekly from a variety of shoreline and open-water stations, including the standard open-water locations: IR01 and CR01 (Fig. 9).

Copco and Iron Gate Reservoir Sampling Locations

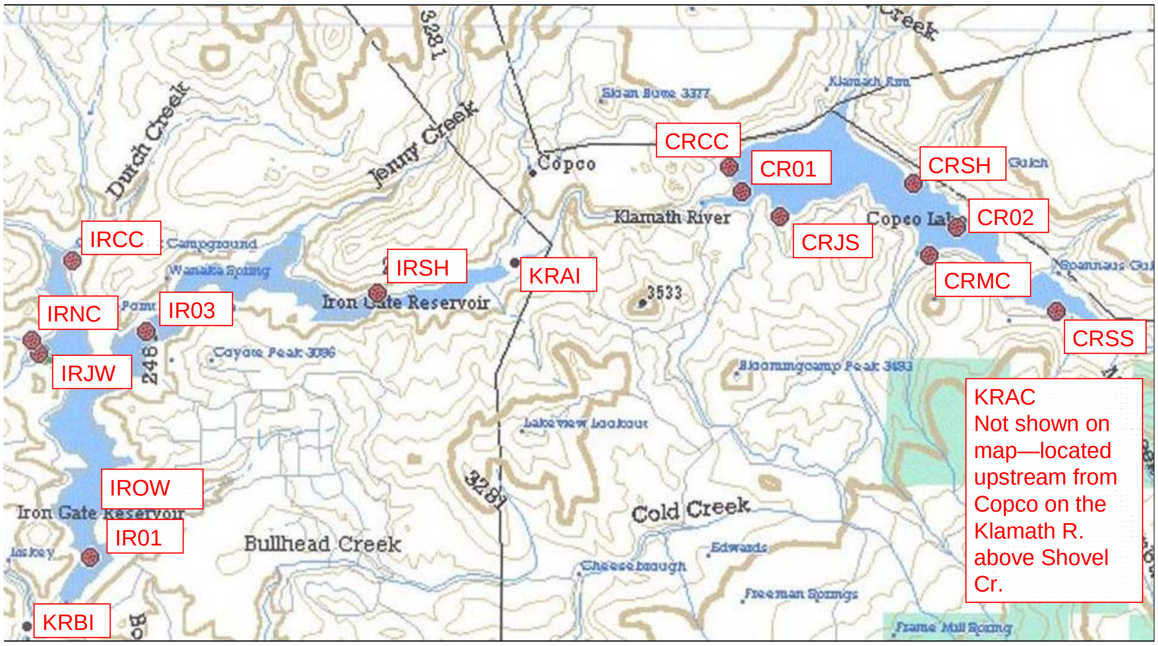

Figure 9. Karuk Tribe/SWRB sample station locations in the Copco/Iron Gate Reservoir system, 2005.

CR01 and IR01 are equivalent to the standard PacifiCorp reservoir stations KR19874 and KR19019 (see Table 2 above). Stations IR01, IR03, and CR01 are open-water locations and were sampled biweekly as part of an ongoing Karuk/SWRB reservoir nutrient loading study. Other stations were routinely sampled biweekly specifically to assess the extent of toxic MSAE, and as described above, the stations KRAC and KRBI are Klamath River stations above Copco (KRAC) and Below Iron Gate (KRBI). The majority of samples analyzed here represent surface grab samples, and as such are not directly comparable to PacifiCorp samples taken at depth or that are integrated over the water column (however see two exceptions noted above).

A representation of all measured 2005 stations grouped by system further illustrates the non-detection of MSAE in the Klamath River above Copco (KRAC), frequent and extreme MSAE values in the reservoirs, and lower but significant values below the reservoirs at KRBI (Figure 10). Similar to the PacifiCorp data, the frequency and abundance of reservoir MSAE colonies/mL was vastly greater than that measured upstream in the PacifiCorp and Klamath Tribes UKL data. Although the years do not overlap in the respective studies, the fact that KRAC showed non-detects for MSAE in 2005 provides evidence that trends are similar among the studies.

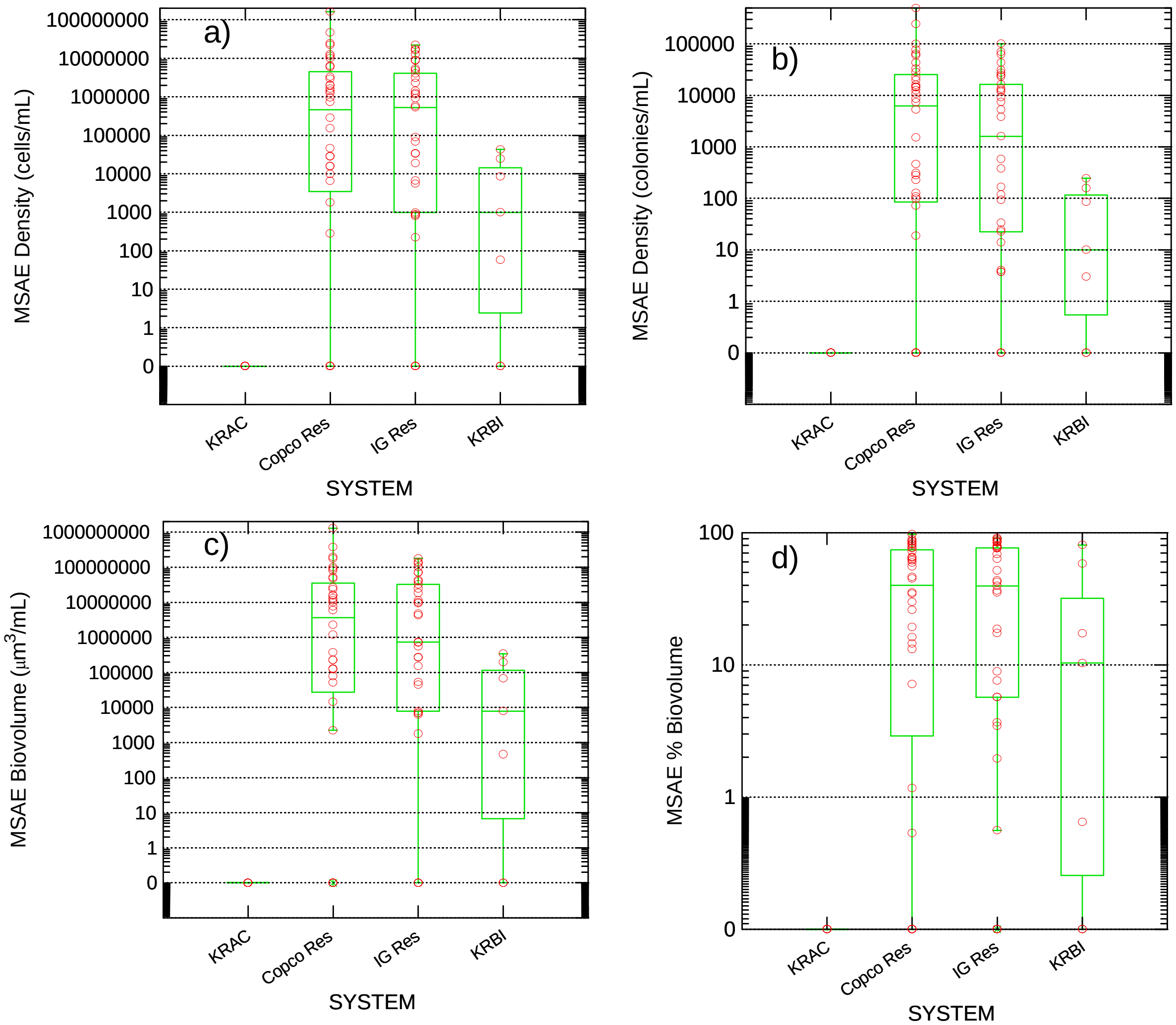

Figure 10. Karuk Tribe/SWRB MSAE cell density (a), colony density (b), biovolume (c), and % biovolume (d) in the Klamath River and Copco and Irongate Reservoirs, July-October 2005.

In contrast to the Klamath River upstream (KRAC; 0%), 87.5% and 89.7% of the samples were positive for MSAE in Copco and Iron Gate, respectively (Figure 10). In fact, 50% and 41.4% of the samples exceeded 10,000 colonies/mL (Figure 10b). If only the PacifiCorp equivalent stations (CRO1 and IR01) are evaluated, the percent of samples exceeding 10,000 colonies/mL is still 30% and 37.5%, respectively. These reservoir values are vastly greater than those upstream, even when compared to those measured in Agency Lake (e.g., see Figure 4a).

Although data indicate MSAE is in the system upstream from Copco and Iron Gate Reservoirs, both the PacifiCorp and Karuk/SWRB data clearly indicate large increases in MSAE in the reservoirs relative to the Klamath River upstream.

Yurok Tribe/USFWS Klamath River Data

During the 2005 sampling period encompassing the above reservoir data, the Yurok Tribe and USFWS sampled a variety of Klamath River stations from below Iron Gate Reservoir to the Klamath River Estuary (Fig 11). Methods and complete results are contained in Fetcho (2006). Station codes corresponding to graphs are shown in Table 3.

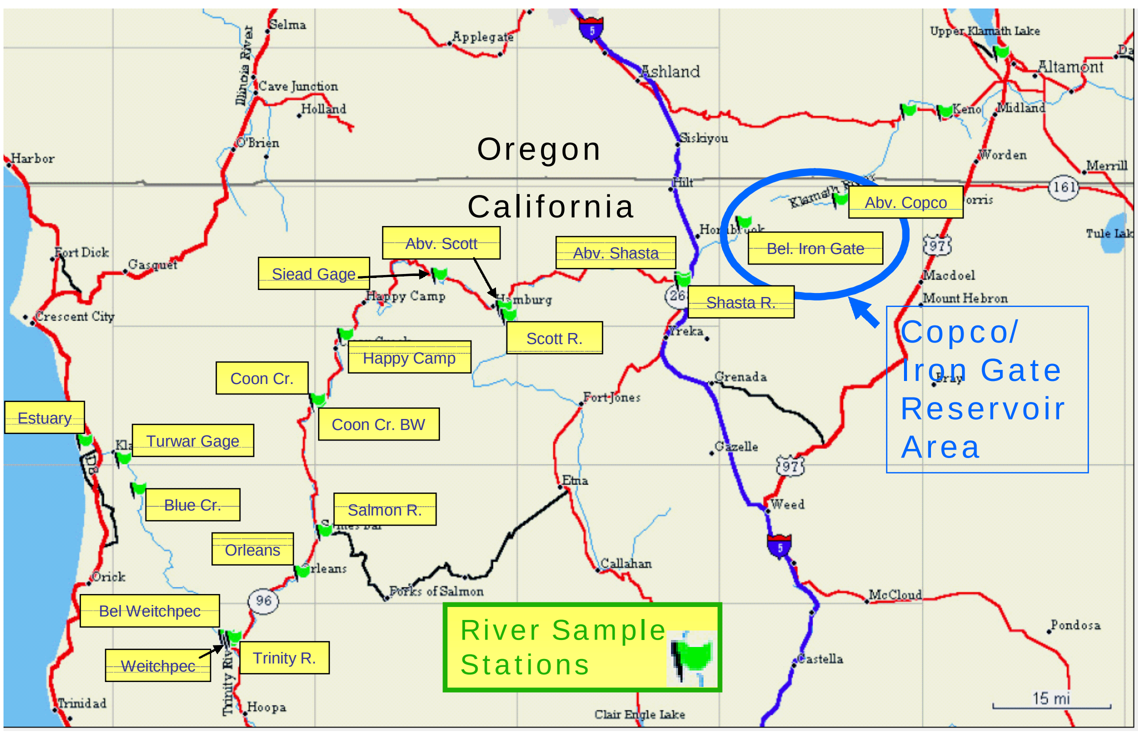

Figure 11. Location of Yurok/USFWS Klamath River sampling stations, 2005.

Table 3. Station codes corresponding to Yurok/USFWS sampling stations on the Klamath River below Irongate Reservoir.

Below Link River Dam	BLRD
Below Keno Dam	KRBK
Below JC Boyle Dam	KRBB
KR Above Copco	KRAC
KR @ Below IG	KRBI
Abv Shasta R.	KRASH
Abv Scott R.	KRASC
Siead Gage	KRSG
Happy Camp	KRHC
Orleans	KROR

Cont.

Weitchpec (abv TR)	KRWE
Below Weitchpec	KRBW
Turwar Gage	KRTG
KR Estuary	KREST
Shasta R.	SHASTA
Scott R.	SCOTT
Salmon R.	SALMON
Trinity R.	TRINITY
KR Above Coon Creek River Access	KRACOON
Backwater pool at Coon Creek River Access	KRCOONB
Edgewater Below Blue Creek	EDGEBBC

Given the above Karuk Tribe/SWRB data showing an increase in MSAE and microcystin toxin from above Copco Reservoir to below Iron Gate Reservoir (KRBI), the potential exists for export of both cells and toxin to downstream environments. Apparent downstream blooms were noted in August of 2005, and Figure 12 shows a micrograph of a typical MSAE colony from a collection made by USFWS (written comm. Randy Turner) at Weitchpec, well downstream on the Klamath River (Figure 11).

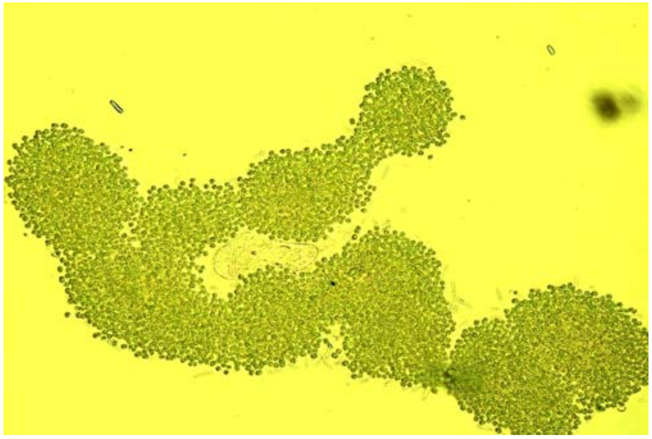

Figure 12 Micrograph of a *Microcystis* colony in the Klamath River at Weitchpec, 2005; USFWS- Randy Turner/Paul Zedonis.

A plot of Yurok Tribe/USFWS stations below Iron Gate Reservoir shows the continued downstream presence of MSAE at all stations, including the Klamath River estuary (Figure 13; KREST). Although cell densities did not exceed the WHO MPHAHE level of 100,000 cell/mL, densities frequently exceeded 10,000 cells/mL (Figure 13).

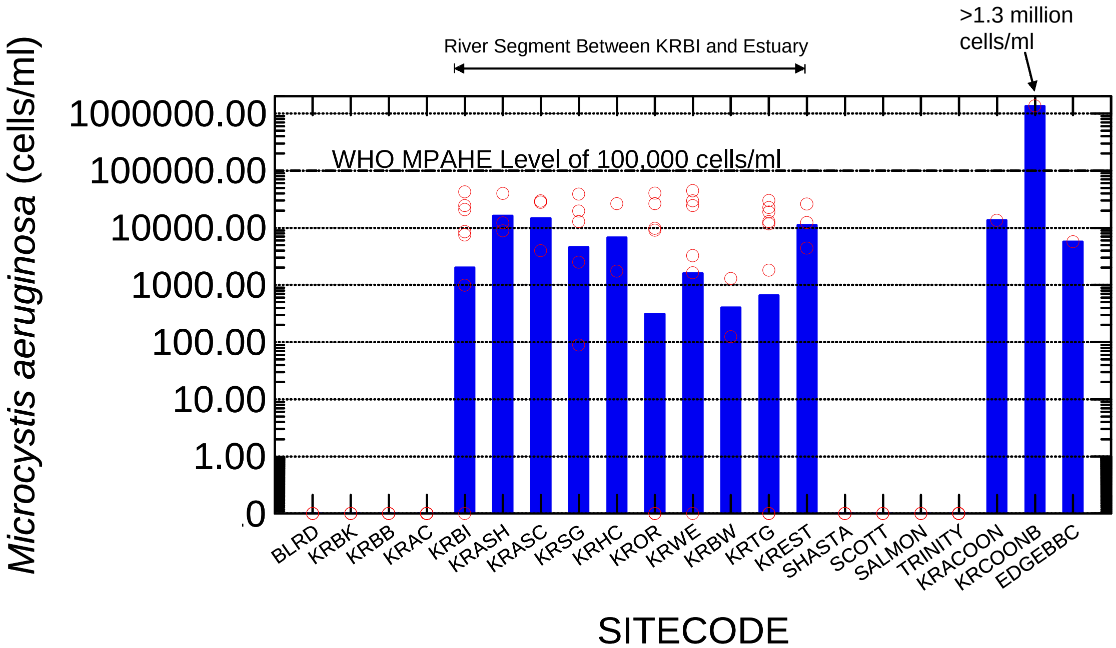

Figure 13. Yurok Tribe/USFWS MSAE cell density trends in the Klamath River system, 2005. Stations from KRBI to KREST are ordered from upstream on the left to downstream on the right. Blue bars are station means and red circles are individual data points.

This is in contrast to the PacifiCorp 2001-2004 data for Klamath River stations above the Copco/Iron Gate reservoirs, where the only stations exceeding 10,000 cells/mL were those in the reservoirs or directly below (Table 2). Although the PacifiCorp study years do not overlap with these data, the Karuk/SWRB data for 2005 shows no values exceeding 10,000 cells/mL above Copco at KRAC; and in fact, shows that MSAE was not detected at all at this station (Figure 10) during the same period encompassing the Yurok/USFWS data collection effort.

In addition, MSAE cell concentration exceeded 1.3 million cells/ml in a backwater area near the confluence of Coon Creek nearly 100 miles downstream from Iron Gate Dam (KRCOONB; Figure 13). The lowest detected microcystin level, 0.2 µg/L, was measured at the KRTG site on September 21, 2005, and the highest microcystin level, 6.25 µg/L, was measured at the KRWE site on September 8, 2005 (Fetcho 2006).

The Yurok Tribes Environmental and Fisheries Programs also conducted fish tissue analyses on select Chinook salmon and steelhead from the lower Klamath River in 2005. These limited results indicate that of 9 adult salmon liver and muscle samples from Weitchpec and Iron Gate Hatchery, all were below the detection limit of 0.147 ppb; of 2

Steelhead (one adult and one ½ pounder) muscle samples from Weitchpec, both were below the detection limit of 0.147 ppb; and of 2 Steelhead (one adult and one half-pounder) liver samples from Weitchpec the adult had a trace amount of 0.17 ppb and the ½ pounder had 0.54 ppm (μg/g) (Table 4).

Table 4. From Fetcho (2006): Microcystin results for fish tissue samples collected within Yurok Reservation boundaries, Water Year 2005.

Date	Site	Tissue Type	Species	Microcystin μg/g	Sampling Crew
9/13/2005	KBW	Liver	Chinook salmon	BDL	YTFP
9/14/2005	KBW	Filet	Chinook salmon	BDL	YTFP
9/14/2005	KBW	Liver	Chinook salmon	BDL	YTFP
9/14/2005	KBW	Filet	Chinook salmon	BDL	YTFP
9/14/2005	KBW	Liver	Chinook salmon	BDL	YTFP
9/30/2005	IG	Male Liver	Chinook salmon	BDL	CDF&G
9/30/2005	IG	Male filet	Chinook salmon	BDL	CDF&G
9/30/2005	IG	Female Liver	Chinook salmon	BDL	CDF&G
9/30/2005	IG	Female Filet	Chinook salmon	BDL	CDF&G
10/03/205	WE	Adult Liver	Steelhead	Trace	YTFP
10/03/205	WE	Adult Filet	Steelhead	BDL	YTFP
10/03/205	WE	1/2 pounder Liver	Steelhead	0.54	YTFP
10/03/205	WE	1/2 pounder Filet	Steelhead	BDL	YTFP

KBW=Klamath River Below Weitchpec
WE=Klamath River at Weitchpec
IG=Klamath River Iron Gate Hatchery
YTFP=Yurok Tribe Fisheries Program
CDF&G=California Dept. of Fish and Game
BDL=Below Detection Limit (0.147 μg/L)
Trace=(0.17 μg/L)

Although sample size is limited, low to trace quantities of microcystin in steelhead livers in the lower Klamath River indicate that these fish were exposed to toxin levels in the river environment, and indicate the potential for toxin uptake to occur. Steelhead residing in the Klamath River at the time of sampling would have increased exposure time relative to salmon.

The 2005 Yurok Tribe/USFWS data for the lower Klamath River show the continued presence of MSAE and associated microcystin toxin in the river below Iron Gate Dam. Although mean values tend to decrease downstream from KRBI, MSAE values were still higher and more frequent than those upstream from Copco Reservoir. These data provide a clear indication that MSAE presence in the lower river is a function of increased inoculums from the massive MSAE growth occurring in Copco and Iron Gate Reservoirs.

CONCLUSIONS

Several lines of evidence point to the role of the KHP Copco and Iron Gate Reservoirs in providing ideal habitat conditions for MSAE. First, although MSAE clearly exists in UKL and Agency Lakes and is known to form periodic blooms in both systems, when data are filtered by excluding Agency Lake and by evaluating only what is leaving UKL and entering the Klamath River system, occurrences were rare and density very low over an 8-year period (generally< 1 colony/mL); especially in contrast to MSAE values commonly exceeding 10,000 colonies/mL in Copco and Iron Gate Reservoirs.

Second, similar to the Karuk/SWRB 2005 data set and the Klamath Tribes UKL data set, the PacifiCorp data set described above showed low incidence and magnitude of MSAE leaving UKL and in the Klamath River above Copco Reservoir, and high incidence and magnitude in Copco and Irongate Reservoirs.

Third, MSAE was not detected at KRAC (above Copco reservoir) during the Karuk/SWRB 2005 data collection effort, even when reservoir stations showed substantial concentrations of both toxin and MSAE cell density. In contrast to the Klamath River upstream, 87.5% and 89.7% of the samples were positive for MSAE in Copco and Iron Gate, respectively.

Fourthly, as indicated by cell count and toxin values at KRBI and in the Yurok/USFWS data that were higher than those measured in the Klamath River upstream from the reservoirs, export from the reservoirs of both cells and toxin to downstream environments is occurring.

These data are consistent with literature showing that MSAE and other buoyant cyanobacteria do not dominate in conditions of turbulent mixing such as that known to occur in the Klamath River above Copco and Iron Gate Reservoirs. For example, Huisman et al. (2004) demonstrate that potentially toxic MSAE dominate at low turbulent diffusivity (calm-stable conditions) when their flotation velocity exceeds the rate of turbulent mixing. Such conditions are more likely to occur in lakes and reservoirs as velocity and turbulence are reduced. In addition, MSAE has been shown in numerous studies to be favored in lake and reservoir environments that tend to be warmer and less turbulent than riverine ones (Reynolds 1986).

In areas where turbulent diffusivity may decrease as rivers widen and increase in depth, or such as would occur in backwater areas, the potential also exists for MSAE blooms in slow-moving riverine environments as well. In addition, others have noted a linkage between MSAE bloom formation and low river flow (e.g., Paerl [1987]; Christian et al. [1986]). Given the tens of thousands of MSAE cells introduced to the lower-Klamath River from Copco and Iron Gate Reservoirs above, the potential for recurring blooms downstream increases as slower-moving water is encountered. For example, as described above, MSAE cell concentration exceeded 1.3 million cells/ml in a backwater area near the confluence of Coon Creek nearly 100 miles downstream from Iron Gate Dam.

Taken together these data provide compelling evidence that Copco and Iron Gate Reservoirs are providing ideal habitat for MSAE; increasing concentrations dramatically from those upstream, and exporting MSAE to the downstream environment.

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APPENDIX I. – PacifiCorp Submittal to FERC in Response to Agency Comments (including portion of Table 10 dealing with MSAE in the Klamath River).

825 N.E. Multnomah
Portland, Oregon 97232

PACIFICORP
PACIFIC POWER UTAH POWER

December 16, 2005

E-Filed 12/16/05

Ms. Magalie R. Salas, Secretary
Federal Energy Regulatory Commission
888 First Street, N.E.
Washington, D.C. 20426

Re: Klamath Hydroelectric Project (FERC Project No. 2082-027); Response to Agency Comments

Dear Ms. Salas:

With this letter and associated enclosures, PacifiCorp submits Response to Agency Comments in regard to the Klamath Hydroelectric Project (FERC Project No. 2082) as detailed below.

Response to Agency Comments

As requested by the Commission in the February 17, 2005 AIR, PacifiCorp asked several agencies and tribes to provide comments on documents we prepared in response to AIRs AR-1 (Anadromous Fish Protection), AR-2 (Anadromous Fish Restoration) and AR-5 (Instream Flow Studies). PacifiCorp has received several comment letters, and has prepared detailed response tables for these letters (attached). Tables 1 through 4 provide our comment responses to letters received on AIR AR-2 from the Oregon Department of Fish and Wildlife (ODFW), State Water Resource Control Board (SWRCB), U.S. Fish and Wildlife Service (USFWS), and California Department of Fish and Game (CDFG). Tables 5 through 8 provide our comment responses to letters received on AIR AR-1 from SWRCB, CDFG, USFWS, and the National Marine Fisheries Service (NOAA-Fisheries). These tables are in addition to the AR-1 comment letter responses we previously submitted to the Commission on October 17, 2005. Table 9 provides comment responses to the letter received on AIR AR-5 from NOAA-Fisheries. This table is in addition to the AR-5 comment letter responses we previously submitted to the Commission on September 30, 2005.

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On November 15, 2005, SWRCB submitted a letter to the Commission describing a study by the Karuk Tribe of California on 2002 nutrient and hydrologic loading to Iron Gate and Copco reservoirs. Table 10 provides PacifiCorp's responses to the November 15 SWRCB letter.

If you have any questions about this information, please contact me at (503) 813-6011.

Sincerely,

Cory E. Scott

Cory Scott
Licensing Project Manager
PacifiCorp

cc: John Mudre - FERC
FERC Klamath Service List

Enclosures:

1) Response to Agency Comments:
   a. Table 1. Responses by PacifiCorp to comments from Oregon Department of Fish and Wildlife (Amy M. Stuart) (dated October 13, 2005) on PacifiCorp's draft report on Additional Information Request (AIR) GN-2 and AR-2, Anadromous Fish Restoration, Klamath Hydroelectric Project, FERC No. 2082.
   b. Table 2. Responses by PacifiCorp to comments from State Water Resources Control Board (via letter from Russ Kanz dated October 13, 2005) on PacifiCorp's draft report on Additional Information Request (AIR) AR-2, Anadromous Fish Restoration, Klamath Hydroelectric Project, FERC No. 2082.
   c. Table 3. Responses by PacifiCorp to comments from U.S. Fish and Wildlife Service (via letter from Phil Detrich dated October 17, 2005) on PacifiCorp's draft report on Additional Information Request (AIR) AR-2, Anadromous Fish Restoration and GN-2, Fish Passage Planning and Evaluation, Klamath Hydroelectric Project, FERC No. 2082.
   d. Table 4. Responses by PacifiCorp to comments from California Department of Fish and Game (Donald B. Koch) (dated October 31, 2005) on PacifiCorp's Response to Federal Energy Regulatory Commission (FERC) Additional Information Request (AIR) AR-2: Fish Passage Planning and Evaluation, Klamath Hydroelectric Project (Project) FERC No. 2082.
   e. Table 5. Responses by PacifiCorp to comments from the State Water Resources Control Board (via letter from Russ J. Kanz to Cory Scott of PacifiCorp dated October 20, 2005) on PacifiCorp's September 2005 submittal in response to Federal Energy Regulatory Commission (FERC) Additional Information Requests (AIR) AR-1 on anadromous fish protection, Klamath Hydroelectric Project, FERC No. 2082.
   f. Table 6. Responses by PacifiCorp to comments from the California Department of Fish and Game (via letter from Donald B. Koch to Cory Scott of PacifiCorp dated October 27, 2005) on PacifiCorp's September 2005 submittal in response to Federal Energy Regulatory Commission (FERC) Additional Information Requests

(AIR) AR-1 Part (a) and AR-1 Part (b) on anadromous fish protection, Klamath Hydroelectric Project, FERC No. 2082.

g. Table 7. Responses by PacifiCorp to comments from the U.S. Fish and Wildlife Service (via letter from Phil Detrich to Cory Scott of PacifiCorp dated November 17, 2005) on PacifiCorp's October 17, 2005 response to the U.S. Fish and Wildlife Service comments dated October 12, 2005 on PacifiCorp's September 2005 submittal in response to Federal Energy Regulatory Commission (FERC) Additional Information Requests (AIR) AR-1 Part (a) on anadromous fish protection, Klamath Hydroelectric Project, FERC No. 2082.
h. Table 8. Responses by PacifiCorp to comments from the NOAA-Fisheries (via letter from Steven A. Edmondson to Cory Scott of PacifiCorp dated November 23, 2005) on PacifiCorp's September 2005 submittal in response to Federal Energy Regulatory Commission (FERC) Additional Information Requests (AIR) AR-1 Part (a) and AR-1 Part (b) on anadromous fish protection, Klamath Hydroelectric Project, FERC No. 2082.
i. Table 9. Responses by PacifiCorp to comments from the NOAA-Fisheries (via letter from Steven A. Edmondson to Cory Scott of PacifiCorp dated October 3, 2005) on PacifiCorp's April 2005 submittal in response to Federal Energy Regulatory Commission (FERC) Additional Information Requests (AIR) AR-5 on instream flow studies report, Klamath Hydroelectric Project, FERC No. 2082.
j. Table 10. Responses by PacifiCorp to a letter from State Water Resources Control Board (from Russ Kanz dated November 15, 2005) to FERC on the subject of 2002 nutrient and hydrologic loading to Iron Gate and Copco reservoirs, Klamath Hydroelectric Project, FERC No. 2082.

Table 10. Responses by PacifiCorp to a letter from State Water Resources Control Board (from Russ Kanz dated November 15, 2005) to FERC on the subject of 2002 nutrient and hydrologic loading to Iron Gate and Copco reservoirs, Klamath Hydroelectric Project, FERC No. 2082.

<table>
<tr><th>COMMENT</th><th>COMMENT RESPONSE</th></tr>
<tr>
<td>SPECIFIC COMMENT – Finally, enclosed are results of phytoplankton sampling conducted this year in Iron Gate and Copco Reservoirs, and in the Klamath River above Copco Reservoir and below Iron Gate Dam. This information is preliminary, but shows the high levels of Microcystic aeruginosa were found in Iron Gate and Copco Reservoirs this summer. In addition, the data shows that no Microcystis was found in the Klamath River above Copco Reservoir, while it was found in the river below Iron Gate Dam. Additional samples were collected in the river from Iron Date Dam to the estuary by US Fish and Wildlife Service, Karuk Tribe and Yurok Tribe.</td>
<td>The suggestion in SWRCB's letter that no Microcystis or Anabena algae were found in the Klamath River above Copco is inaccurate. Microcystis aeruginosa is ubiquitous in the Klamath River, and has been frequent and abundant in Upper Klamath Lake (Figure 1).

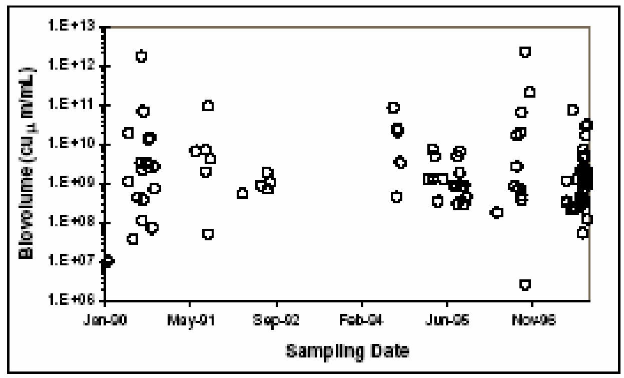

Figure 1. Occurrence of Microcystis aeruginosa in Upper Klamath Lake (Klamath Tribes data in Geiger 2005).

Microcystis aeruginosa has been observed in samples from various locations, such as J. C. Boyle Reservoir, Keno reservoir the Klamath River below Boyle dam, the Klamath River above Shovel Creek, Copco reservoir, the Klamath River above Iron Gate reservoir, Iron Gate reservoir, the Klamath River below Iron Gate dam, and the Klamath River at I-5 (see phytoplankton data available at PacifiCorp's website).</td>
</tr>
</table>

Added Comment by Kann for this report.

Note: The graph above is a misrepresentation of Upper Klamath Lake MSAE data for several reasons:

1. The reported biovolume units in the Klamath Tribes phytoplankton database are in μm^3/**L**, not as μm^3/**mL** as shown above. Thus, the magnitudes shown in PacifiCorp's Table 10-Figure 1 are high by **3 orders of magnitude**, or 1000x.
2. The title for Figure 1 incorrectly states that the data shown are for Upper Klamath Lake; however, stations from Agency Lake are also included in the graph, and these stations constitute most of the higher values shown. See Figures 4a and 4b above showing that most of the biovolume values greater than $1x10^7$ are from Agency Lake (these correspond to the values greater than $1x10^{10}$ [1.E+10] in PacifiCorp's Figure 1).
3. None of the non-detects or zero values for MSAE are shown in Figure 1; this causes the graph to misrepresent the frequency of MSAE in the lakes. See Figure 4a above showing all measurements, including zero biovolume samples.

APPENDIX II. – Letter submitted to FERC by California State Water Resources Board—see red highlighted section of Klamath River MSAE.

State Water Resources Control Board

Division of Water Rights
1001 I Street, 14th Floor ♦ Sacramento, California 95814 ♦ 916.341.5300
P.O. Box 2000 ♦ Sacramento, California 95812-2000
Fax: 916.341.5400 ♦ www.waterrights.ca.gov

Alan C. Lloyd, Ph.D.
Agency Secretary

Arnold Schwarzenegger
Governor

November 15, 2005

Magalie R. Salas, Secretary
Federal Energy Regulatory Commission
888 First Street, N.E.
Washington, DC 20426

Dear Ms. Salas:

2002 NUTRIENT AND HYDROLOGIC LOADING TO IRON GATE AND COPCO RESERVOIRS, KLAMATH HYDROELECTRIC PROJECT, FERC #2082

The Karuk Tribe of California recently completed a study on the nutrient loading of Iron Gate and Copco Reservoirs. These reservoirs are part of the Klamath Hydroelectric Project (Project), Federal Energy Regulatory Commission (FERC) #2082, which is owned and operated by PacifiCorp. The objectives of the study is to 1) compile existing nutrient and hydrologic data for Copco and Iron Gate Reservoirs, 2) construct mass-balance nutrient budgets to evaluate potential effects of the reservoirs on nutrient dynamics in the Klamath River, and 3) identify data gaps to help design future studies.

The study involves the construction of a nutrient budget combining nutrient concentration data with the hydrologic data to compute nutrient mass. The results show the reservoirs have periods during which they both trap and generate nutrients. The conclusion of the study is that "The more robust seasonal analysis presented here does not support an earlier PacifiCorp (2004a; 2005b) broad postulation that the reservoirs benefit water quality by processing organic matter and nutrients from upstream sources. With the given data set, there is a clear indication that the reservoirs periodically increase nutrient loading downstream. Likely pathways for this increased load include internal sediment loading and nitrogen fixation by cyanobacteria." The study can be downloaded at http://www.krisweb.com/ftp/KlamWQdatabase/Copco_IG_Budgets.zip. Because of the limitation of this study, and the importance of understanding how nutrients cycle through these reservoirs, State Water Resources Control Board (State Water Board) staff applied for, and received a grant from the US EPA to conduct a nutrient budget study of Iron Gate and Copco Reservoirs. The study should be completed in the summer of 2006.

Finally, enclosed are results of phytoplankton sampling conducted this year in Iron Gate and Copco Reservoirs, and in the Klamath River above Copco Reservoir and below Iron Gate Dam. This information is preliminary, but shows the high levels of Microcystic aeruginosa were found in Iron Gate and Copco Reservoirs this summer. In addition, the data shows that no Microcystis was found in the Klamath River above Copco Reservoir, while it was found in the river below Iron Gate Dam. Additional samples were collected in the river from Iron Gate Dam to the estuary by US Fish and Wildlife Service, Karuk Tribe, and Yurok Tribe.

California Environmental Protection Agency

Recycled Paper

Magalie R. Salas, Secretary - 2 - November 15, 2005

If you have any questions about this letter or need additional information, please contact me at (916) 341-5341.

Sincerely,

ORIGINAL SIGNED BY

Russ J. Kanz
Staff Environmental Scientist

Enclosure

cc: Klamath Service List

bcc: Jim Kassel
Jim Canaday
Sharon Stohrer
Matt Myers
Beth Lawson
Dana Heinrich, OCC
Matt St. John, RB1
David Leland, RB1

RK:llv 11/14/05
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