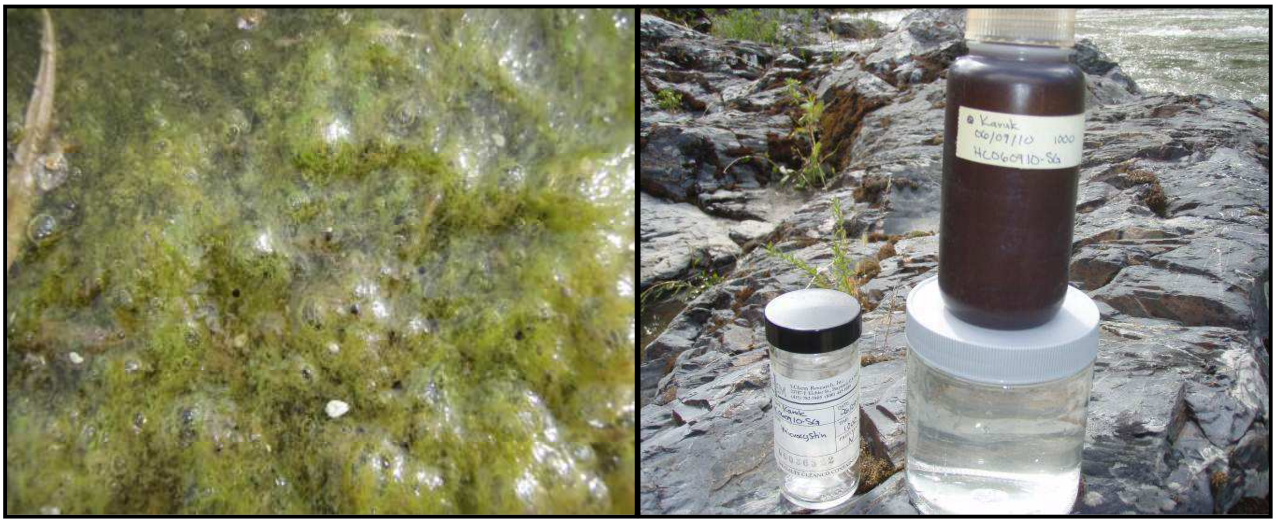
TECHNICAL MEMORANDUM

Middle Klamath River Toxic Cyanobacteria Trends, 2010



Prepared By:

Jacob Kann, Ph.D.
Aquatic Ecosystem Sciences LLC
295 East Main St., Suite 7
Ashland, OR 97520

and

Crystal Bowman
Karuk Tribe Department of Natural Resources
PO Box 282
Orleans, CA 95556

Prepared For:

Karuk Tribe Department of Natural Resources
PO Box 282
Orleans, CA 95556

February 2012

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

As outlined in previous reports (e.g., Kann 2007; Kann and Corum 2009; 2010; Jacoby and Kann 2007) Copco and Iron Gate Reservoirs (the lowermost projects of PacifiCorp's Klamath Hydropower Project-- KHP) experienced extensive blooms of toxigenic *Microcystis aeruginosa* (MSAE) from 2004-2009. These blooms were associated with high levels of microcystin, a potent hepatotoxin capable of causing chronic liver damage and acting as a tumor promoter (Carmichael 1995; Chorus et al. 1999; Chorus 2001).

Results of the previous 2005-2009 sampling program have consistently demonstrated widespread and high abundance of toxigenic MSAE blooms in Copco and Iron Gate reservoirs and in the Klamath River downstream, exceeding World Health Organization Moderate Probability of Adverse Health Effect Levels (WHO MPHAEL) for both cell density and toxin by 10 to over 1000 times Although both cell density and toxin data indicated that MSAE cells and microcystin were either not detectable or detected at very low levels in the Klamath River directly above the reservoirs, levels of both parameters increased directly below the reservoirs in all years. In addition, bioaccumulation studies undertaken in 2007 and 2008 showed accumulation of microcystin toxin in muscle and/or liver tissues of yellow perch, hatchery salmon, and freshwater mussels (Mekebri et al. 2009; Kann 2008; Kanz 2008). Microcystin levels in biota exceeded public health threshold values for safe consumption (Kann 2008; OEHHA 2008). In addition, bioaccumulation studies carried out in 2009 continued to show microcystin bioaccumulation in freshwater mussels (Kann et al. 2010), and sampling in 2010 showed evidence of microcystin bioaccumulation in both Chinook salmon and steelhead in the Klamath River (Kann et al. 2011).

Similar to previous years, a toxic algal monitoring program was undertaken by the Karuk Tribe during February-December, 2010. In 2010 the Karuk Tribe monitored only the river stations below the reservoirs, while PacifiCorp provided monitoring results for Copco and Iron Gate Reservoirs. The following report summarizes 2010 toxigenic MSAE trends in the Klamath River below the reservoir complex, as well as provides a comparison to upstream reservoir concentrations to provide consistency with previous years monitoring trends.

METHODS

Station Location

During the 2010 sampling season, MSAE cell density, cell biovolume, and microcystin toxin samples were collected from standard river stations KRBI (also recorded as IG), IB (I-5 Bridge), WA (Walker Bridge), BB (Brown Bear), SV (Seiad Valley), HC (Happy camp) and OR (Orleans) located below Iron Gate Reservoir. In addition, tributary mouths for the Shasta River (SH), the Scott River (SC), and the Salmon River (SA) were also sampled (Table 1; Figure 1). Reservoir and river stations monitored by PacifiCorp consisted of grab samples at CRCC, CRMC, IRCC, IRJW, and KRBI (Raymond 2010). Data provided by PacifiCorp in 2010 did not include public health samples for KRAC, CR01 or IR01 as in previous years. Sampling resolution for PacifiCorp samples was approximately biweekly for reservoir stations and weekly at KRBI. Karuk OC sampling frequency was biweekly at WA, SV, and OR, and monthly at KRBI and HC. Karuk SG sampling frequency was biweekly beginning in June and approximately weekly once toxigenic species exceeded the public health standards at stations IB, SV, BB, HC, and OR. Frequency of OC sampling at tributary mouths was biweekly.

Table 1. Phytoplankton/microcystin sampling locations in Copco and Iron Gate Reservoirs and Klamath River stations, 2010.

STATION NAME	STATION LAT/LON	Station Description	Shoreline (SL or SG) or Open Water (OW aka OC)
CRCC	N41 59.035 W122 19.802	Copco Res. Copco Cove Boat Ramp/Recreation Area	SL
CRMC	N41 58.441 W122 17.869	Copco Res. Mallard Cove Boat Ramp/Recreation Area	SL
IRCC	N41 58.368 W122 26.114	Iron Gate Res. Camp Creek Boat Ramp/Recreation Area	SL
IRJW	N41 57.721 W122 26.425	Iron Gate Res. Jay Williams Boat Ramp/Recreation Area	SL
KRAC	N41 58.345 W122 12.101	Klamath River Above Copco Reservoir	River-OW
KRBI	N41 55.865 W122 26.532	Klamath River Below Iron Gate Reservoir (Sample Name IG in 2009-2010)	River-OW by Karuk Tribe SG by PC
IB	N 41 51.417 W 122 34.233	I-5 Bridge	River-SL
WA	N41 50.252 W122 51.811	Located downstream of the town of Klamath River. Samples were collected off of Walker Bridge.	River-OW
BB	N41 49.399 W122 57.650	Brown Bear River Access just east of Horse Creek (Sample name BRBE in 2008)	River-SL
SV	N41 50.561 W 123 13.132	Seiad Valley at Sluice Box River Access	River-OW/SL
HC	N 41 43.780 W 123 25.775	Happy Camp	River-OW/SL
OR	N41 18.336 W 123 31.895	Orleans just north of Orleans Bridge	River-OW/SL
SA	N 41 22.617 W 123 28.633	Mouth of Salmon River	River-OW
SC	N 41 46.100 W 123 01.567	Mouth of Scott River	River-OW
SH	N 41 49.390 W 122 35.700	Mouth of Shasta River	River-OW

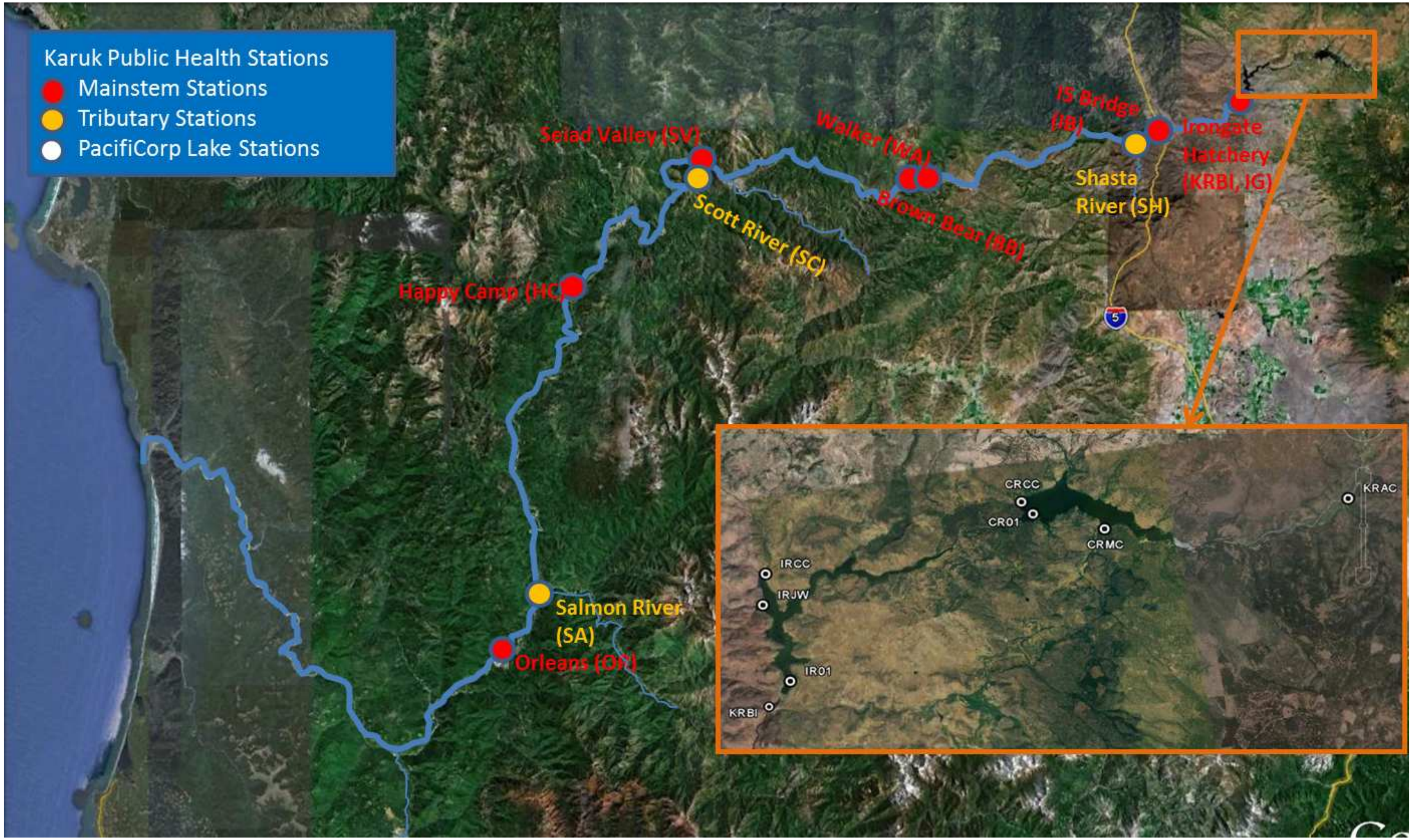


Figure 1. Location of Copco and Iron Gate Reservoirs and Klamath River toxic cyanobacteria sampling stations, 2010. Stations CR01 and IR01 were not sampled in 2010.

Sample Collection and Lab Analysis

Samples of surface algal material taken from shoreline or river-edge areas (denoted SG in the depth column of Appendix I below) utilized the standard operating procedure (SOP) developed by the Klamath Blue-Green Algae Working Group, and is depicted in (Figure 2). River open-water samples were composited in a churn splitter by wading towards the center of the channel (in mixed areas of noticeable velocity), and then submersing and filling the churn prior to distributing to appropriate sample bottles. Samples for microscopic determination of phytoplankton density and biovolume were preserved in Lugol's Iodine and sent to Aquatic Analysts in White Salmon, WA where enumeration and biovolume measurements were determined according to APHA Standard Methods (1992).

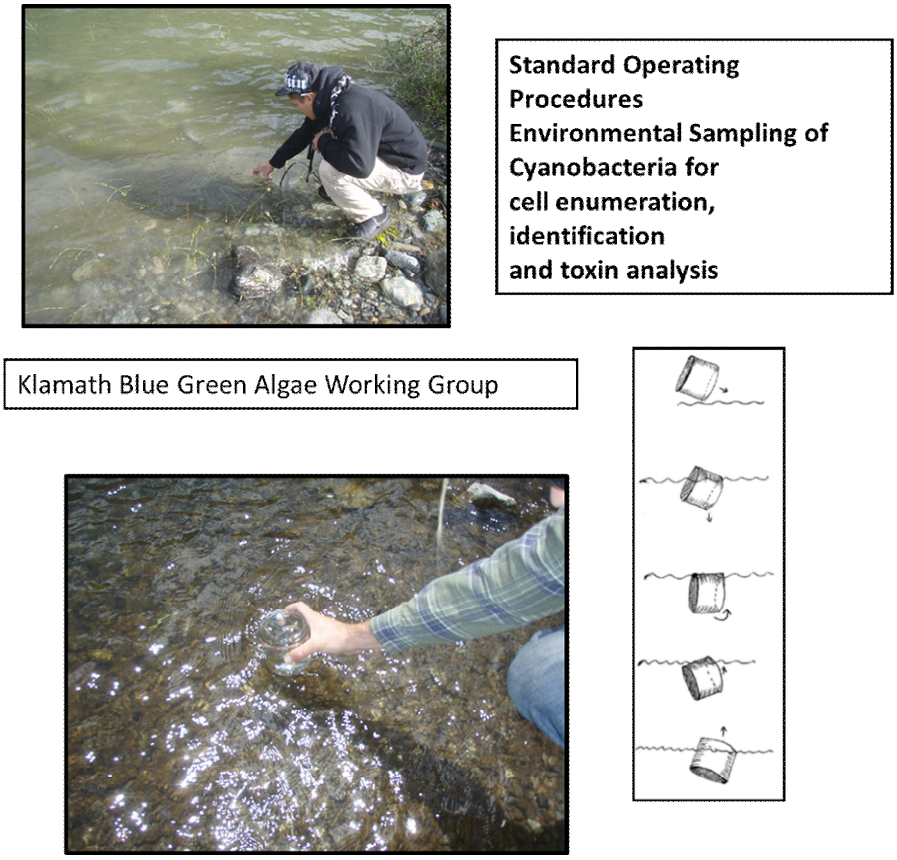


Figure 2. Klamath Blue Green Algae Working Group grab sample collection method, Klamath River 2010.

Because previous work showed higher variability among split samples when MSAE levels were in the lower range (e.g. 0-30,000 cells/ml), toxigenic species in samples from the Klamath River stations were enumerated at an increased counting resolution that included cell counts equating to a minimum count of 400 algal units.

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

A set of "blind duplicate" quality assurance samples were collected for cell density and microcystin toxin. Quality assurance (QA) sampling was performed by splitting samples in the field using a churn splitter. One of the pair of split samples was disguised and sent with its associated split for analysis of both cell density and microcystin toxin.

Comparison to Public Health Threshold Values

Cell density and toxin concentration were compared to California State Water Resources Control Board (SWRCB) and Office of Environmental Health and Hazard Assessment (OEHHA) public health guideline levels that are similar to those used by the state of Oregon (Stone and Bress (2007). These levels are 40,000 cells/ml of MSAE and 8 μg/L of microcystin and are also consistent with recent Australian analysis of health risk threshold values (NHMRC 2005).

The SWRCB/OEHHA levels are specific for MSAE and microcystin, whereas previously used World Health Organization (WHO) threshold values for Moderate Probability of Adverse Health Effects (MPAHEL as published in documents for the WHO and EPA: e.g., Falconer el al. 1999 and Chorus and Cavalieri 2000) are general levels for a variety of toxigenic cyanobacteria. These WHO guidelines indicated 4 μg/L of microcystin constituted a low probability of adverse health effects and 20 μg/L constituted a moderate probability of adverse health effects.

Microcystin concentration was also compared to the tolerable daily intake level (TDI: 0.04 µg microcystin per kg of body weight/day as described in WHO 1998) computed for a 20kg child ingesting 100 mls of reservoir water. The TDI as computed here for a 20kg child is equivalent to the exceedance of the 8µg/L public health guideline value described by SWRCB/OEHHA (www.waterboards.ca.gov/water_issues/programs/bluegreen_algae/docs/bga_volguidance.pdf). The WHO (Falconer et al. 1999) also lists cyanobacterial scums in swimming areas as having a high probability of adverse health effects (i.e., the potential to cause acute poisoning) and recommends immediate action to prevent contact with scums. As noted above, public health threshold values were also evaluated by relating microcystin concentration to MSAE cell density.

RESULTS/DISCUSSION

Quality Assurance Samples

Microcystin analyses showed less variability than MSAE cell counts with good agreement between paired microcystin samples and duplicates (Table 2). With respect to public health threshold values there were no instances when management based on the 8 µg/L microcystin would have differed. Two instances where the 40,000 cells/ml MSAE threshold would have differed occurred on 9/15 and 10/6. In both cases cell density varied by more than 10,000 cells/ml. Overall, the utilized phytoplankton and toxin methodology had adequate sensitivity relative to public health threshold values.

Table 2. Field duplicate samples for MSAE cell density and microcystin concentration. ND denotes non-detect and NT denotes not tested.

Date	Station Name	Station Description	Depth	*Microcystis aeruginosa* (cells/ml)	*Planktothrix (Oscillatoria) sp.* (cells/ml)	*Anabaena sp.* (cells/ml)	Microcystin Total (µg/L)
4/15/10	SV	Seiad Valley	OC	0	0	0	NT
4/15/10	SD	Seiad Valley Dup	OC	0	0	0	NT
5/12/10	SV	Seiad Valley	OC	0	0	156	0
5/12/10	SD	Seiad Valley Dup	OC	0	0	0	0
6/9/10	SV	Seiad Valley	SG	0	0	0	ND
6/9/10	SD	Seiad Valley Dup	SG	0	0	0	ND
6/23/10	SV	Seiad Valley	OC	0	0	0	ND
6/23/10	SD	Seiad Valley Dup	OC	0	53	0	ND
7/8/2010	SV	Seiad Valley	OC	0	0	0	ND
7/8/2010	SD	Seiad Valley Dup	OC	0	0	0	ND
7/8/2010	SV	Seiad Valley	SG	0	0	0	ND
7/8/2010	SD	Seiad Valley Dup	SG	0	0	0	ND
8/4/2010	SV	Seiad Valley	SG	0	0	0	ND
8/4/2010	SD	Seiad Valley Dup	SG	0	0	0	ND
8/11/2010	SV	Seiad Valley	OC	0	0	0	ND
8/11/2010	SD	Seiad Valley Dup	OC	0	0	0	ND
8/18/2010	IB	IB (I5 Bridge)	SG	362	0	0	1.1
8/18/2010	SD	IB (I5 Bridge) Dup	SG	1,992	0	0	0.86
9/1/2010	SV	Seiad Valley	SG	31,075	0	0	12
9/1/2010	SD	Seiad Valley Dup	SG	36,656	0	0	19
9/15/2010	SV	Seiad Valley	SG	37,503	0	0	11
9/15/2010	SD	Seiad Valley Dup	SG	66,447	0	0	8.9
9/22/2010	SV	Seiad Valley	SG	39,780	0	0	4.2
9/22/2010	SD	Seiad Valley Dup	OC	31,707	0	0	4.5
9/29/2010	SV	Seiad Valley	SG	15,481	0	0	8.6
9/29/2010	SD	Seiad Valley Dup	SG	17,476	0	0	9.4
10/6/2010	SV	Seiad Valley	SG	56,359	0	0	12
10/6/2010	SD	Seiad Valley Dup	OC	37,208	0	0	8.2
10/20/2010	SV	Seiad Valley	SG	12,748	0	0	5.4
10/20/2010	SD	Seiad Valley Dup	SG	22,566	0	0	5.4

Date	Station Name	Station Description	Depth	*Microcystis aeruginosa* (cells/ml)	*Planktothrix (Oscillatoria) sp.* (cells/ml)	*Anabaena sp.* (cells/ml)	Microcystin Total (µg/L)
11/17/2010	SV	Seiad Valley	OC	0	0	0	ND
11/17/2010	SD	Seiad Valley Dup	OC	0	0	0	NT
12/15/2010	SV	Seiad Valley	OC	0	0	0	NT
12/15/2010	SD	Seiad Valley Dup	OC	0	0	0	NT
NT= not tested ND= non detect							

2010 Temporal/Spatial Trends

The standard reservoir sampling stations had low levels of microcystin concentration throughout June, and Copco Reservoir was first posted for *Anabaena* on June 21, 2010. The first detection of MSAE did not occur until 7/25 at station KRBI (Figure 3), and MSAE first exceeded the 40,000 cell/ml public health threshold on 8/2 at both CRCC and IRJW, when microcystin concentrations were 200 µg/L (exceeding the public health TDI by 25x) and 280µg/L, respectively (exceeding the public health TDI by 35x). During the 8/16 sample date the standard sampling stations (CRCC, CRMC and IRCC) exceeded 40,000 cells/ml of MSAE and 8 µg/L of microcystin (Figure 3). On this date station CRMC also exceeded thresholds for MSAE and *Anabaena* resulting in a microcystin concentration of 1,500 µg/L, more than 187x the public health TDI.

Overall MSAE and microcystin levels increased from July through October. Beginning September 7 and continuing to mid-October, all reservoir stations exceeded the MSAE and microcystin public health levels (Figure 3). The maximum toxin concentration occurred on 9/13 with a microcystin concentration of 7,200 µg/L at CRCC, exceeding the public health TDI by 900x (Figure 3). An evaluation of the ratio of toxin produced per unit MSAE indicates that unlike some previous years, 2010 ratios did not show a sharp decline in September or October (Figure 4a). Similar to 2009, an increased ratio occurred in Copco Reservoir relative to Iron Gate Reservoir in 2010 (Figure 4b). Of the six years, the ratio of toxin produced per unit MSAE in 2010 ranked among the highest for July, September and October (Figure 4a).

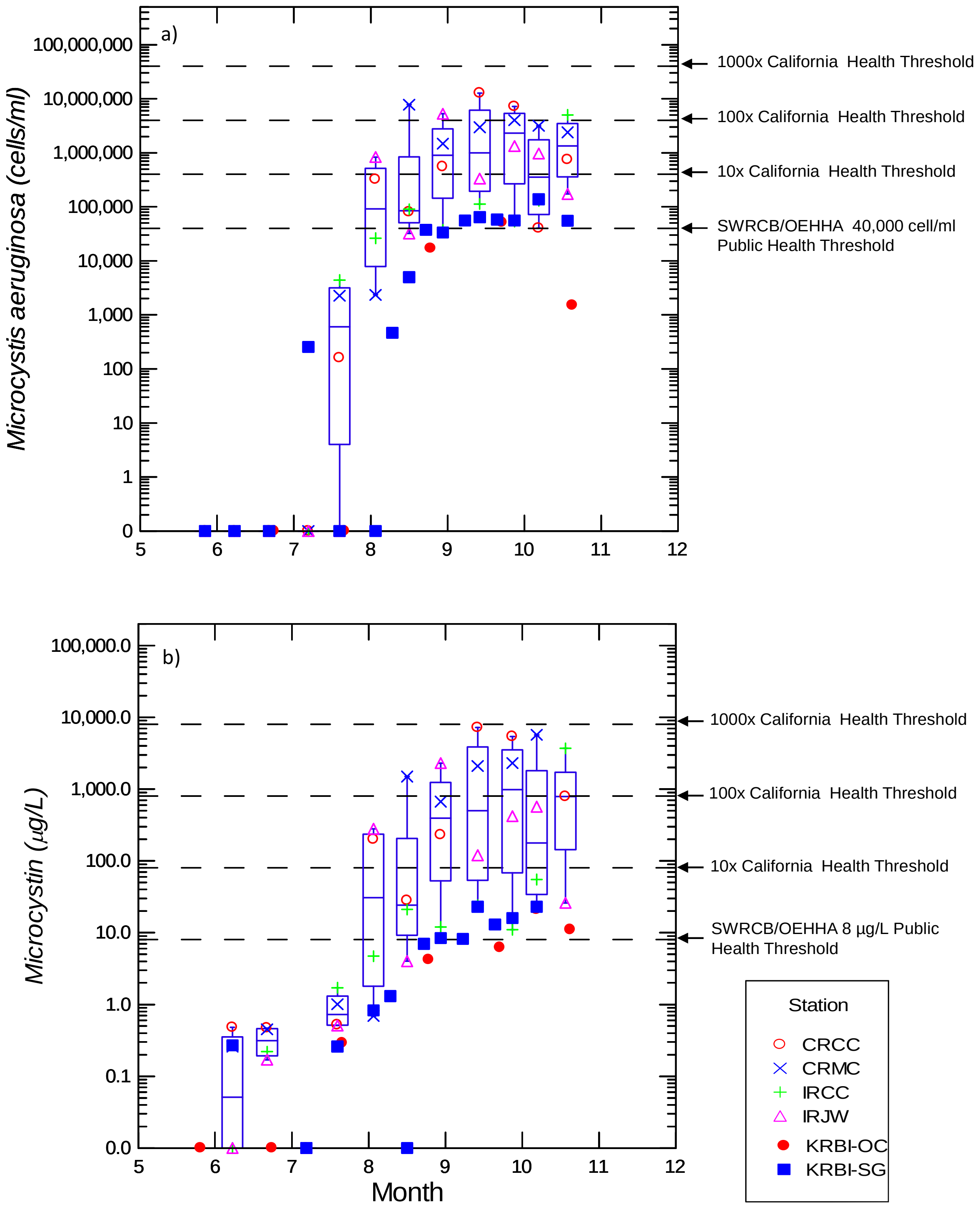


Figure 3. Time-series of MSAE cell density (a) and microcystin toxin concentration (b) for Copco and Iron Gate Reservoir stations, 2010. The box plot (blue box) is for standard reservoir stations, CRCC, CRMC, IRCC, and IRJW only; the river station KRBI is shown independently. All data for reservoir and KRBI-SG stations were provided by PacifiCorp (www.pacificorp.com/es/hydro/hl/kr.html). Note: No data were provided by PacifiCorp for either CR01 or IR01 in 2010.

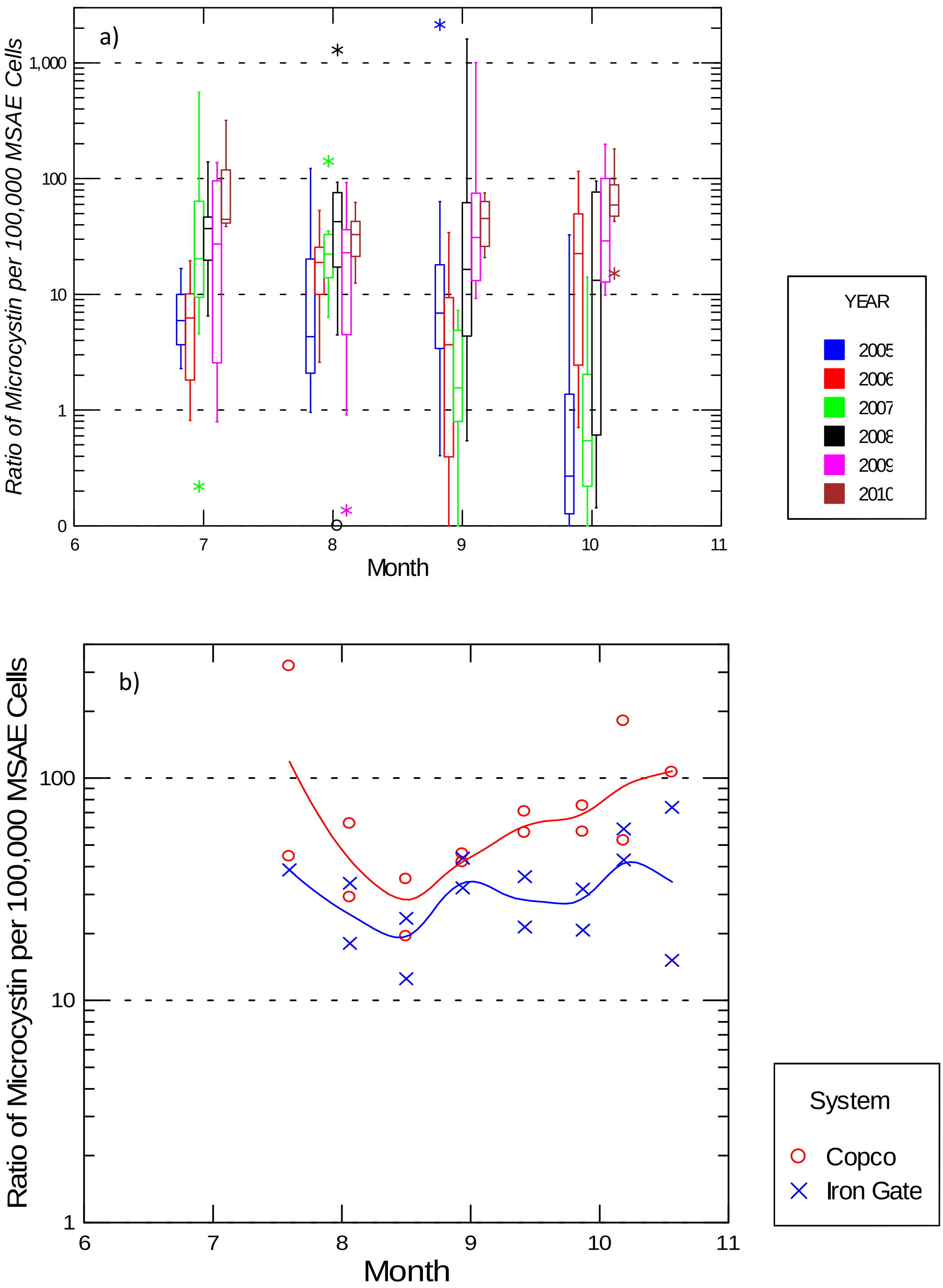


Figure 4. Box plot of the ratio of microcystin concentration per 100,000 MSAE cells at standard stations in Copco and Iron Gate Reservoirs, July through October 2005-2010 (a) and the Ratio of microcystin concentration per 100,000 MSAE cells compared between Copco and Iron Gate Reservoirs for 2010 (b). Trend line is the distance weighted least squares smoother; red Copco, blue Iron Gate. All data for reservoir and KRBI-SG stations were provided by PacifiCorp (www.pacificorp.com/es/hydro/hl/kr.html). Note: No data were provided by PacifiCorp for either CR01 or IR01 in 2010.

A comparison of station distributions for 2010 shows a trend of moderate to high levels for microcystin and MSAE at all reservoir stations (Figure 5a,b). Iron Gate station IRJW was similar in concentration to Copco station CRCC, but station IRCC was noticeably lower than both CRCC and CRMC for both microcystin and MSAE levels (Figure 5a,b).

Continuing downstream to KRBI and below to Orleans (OR), levels of both MSAE and microcystin toxin were lower relative to the reservoir stations; however, on numerous occasions river samples taken in both the mixed portion of the channel and along the shoreline exceeded the threshold guideline values of 40,000 cells/ml MSAE or 8 µg/L microcystin (Figure 5a,b; Appendix I). Similar to previous years, samples taken in areas of low velocity in Klamath River edge habitat showed that MSAE cell density and microcystin concentration were often higher than the open water samples, and more frequently exceeded the 40,000 cells/ml MSAE and 8 µg/L microcystin public health guideline values (Figure 6 and 7; stations where both OC and SG samples collected). The edge-water concentrations typically observed are illustrated in Figure 8. Public health exceedances were typically highest at station KRBI (Figure 6 and7; Appendix 1). As in previous years, from a public health perspective these data illustrate that low MSAE or toxin values in open-water (collected in mixed areas of higher velocity) Klamath River samples often translates to values exceeding public health thresholds in river-edge areas where algae become trapped among other algae and aquatic vegetation.

Because the jar method (as outlined above) of collecting surface algal material does not allow for easy sampling of scum material in shoreline algal mats, areas of high algal concentration adjacent to some of the samples above are likely to exceed posting guideline levels in some cases. For example, station SV showed MSAE levels of 37,503 cells/ml on September 15th; yet a photo of algal mats near that station (Figure 8a) indicate MSAE cells to be more highly concentrated than the cell counts would indicate. River users should be aware to avoid such areas (especially if they have pets). For example, on the same date, the algal mat at station BB (Figure 8b) had an MSAE cell density of 295,272 cells/ml and 85 µg/L of microcystin (Appendix I).

With the exception of one instance of *Anabaena* cell density (4,004 cells/ml) detected at the mouth of the Shasta River (SH) on 7/21, *Anabaena* and MSAE was not detected in any other tributary samples during 2010 (Appendix I). Low levels of microcystin (less than 1 µg/L) were detected at SC, SA and SH throughout the sampling period. The cause of and or source of the low levels is unknown, but given the low level and infrequent detection, is not of general concern at this time.

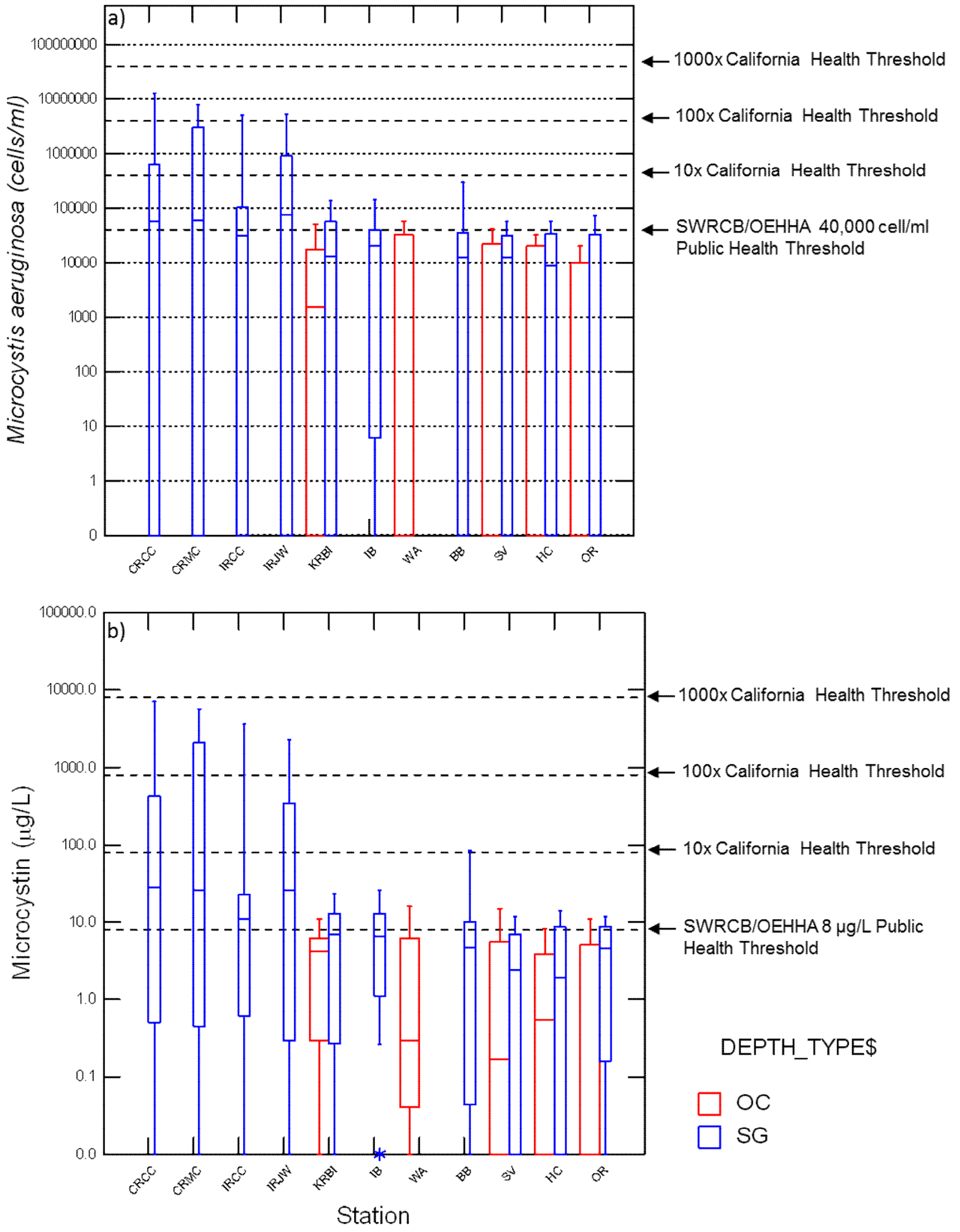


Figure 5. Station comparison of MSAE cell density (a) and microcystin toxin concentration (b) for Klamath River and Reservoir locations May through October, 2010. Stations ordered longitudinally left (upstream) to right (downstream). All data for reservoir and KRBI-SG stations were provided by PacifiCorp (www.pacificorp.com/es/hydro/hl/kr.html). Note: since data for OC depths was collected only at a monthly resolution for KRBI and HC River stations these boxes are not directly comparable to those with higher sampling frequency.

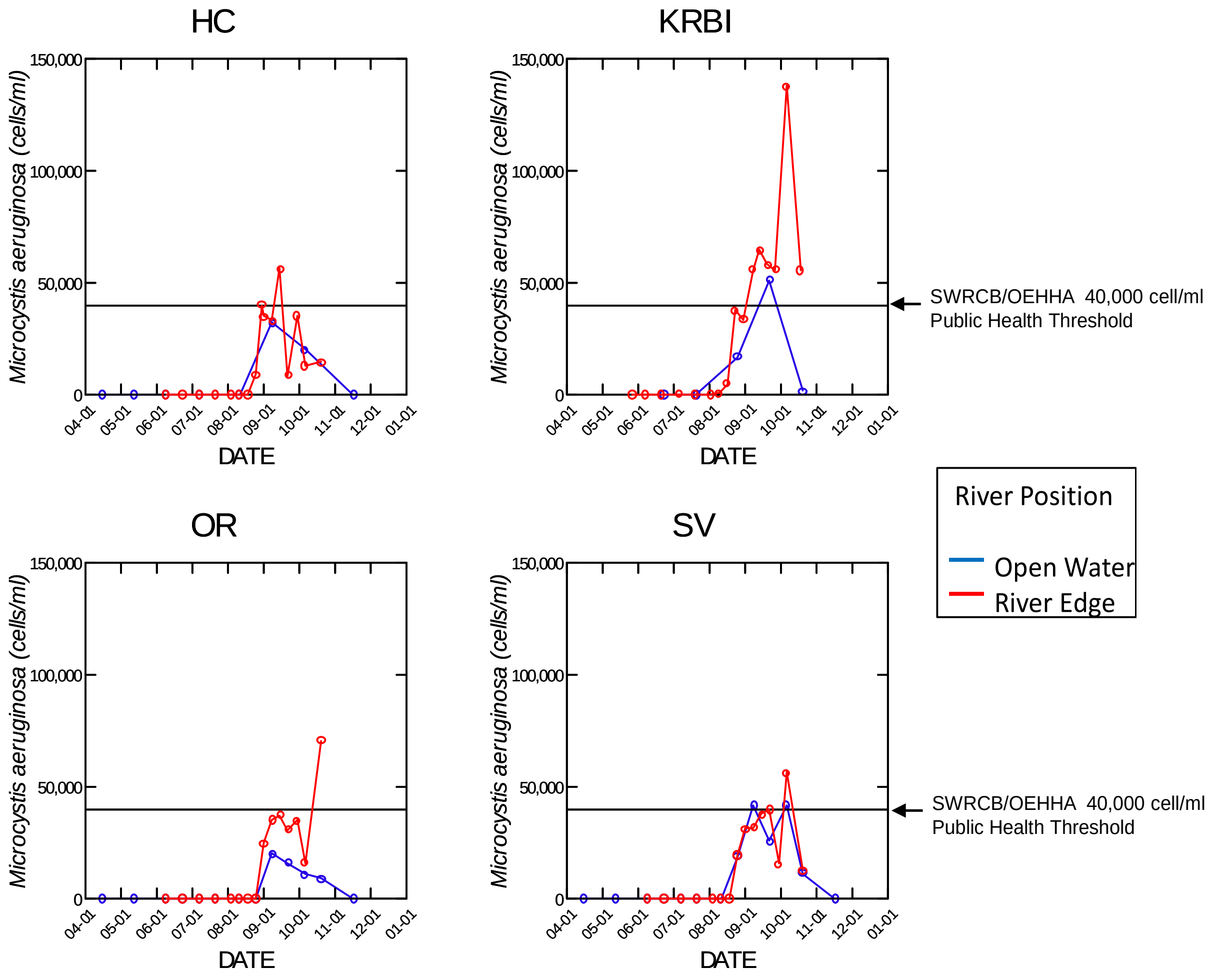


Figure 6. MSAE cell density for standard Klamath River stations sampled in areas of open water (OC) and low velocity at the river's edge (SG) April-November, 2010. Data for KRBI-SG station were provided by PacifiCorp (www.pacificorp.com/es/hydro/hl/kr.html).

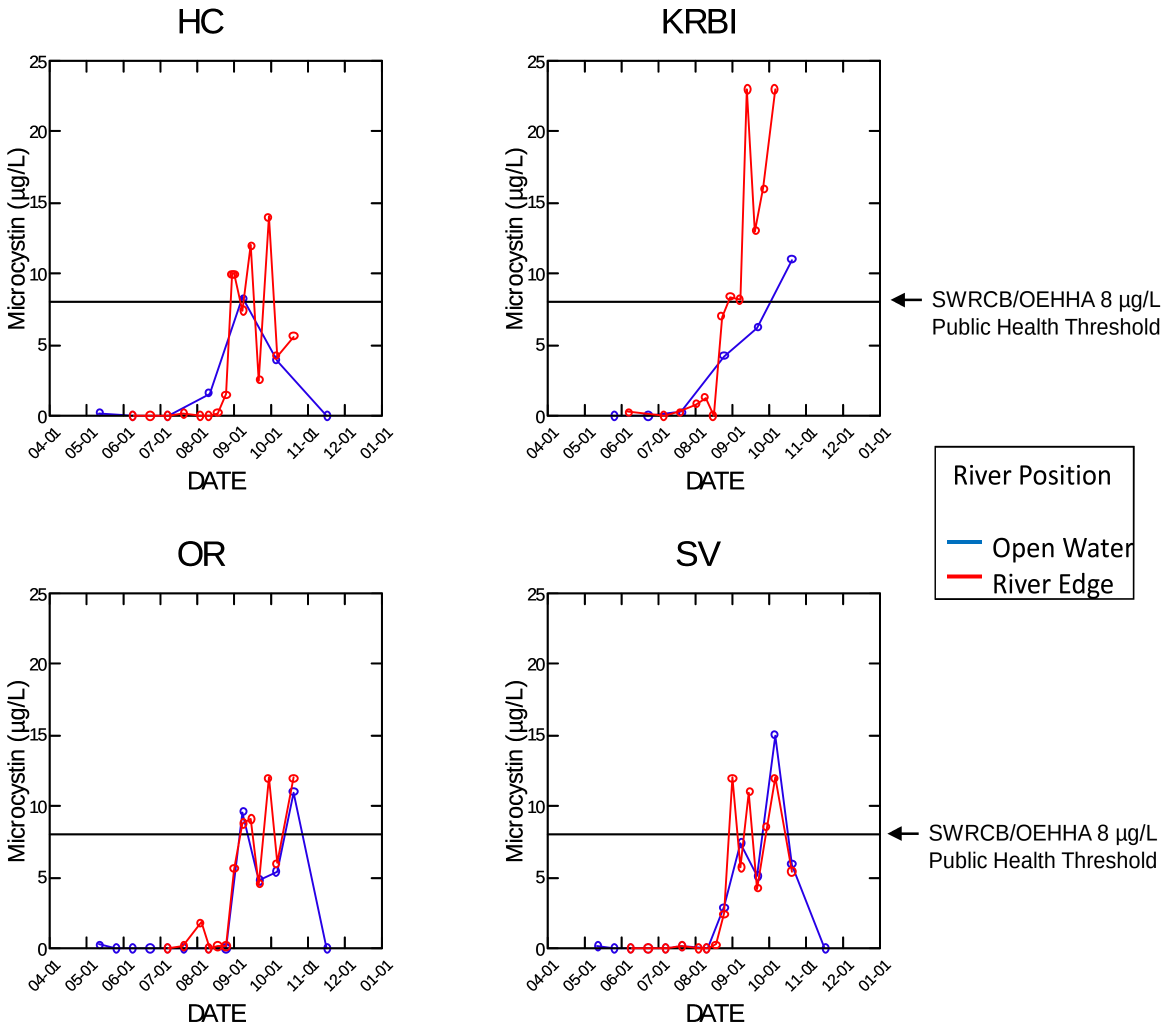


Figure 7. Microcystin concentration for standard Klamath River stations sampled in areas of open water (OC) and low velocity at the river's edge (SG) April-November, 2010. Data for KRBI-SG stations were provided by PacifiCorp (www.pacificorp.com/es/hydro/hl/kr.html).

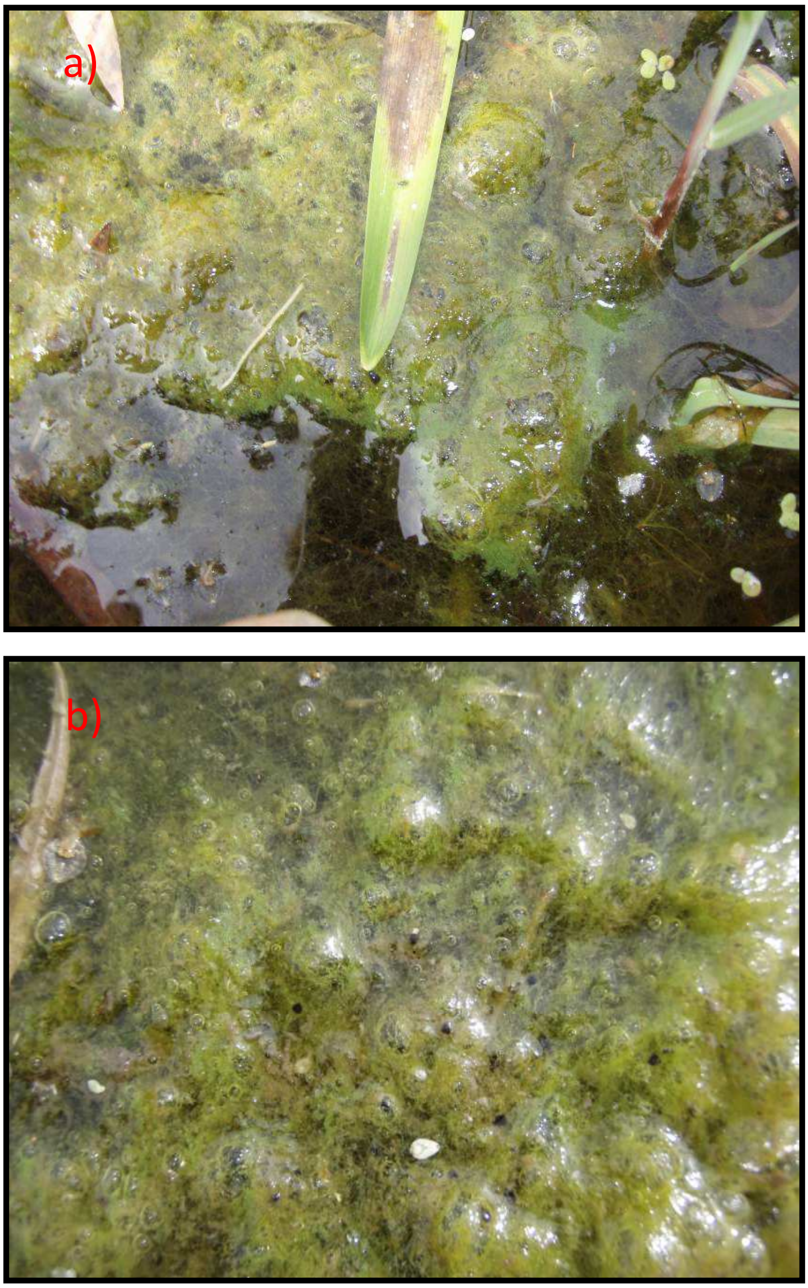


Figure 8. Photos of algal mats with apparent accumulation of *Microcystis* at Seiad Valley (a) and Brown Bear (b), Klamath River, September 15, 2010.

Inter-annual Comparisons

A comparison of combined 2010 reservoir data for Copco and Iron Gate reservoirs with 2005-2009 data showed both the median MSAE density and overall distribution to be lower than 2009, but higher than 2007 and 2008 (Figure 9a). Further breakdown shows the upper quartile values for Copco reservoir notably lower in 2010 than 2009 however, the upper quartile values for Iron gate reservoir were slightly higher in 2010 than 2009 (Figure 6b). Of the 6 year period of record, 2008 showed the lowest MSAE distribution both on a combined basis and for reservoirs individually. Aside from 2005 when Copco and Iron Gate showed similar MSAE levels, Iron Gate reservoir had lower overall MSAE densities than Copco Reservoir (Figure 6b).

The overall microcystin distribution of both reservoirs combined (Figure 10a) was also lower than the previous year (Figure 10a), and although the median was lower than 2005 and 2006, the upper quartile in 2010 (top line of the box or 75th percentile in Figure 10a) was the second highest of the 6 years. Microcystin distribution in 2010 for the reservoirs individually also showed lower values for Copco reservoir than 2009 and higher values for Iron Gate (Figure 10b). The overall distribution of microcystin toxin concentration tended to be lower in Iron Gate Reservoir than in Copco Reservoir in all years (Figure 10b).

A plot of reservoir and river stations (mid channel OC stations only) oriented longitudinally for the years 2008-2010 (these sites and years were chosen because they provided a consistent record for comparison) shows that there is a general decreasing downstream trend in both MSAE cell density and microcystin toxin over the 2008-2010 period (Figure 11a,b). Although as shown above MSAE cells can accumulate in river edge areas, such a trend near mid-channel is consistent with the reservoirs acting as the source for riverine levels of MSAE and microcystin.

MSAE Cell Density-Microcystin Concentration Relationships

As noted previously, the relationship between MSAE cell density and microcystin toxin is variable, particularly when low or zero levels of MSAE are associated with high microcystin levels or with changing microcystin to cell ratios as noted above. However, despite this variability and similar to plots produced for past years (Kann and Corum 2009) a scatter plot of 2010 data fitted with a distance weighted least squares smoother (DWLS) shows a general increasing trend of toxin concentration with cell density (Figure 12). As noted above, data points along the y-axis depict instances of microcystin detection when MSAE cells were not detected. As expected based on ratios of microcystin per unit cell density that did not decline during the fall months of 2010, these months fit the general trend (Figure 12; solid red circles).

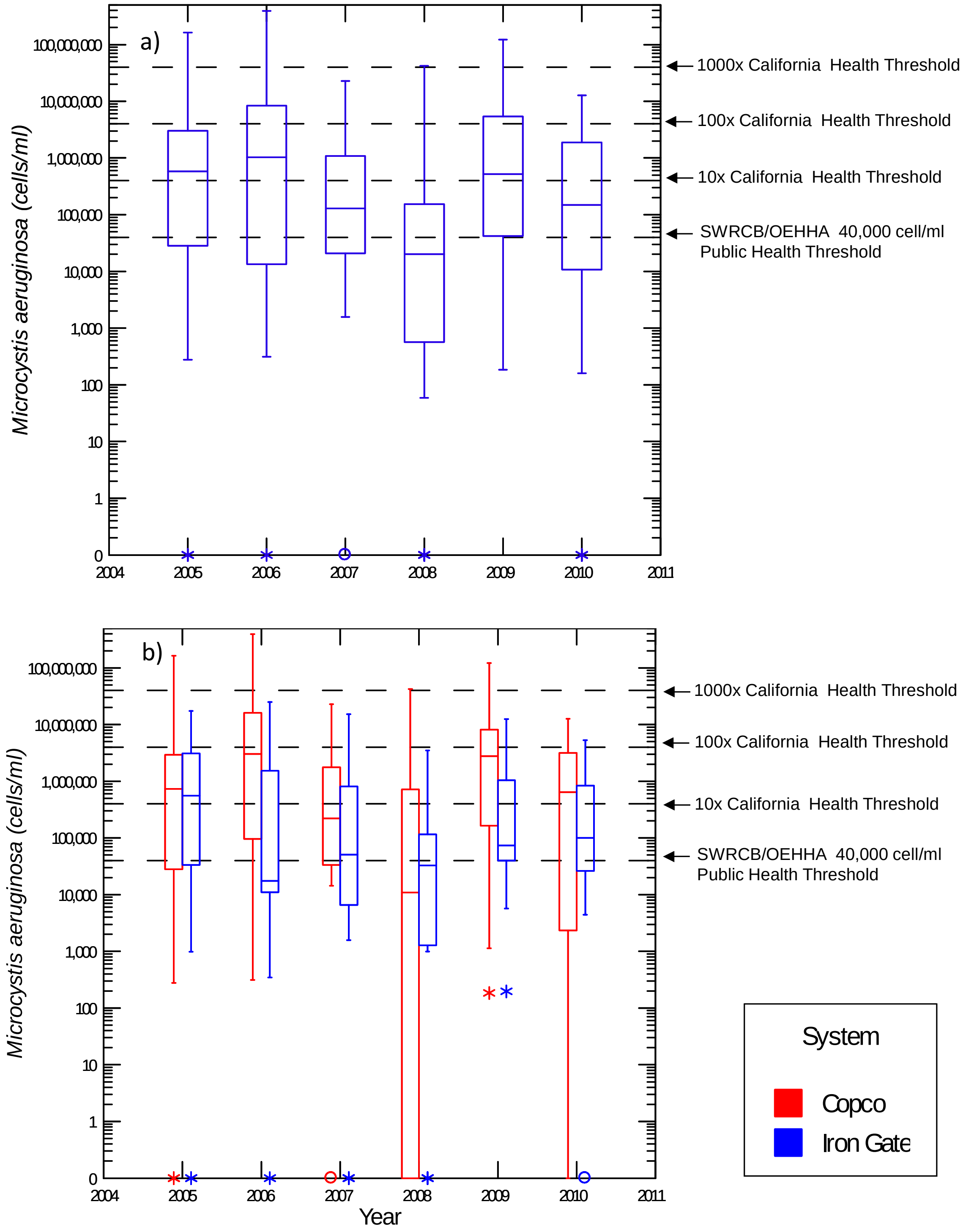


Figure 9. Inter annual comparison of MSAE cell density for standard reservoir stations (a) and Copco and Iron Gate Reservoirs individually (b) July through October 2005-2010. All data for reservoir and KRBI-SG stations were provided by PacifiCorp (www.pacificorp.com/es/hydro/hl/kr.html). Note: No data were provided by PacifiCorp for either CR01 or IR01 in 2010.

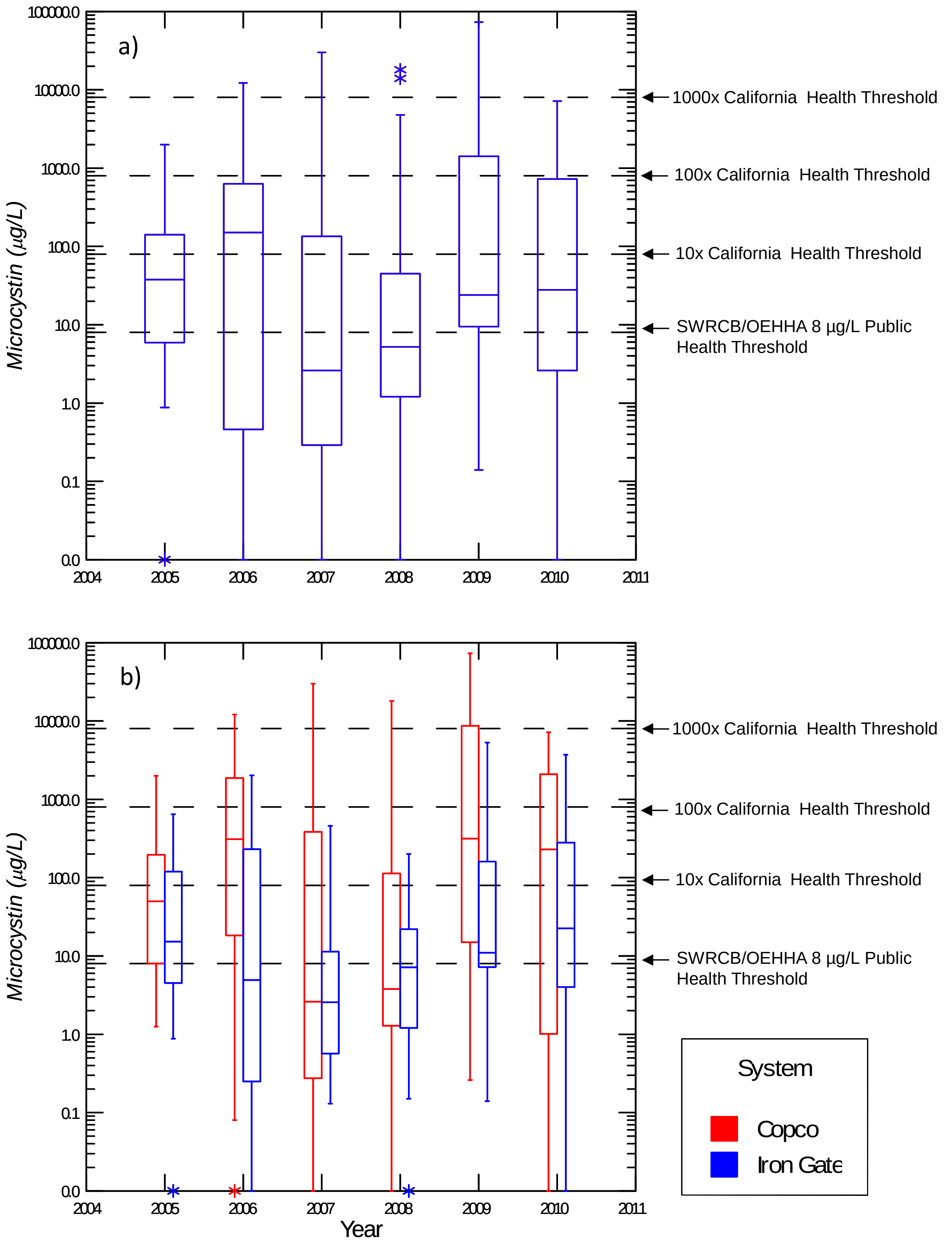


Figure 10. Inter annual comparison of microcystin concentration for standard reservoir stations (a) and Copco and Iron Gate Reservoirs individually (b) July through October 2005-2010. All data for reservoir and KRBI-SG stations were provided by PacifiCorp (www.pacificorp.com/es/hydro/hl/kr.html). Note: No data were provided by PacifiCorp for either CR01 or IR01 in 2010.

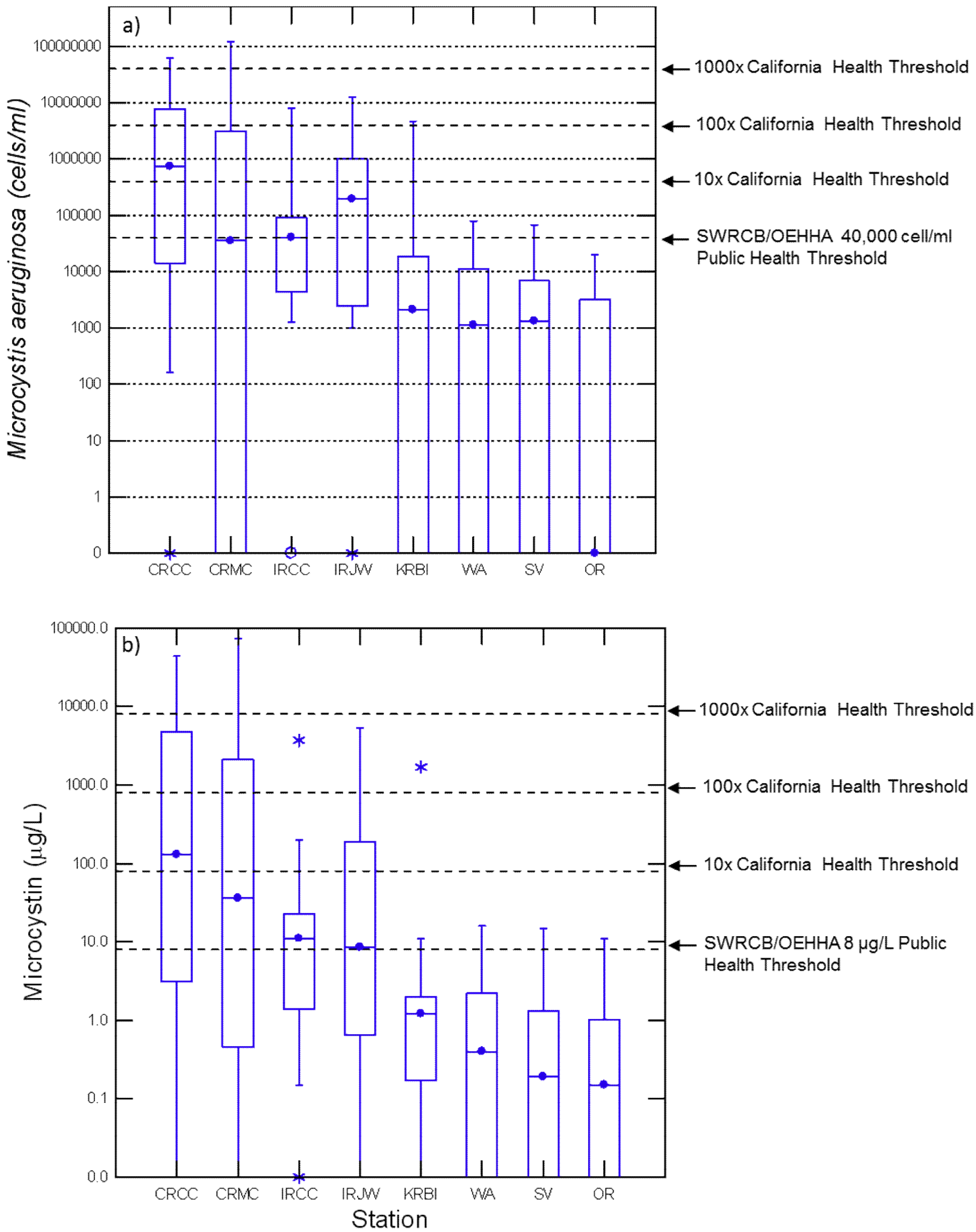


Figure 11. Station comparison of MSAE cell density (a) and microcystin toxin concentration (b) for Klamath River and Reservoir locations June through October, 2008-2010. Stations ordered longitudinally left (upstream) to right (downstream). Reservoir data shown for SG samples, River data shown for OC samples.

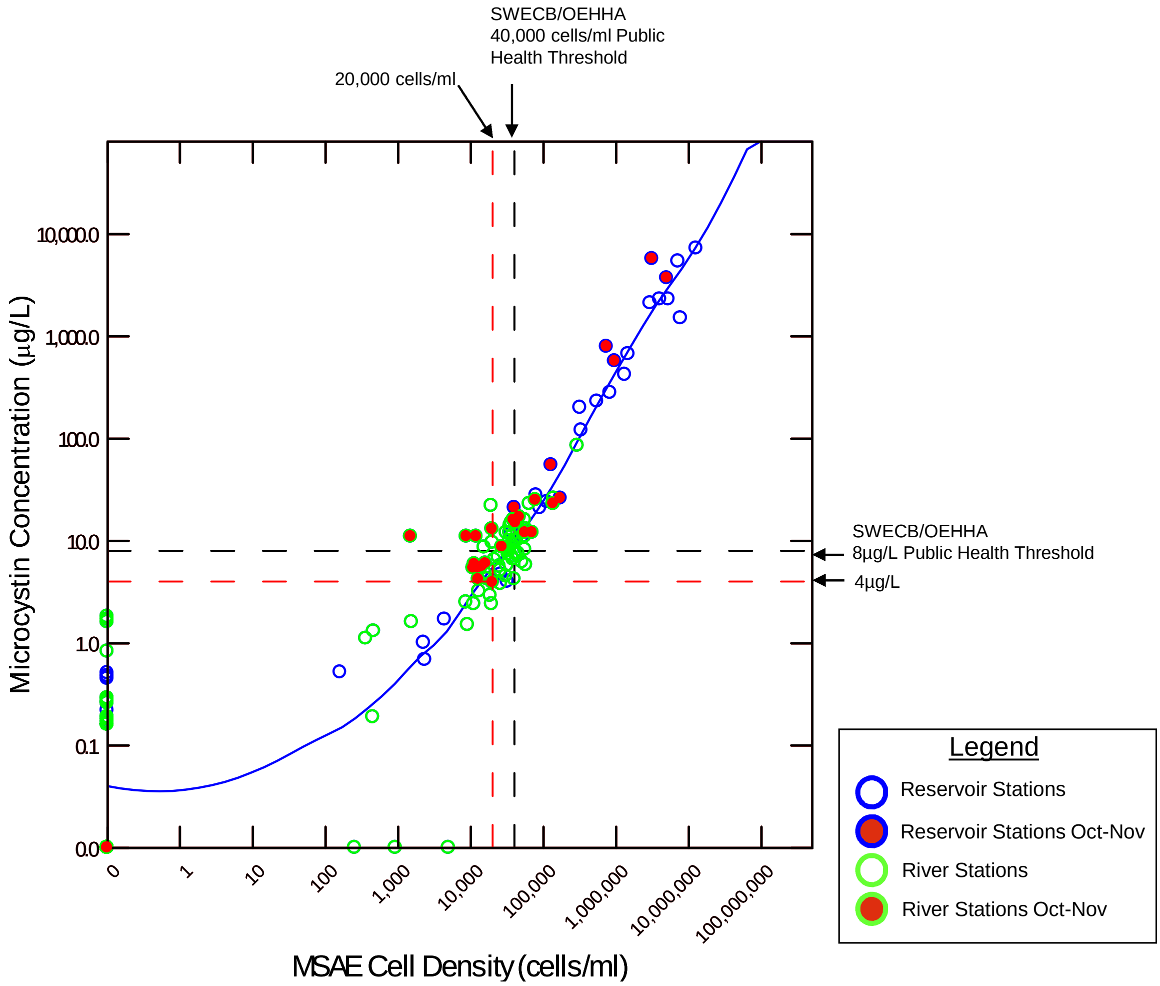


Figure 12. Relationship between MSAE cell density and microcystin toxin concentration; shown with distance weighted least squares (DWLS) smoother applied to all data, 2010. Data for reservoir and KRBI-SG stations were provided by PacifiCorp (www.pacificorp.com/es/hydro/hl/kr.html).

The 2010 relationship of MSAE cell density vs. microcystin relative to public health thresholds continues to indicate that the majority of 8 µg/L microcystin exceedances occurred at MSAE levels greater than 40,000 cells/ml (upper right quadrant black dashed line; Figure 12). However, there were also numerous exceedances of 8 µg/L when MSAE cell density was less than 40,000 cells/ml (upper left quadrant: Figure 12). This is consistent with expectations based upon variable toxin production and presence of non-cell bound toxin as described in Kann and Corum (2009). These relationships continue to indicate that the SWRCB/OEHHA guideline value for MSAE density is generally protective of the 8 µg/L microcystin moderate probability of adverse health effect threshold, but that 20,000 cells per ml provides a greater level of protection with respect to remaining below 8 µg/L microcystin.

Further evaluation of the relationship between MSAE cell density and microcystin concentration was performed using the World Health Organization low probability of adverse health effect guideline values of 20,000 cells/ml MSAE and 4 µg/L microcystin (red dashed line Figure 12,13). Whereas the SWRCB/OEHHA guidelines are considered to protect against a moderate probability of adverse effects, this lower threshold is utilized by the CA North Coast Regional Water Quality Control Board (NCRWQCB) for Total Maximum Daily Load calculations that are expected to further reduce the probability of adverse levels that can impact public health. Again these evaluations indicate that the more conservative level of 20,000 cells/ml MSAE decreases the frequency of exceeding the 8 µg/L public health guideline value for microcystin (compare upper right quadrants based on black and red dashed lines; Figure 12). A similar trend is noted when data for the entire 2005-2010 period are plotted (Figure 13).

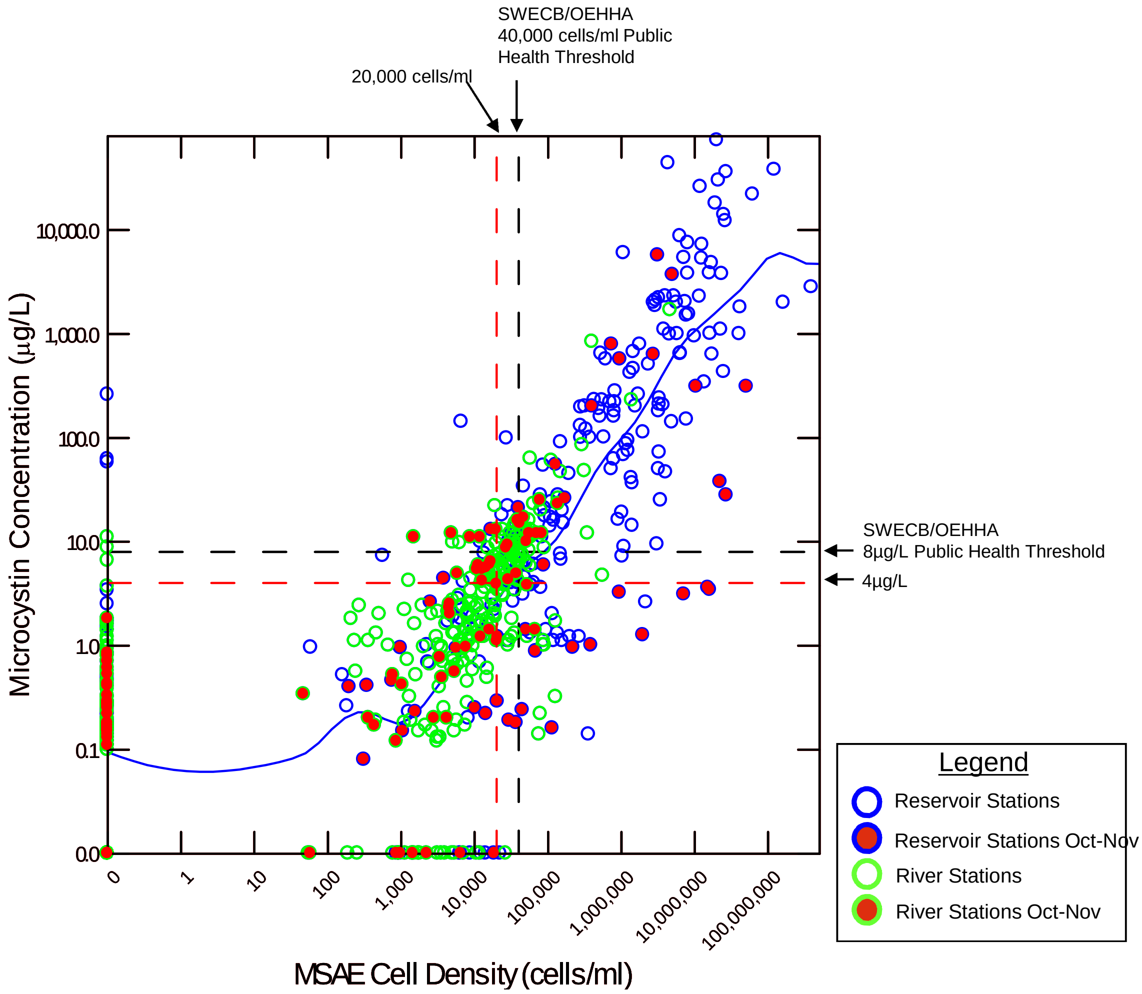


Figure 13. Relationship between MSAE cell density and microcystin toxin concentration for standard reservoir and river stations 2005-2010; shown with distance weighted least squares (DWLS) smoother. Data for reservoir and KRBI-SG stations were provided by PacifiCorp (www.pacificorp.com/es/hydro/hl/kr.html).

Linear regression modeling (excluding periods when MSAE was not detected) revealed, despite variability in the relationship of toxin produced per unit MSAE, that overall a significant relationship existed between MSAE cell density and microcystin toxin (Figure 14; Table 3). Further analysis showed that the relationship was less variable for August-only, resulting in an improvement in the r^2 of over 10% (Figure 15; Table 3). Both the entire model and the August-only model show that at the State of CA public health threshold level of 40,000 cells/ml MSAE that a *mean* microcystin level slightly under, but close to, the public health threshold of 8 µg/L was predicted (Table 3).

Evaluation of the 95% prediction bands, however, also reveals the inherent variability and demonstrates that at the upper prediction band (portraying a conservative perspective) ~100 µg/L is predicted at 40,000 cells per ml MSAE (Figure 14; Figure 15). Thus, although strong linear relationships are demonstrated between MSAE cell density and microcystin, variability is such that wide prediction bands are calculated around the mean regression line. As demonstrated previously though, from a probability perspective, exceedance of 8 µg/L microcystin greatly decreases when MSAE cell density is below 40,000, and especially 20,000 cells/ml (Kann and Corum 2009).

Inter-annual variability was also observed in the linear relationship between cell density and toxin (Table 3). For, example, as expected based upon the relatively high toxin to cell ratio experienced in 2010 (see Figure 4a above) the linear relationship between MSAE density and microcystin in 2010 was stronger than other years (r^2=0.88) with a mean microcystin concentration of 13.6 µg/L predicted at an MSAE density of 40,000 cells/ml (Figure 16; Table 3). In fact, even at 20,000 cells per ml a microcystin concentration of 7.1 µg/L is predicted for 2010; a value approaching the public health threshold level. These results indicate that in years when a high ratio of toxin to cell density occurs, that the 40,000 MSAE cells/ml public health threshold may not be protective of public health.

Table 3. Regression statistics for relationships between MSAE vs. microcystin in the Middle Klamath River System. Includes only observations when MSAE was detected.

Year	N	R^2	constant	slope	p value	Predicted Microcystin at 40,000 cells/ml Microcystis
All Years	460	0.681	-2.868	0.807	<0.001	7.0
All Years (August only)	150	0.787	-3.448	0.928	<0.001	6.6
2010	101	0.876	-3.219	0.946	<0.001	13.6
2009	145	0.73	-3.39	0.92	<0.001	7.0
2008	71	0.601	-2.391	0.709	<0.001	7.4
2007	65	0.599	-3.747	0.927	<0.001	3.3
2006	45	0.83	-2.932	0.805	<0.001	5.9
2005	33	0.278	-1.278	0.481	<0.001	8.6

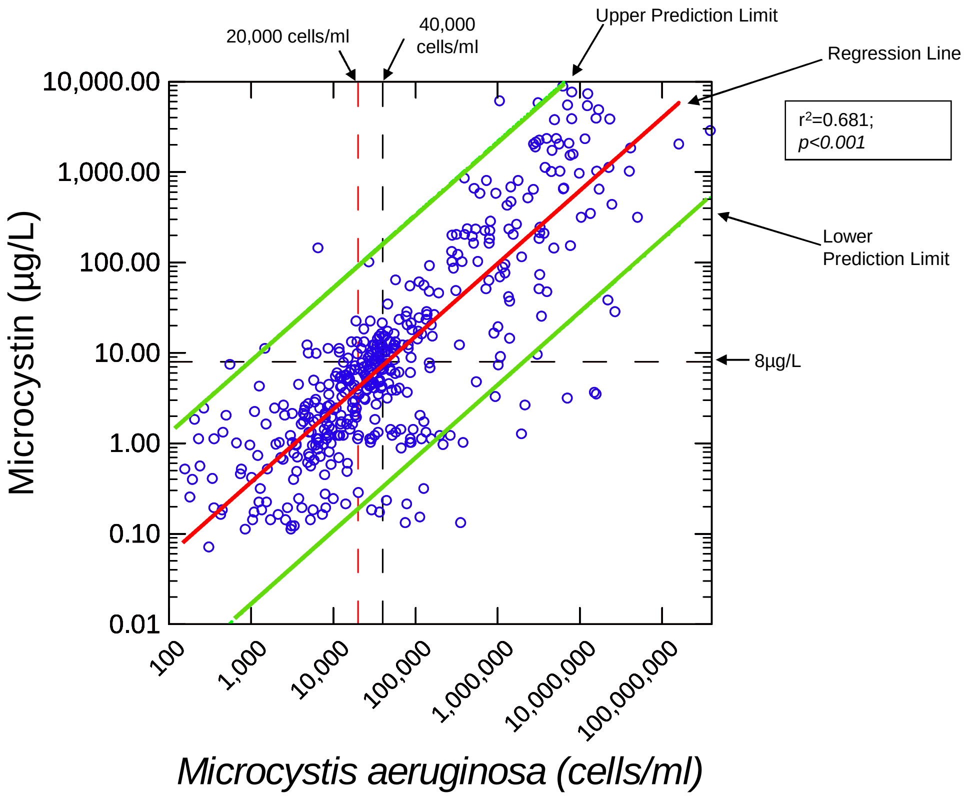


Figure 14. Regression analysis between MSAE cell density and microcystin toxin; May-November, 2005-2010. Includes only observations when MSAE was detected.

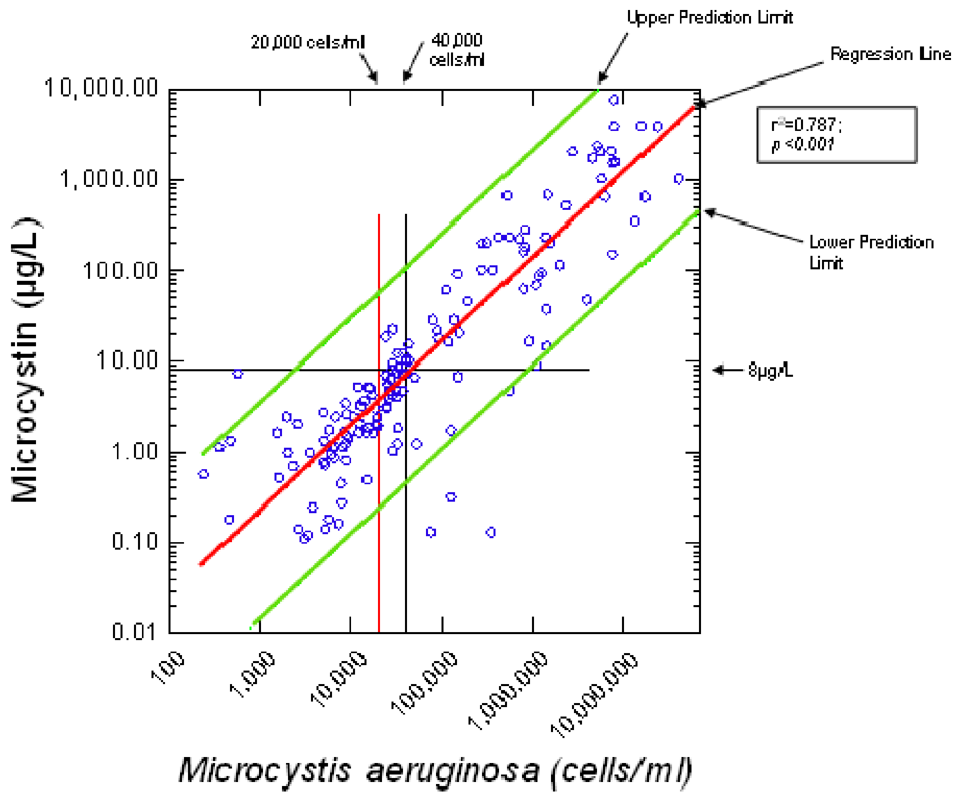


Figure 15. . Regression analysis between MSAE cell density and microcystin toxin; August-only, 2005-2010. Includes only observations when MSAE was detected.

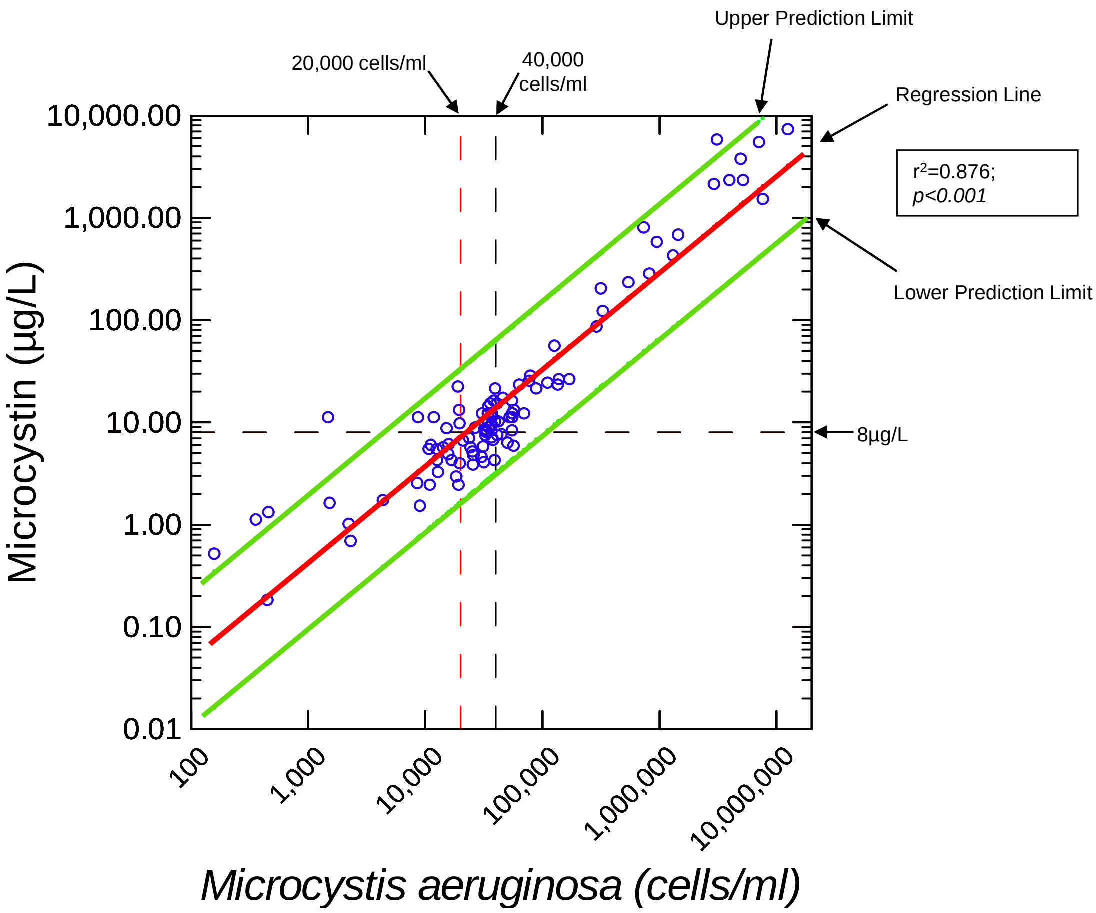


Figure 16. Regression analysis between MSAE cell density and microcystin toxin; 2010-only. Includes only observations when MSAE was detected.

SUMMARY

Middle Klamath River sampling in 2010 continued to show widespread and high abundance of toxigenic MSAE from August-October, exceeding public health thresholds by numerous times during these months. River stations downstream from Copco and Iron Gate Reservoirs showed levels of both MSAE and microcystin toxin that were lower relative to the reservoir stations; however, on numerous occasions river samples taken in both the mixed portion of the channel and along the shoreline exceeded the threshold guideline values of 40,000 cells/ml MSAE or 8 µg/L microcystin. Similar to 2009, samples taken in areas of low velocity in Klamath River edge habitat in 2010 showed that MSAE cell density and microcystin concentration were often higher than the open water samples, and more frequently exceeded the 40,000 cells/ml MSAE and 8 µg/L microcystin public health guideline values. Public health exceedances were typically highest at KRBI in 2010. As in 2009, from a public health perspective these data illustrate that low MSAE or toxin values in open-water (collected in mixed areas of higher velocity) Klamath River samples often translates to values exceeding public health thresholds in river-edge areas.

The ratio of toxin produced per unit MSAE showed that unlike some previous years, 2010 ratios did not show a sharp decline in September or October, and of the six years of record, the ratio of toxin produced per unit MSAE in 2010 ranked among the highest for July, September and October.

A comparison of 2010 data with 2005-2009 data showed generally lower MSAE and microcystin concentrations than the previous year, and higher concentrations relative to 2007 and 2008 for both the reservoirs as a whole and for Copco and Iron Gate individually. Of the 6 year period of record, 2008 showed the lowest MSAE distribution both on a combined basis and for reservoirs individually. Aside from 2005 when Copco and Iron Gate showed similar MSAE levels, Iron Gate reservoir had lower overall MSAE densities than Copco Reservoir . Although median microcystin in 2010 was lower than 2005 and 2006, the upper quartile was the second highest of the 6 years. The overall distribution of microcystin toxin concentration tended to be lower for Iron Gate Reservoir than for Copco Reservoir in all years.

Similar to relationships indicated for past years, a scatter plot of 2010 data showed a general increasing trend of toxin concentration with cell density. The 2010 relationship of MSAE cell density vs. microcystin relative to public health thresholds continues to indicate that the majority of 8 µg/L microcystin exceedances occurred at MSAE levels greater than 40,000 cells/ml. However, consistent with expectations based upon variable toxin production and presence of non-cell bound toxin there were also numerous exceedances of 8 µg/L when MSAE cell density was less than 40,000 cells/ml. The data plots indicate that a level of 20,000 cells/ml MSAE further decreases the frequency of exceeding the 8 µg/L public health guideline value for microcystin. Regression analyses showed that significant linear relationships existed between MSAE density and microcystin and that predictive equations developed from these regressions indicated that mean predicted microcystin toxin concentration was close to 8 µg/L at an MSAE density of 40,000 cells/ml. These analyses also showed high variability as demonstrated by wide prediction bands around the mean. Especially in 2010 when a high microcystin to cell density ratio was observed, the 40,000 cells/ml public health threshold was not always protective in terms of preventing microcystin concentrations greater than 8 µg/L.

Disclaimer

Due to the patchy nature of blue-green algal blooms it is possible for higher Microcystis aeruginosa densities (and therefore higher microcystin toxin concentrations) to have been present in locations not covered in this survey, particularly along shorelines or protected coves and backwaters during calm conditions of little to no wind. Recreational users should always avoid contact with water whenever noticeable surface concentrations of algae are evident. Moreover, because pets or other domestic animals are the most likely to ingest contaminated water, these animals should not be allowed access to areas of either noticeable surface concentrations of algae or when an obvious green to blue-green appearance is evident.

Acknowledgements

Field data collection was provided by Grant Johnson, Water Quality Biologist for the Karuk Tribe. Support for the Public Health monitoring program was cooperatively provided by PacifiCorp, Klamath Hydroelectric Settlement Agreement in Principle Water Quality Workgroup, EPA Region IX, and the North Coast Regional Water Quality Control Board.

BIBLIOGRAPHY

American Public Health Association (APHA). 1992. Standard Methods for the Examination of Water and Wastewater. 18th ed. APHA, AWWA, and WPCF, Washington, D.C.

Carmichael, W.W. 1995. Toxic *Microcystis* in the environment. In M.F. Watanabe, K. Harada, W.W. Carmichael & H. Fujiki (eds), Toxic *Microcystis*. CRC Press, New York: 1-12.

Chorus I, Bartram, J, editors. 1999. Toxic cyanobacteria in water. E & FN Spon: London.

Chorus I, editor. 2001. Cyanotoxins: occurrence, causes, consequences. Springer-Verlag: Berlin.

Chorus, I, and M. Cavalieri. 2000. Cyanobacteria and algae. Pages 219-271 *in*: J. Bartram and G Rees, editors. *Monitoring Bathing Waters: a practical guide to the design and implementation of assessments and monitoring programmes*. World Health Organization Report. E & FN Spon, London and New York.

Falconer et al. 1999. Safe levels and safe practices. Pages 155-177 *in*: I. Chorus and J. Bartram, editors. *Toxic Cyanobacteria in water: a guide to their public health consequences*. World Health Organization Report. E & FN Spon, London and New York.

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

Jacoby, J.M. and J. Kann. 2007. The Occurrence and Response to Toxic Cyanobacteria in the Pacific Northwest, North America. Lake and Reserv. Manage. 23:123-143.

Kann, J. 2008. Microcystin Bioaccumulation in Klamath River Fish and Freshwater Mussel Tissue: Preliminary 2007 Results. Technical Memorandum Prepared for the Karuk Tribe Department of Natural Resources. April 2008.

Kann, J. and S. Corum. 2006. Summary of 2005 Toxic *Microcystin aeruginosa* Trends in Copco and Iron Gate Reservoirs on the Klamath River, CA Technical Memorandum Prepared for the Karuk Tribe of California, March, 2006.

Kann, J. and S. Corum. 2007. Summary of 2006 Toxic *Microcystin aeruginosa* Trends in Copco and Iron Gate Reservoirs, Klamath River, CA Technical Memorandum Prepared for the Karuk Tribe of California, March, 2007.

Kann, J., S. Corum. 2009. Toxigenic Microcystis aeruginosa bloom dynamics and cell density/chlorophyll a relationships with microcystin toxin in the Klamath River, 2005-2008. Technical Memorandum Prepared for the Karuk Tribe of California, May, 2009.

Kann, J, L. Bowater, C. Bowman, G. Johnson. 2011. Preliminary 2010 Microcystin Bioaccumulation Results for Klamath River Salmonids. Technical Memorandum prepared by Aquatic Ecosystem Sciences LLC for the Karuk Tribe Department of Natural Resources, Orleans CA.

Kann J, Corum S, and Fetcho K. 2010. Microcystin Bioaccumulation in Klamath River Freshwater Mussel Tissue: 2009 Results. Prepared by Aquatic Ecosystem Sciences, LLC., the Karuk Tribe Natural Resources Department, and the Yurok Tribe Environmental Program:23 pp. + appendices. Accessed online 12/8/2010 at: http://www.klamathwaterquality.com/documents/2009_Klamath_River_FreshwaterMussel_%20Microcystin_%20Bioaccumulation.pdf

Kann, J. and S. Corum. 2010. Middle Klamath river Toxic Cyanobacteria Trends, 2009. Technical Memorandum. Prepared by Aquatic Ecosystem Sciences, LLC, Ashland, Oregon and the Karuk Tribe Department of Natural Resources for the Karuk Tribe Department of Natural Resources, Orleans, California.

Mekebri A, G.J. Blondina, and D.B. Crane. 2009. Method validation of microcystins in water and tissue by enhanced liquid chromatography tandem mass spectrometry. J Chromatogr A. 1216(15):3147-55

NHMRC. 2005. Cyanobacteria and Algae in Fresh Water. *Pages* 95-120 *in:* Australian Government National Health and Medical Research Council: Guidelines for Managing Risk in Recreational Water. http://www.ag.gov.au/cca

OEHHA. 2008. Information Related to the Occurrence of Microcystin in the Tissues of Klamath River Biota. Letter to Mr. Randy Landolt, PacifiCorp Energy. August 6, 2008.

Raymond, R. 2010. Results of cyanobacteria and Microcystin monitoring in the vicinity of the Klamath hydroelectric project: October 18 and 29, 2010. Technical Memorandum prepared for PacifiCorp, Portland, OR.

Stone, D. and W. Bress. 2007. Addressing public health risks for cyanobacteria in recreational freshwaters: the Oregon and Vermont Framework. Integr. Environ. Assess. Manage. 3(1):137-143.

WHO 1998. Guidelines for Drinking-water Quality. Second Ed. Addendum to Vol. 2, Health Criteria and Other Supporting Information. World Health Organization, Geneva.

WHO 2003. Chapter 8: Algae and Cyanobacteria in Fresh Water. *Pages 128-133* in: Volume 1: Coastal and Fresh Waters. World Health Organization, Geneva.

APPENDIX I: Cell Density and cyanotoxin concentration for the Middle Klamath River, 2010.

BM: Baseline Monitoring
PH: Public Health Sample
SG: Surface grab-sampling near shoreline region of low mixing
OC: Sampling near mid-channel mixed region

Date	Station Name	RM	Sample Event	Station Description	Depth	Microcystis aeruginosa (cells/ml)	Planktothrix (Oscillatoria) or Gloeotrichia echinulata (cells/ml)	Anabaena sp. (cells/ml)	Microcystin Total (µg/L)	Exceedance of SWRCB[1] risk level of 40,000 cells/ml Microcystis or Planktothrix (x greater than 4^5 cells/ml)	Exceedance of microcystin TDI of 0.04 µg/kg/day for a 20kg (44lb) child ingesting 100 mls[2] (x greater than TDI)
2/18/10	SA	0	PH	Salmon River	OC	0	0	0	NT	0.00	
2/18/10	SC	0	PH	Scott River	OC	0	0	0	NT	0.00	
2/18/10	SH	0	PH	Shasta River	OC	0	0	0	NT	0.00	
2/18/10	OR	59.1	PH	Orleans	OC	0	0	0	NT	0.00	
2/18/10	HC	108.4	PH	Happy Camp	OC	0	0	0	NT	0.00	
2/18/10	SV	128.5	PH	Seiad Valley	OC	0	0	0	NT	0.00	
2/18/10	WA	157	PH	Walker Bridge	OC	0	0	0	NT	0.00	
4/15/10	SA	0	PH	Salmon River	OC	0	0	0	NT	0.00	
4/15/10	SC	0	PH	Scott River	OC	0	0	0	NT	0.00	
4/15/10	SH	0	PH	Shasta River	OC	0	0	0	NT	0.00	
4/15/10	OR	59.1	PH	Orleans	OC	0	0	0	NT	0.00	
4/15/10	HC	108.4	PH	Happy Camp	OC	0	0	0	NT	0.00	
4/15/10	SV	128.5	PH	Seiad Valley	OC	0	0	0	NT	0.00	
4/15/10	SD	128.5	PH	Seiad Valley Dup	OC	0	0	0	NT	0.00	
4/15/10	WA	157	PH	Walker Bridge	OC	0	0	0	NT	0.00	
5/12/10	SA	0	PH	Salmon River	OC	0	0	0	0.22	0.00	0.03
5/12/10	SC	0	PH	Scott River	OC	0	0	0	0.24	0.00	0.03
5/12/10	SH	0	PH	Shasta River	OC	0	0	0	0.17	0.00	0.02
5/12/10	OR	59.1	PH	Orleans	OC	0	0	0	0.27	0.00	0.03
5/12/10	HC	108.4	PH	Happy Camp	OC	0	0	0	0.17	0.00	0.02
5/12/10	SV	128.5	PH	Seiad Valley	OC	0	0	156	0.15	0.00	0.02
5/12/10	SD	128.5	PH	Seiad Valley Dup	OC	0	0	0	0.19	0.00	0.02
5/12/10	WA	157	PH	Walker Bridge	OC	0	0	0	0.28	0.00	0.04
5/26/10	SA	0	PH	Salmon River	OC				ND		0.00
5/26/10	SC	0	PH	Scott River	OC				ND		0.00

Date	Station Name	RM	Sample Event	Station Description	Depth	Microcystis aeruginosa (cells/ml)	Planktothrix (Oscillatoria) or Gloeotrichia echinulata (cells/ml)	Anabaena sp. (cells/ml)	Microcystin Total (µg/L)	Exceedance of SWRCB[1] risk level of 40,000 cells/ml Microcystis or Planktothrix (x greater than 4[5] cells/ml)	Exceedance of microcystin TDI of 0.04 µg/kg/day for a 20kg (44lb) child ingesting 100 mls[2] (x greater than TDI)
5/26/10	SH	0	PH	Shasta River	OC				ND		0.00
5/26/10	OR	59.1	PH	Orleans	OC				ND		0.00
5/26/10	SV	128.5	PH	Seiad Valley	OC				ND		0.00
5/26/10	WA	157	PH	Walker Bridge	OC				ND		0.00
5/26/10	IG	189.7	PH	Below Iron Gate	OC				ND		0.00
6/9/10	SA	0	PH	Salmon River	OC	0	0	0	ND	0.00	0.00
6/9/10	SC	0	PH	Scott River	OC	0	0	0	ND	0.00	0.00
6/9/10	SH	0	PH	Shasta River	OC	0	0	0	ND	0.00	0.00
6/9/10	OR	59.1	PH	Orleans	OC	0	0	0	ND	0.00	0.00
6/9/10	OR	59.1	PH	Orleans	SG	0	0	0	NT*	0.00	
6/9/10	HC	108.4	PH	Happy Camp	OC	0	0	0	ND	0.00	0.00
6/9/10	HC	108.4	PH	Happy Camp	SG	0	0	0	ND	0.00	0.00
6/9/10	SV	128.5	PH	Seiad Valley	OC	0	0	0	ND	0.00	0.00
6/9/10	SV	128.5	PH	Seiad Valley	SG	0	0	0	ND	0.00	0.00
6/9/10	SD	128.5	PH	Seiad Valley Dup	SG	0	0	0	ND	0.00	0.00
6/9/10	BB	150	PH	Brown Bear	SG	0	0	0	ND	0.00	0.00
6/9/10	WA	157	PH	Walker Bridge	OC	0	0	465	ND	0.00	0.00
6/9/10	IB	176	PH	IB (I5 Bridge)	SG	0	0	0	ND	0.00	
6/23/10	SA	0	PH	Salmon River	OC	0	0	0	NT	0.00	
6/23/10	SC	0	PH	Scott River	OC	0	0	0	NT	0.00	
6/23/10	SH	0	PH	Shasta River	OC	0	0	0	NT	0.00	
6/23/10	OR	59.1	PH	Orleans	OC	0	0	0	ND	0.00	0.00
6/23/10	OR	59.1	PH	Orleans	SG	0	0	0	NT*	0.00	
6/23/10	HC	108.4	PH	Happy Camp	SG	0	0	0	ND	0.00	0.00
6/23/10	SV	128.5	PH	Seiad Valley	OC	0	0	0	ND	0.00	0.00
6/23/10	SD	128.5	PH	Seiad Valley Dup	OC	0	53[P]	0	ND	0.00	0.00
6/23/10	SV	128.5	PH	Seiad Valley	SG	0	0	0	ND	0.00	0.00
6/23/10	BB	150	PH	Brown Bear	SG	0	0	0	ND	0.00	0.00
6/23/10	WA	157	PH	Walker Bridge	OC	0	0	0	ND	0.00	0.00
6/23/10	IB	176	PH	IB (I5 Bridge)	SG	0	0	74	NT*	0.00	

Date	Station Name	RM	Sample Event	Station Description	Depth	Microcystis aeruginosa (cells/ml)	Planktothrix (Oscillatoria) or Gloeotrichia echinulata (cells/ml)	Anabaena sp. (cells/ml)	Microcystin Total (µg/L)	Exceedance of SWRCB[1] risk level of 40,000 cells/ml Microcystis or Planktothrix (x greater than 4[5] cells/ml)	Exceedance of microcystin TDI of 0.04 µg/kg/day for a 20kg (44lb) child ingesting 100 mls[2] (x greater than TDI)
6/23/10	IG	189.7	PH	Below Iron Gate	OC	0	0	1,110	ND	0.00	0.00
7/8/2010	SA	0	PH	Salmon River	OC	0	0	0	NT	0.00	
7/8/2010	SC	0	PH	Scott River	OC	0	0	0	NT	0.00	
7/8/2010	SH	0	PH	Shasta River	OC	0	0	0	ND	0.00	0.00
7/8/2010	OR	59.1	PH	Orleans	OC	0	0	0	ND	0.00	0.00
7/8/2010	OR	59.1	PH	Orleans	SG	0	0	0	ND	0.00	0.00
7/8/2010	HC	108.4	PH	Happy Camp	OC	0	0	0	ND	0.00	0.00
7/8/2010	HC	108.4	PH	Happy Camp	SG	0	0	0	ND	0.00	0.00
7/8/2010	SV	128.5	PH	Seiad Valley	OC	0	0	0	ND	0.00	0.00
7/8/2010	SD	128.5	PH	Seiad Valley Dup	OC	0	0	0	ND	0.00	0.00
7/8/2010	SV	128.5	PH	Seiad Valley	SG	0	0	0	ND	0.00	0.00
7/8/2010	SD	128.5	PH	Seiad Valley Dup	SG	0	0	0	ND	0.00	0.00
7/8/2010	BB	150	PH	Brown Bear	SG	0	0	0	ND	0.00	0.00
7/8/2010	WA	157	PH	Walker Bridge	OC	0	0	136	0.15	0.00	0.02
7/8/2010	IB	176	PH	IB (I5 Bridge)	SG	0	0	59	ND	0.00	0.00
7/21/2010	SA	0	PH	Salmon River	OC	0	0	0	NT	0.00	
7/21/2010	SC	0	PH	Scott River	OC	0	0	0	NT	0.00	
7/21/2010	SH	0	PH	Shasta River	OC	0	0	4,004	0.16	0.00	0.02
7/21/2010	OR	59.1	PH	Orleans	OC	0	0	0	ND	0.00	0.00
7/21/2010	OR	59.1	PH	Orleans	SG	0	0	0	0.15	0.00	0.02
7/21/2010	HC	108.4	PH	Happy Camp	SG	0	0	0	0.15	0.00	0.02
7/21/2010	SV	128.5	PH	Seiad Valley	OC	0	0	0	0.16	0.00	0.02
7/21/2010	SV	128.5	PH	Seiad Valley	SG	0	0	0	0.15	0.00	0.02
7/21/2010	BB	150	PH	Brown Bear	SG	0	0	0	0.18	0.00	0.02
7/21/2010	WA	157	PH	Walker Bridge	OC	0	0	0	0.17	0.00	0.02
7/21/2010	IB	176	PH	IB (I5 Bridge)	SG	0	0	124	0.25	0.00	0.03
7/21/2010	IG	189.7	PH	Below Iron Gate	OC	0	0	0	0.28	0.00	0.04
8/4/2010	OR	59.1	PH	Orleans	SG	0	0	0	1.8	0.00	0.23
8/4/2010	HC	108.4	PH	Happy Camp	SG	0	0	0	ND	0.00	0.00
8/4/2010	SV	128.5	PH	Seiad Valley	SG	0	0	0	ND	0.00	0.00
8/4/2010	SD	128.5	PH	Seiad Valley Dup	SG	0	0	0	ND	0.00	0.00

Date	Station Name	RM	Sample Event	Station Description	Depth	Microcystis aeruginosa (cells/ml)	Planktothrix (Oscillatoria) or Gloeotrichia echinulata (cells/ml)	Anabaena sp. (cells/ml)	Microcystin Total (µg/L)	Exceedance of SWRCB[1] risk level of 40,000 cells/ml Microcystis or Planktothrix (x greater than 4[5] cells/ml)	Exceedance of microcystin TDI of 0.04 µg/kg/day for a 20kg (44lb) child ingesting 100 mls[2] (x greater than TDI)
8/4/2010	BB	150	PH	Brown Bear	SG	0	0	0	1.7	0.00	0.21
8/4/2010	IB	176	PH	IB (I5 Bridge)	SG	1,552	0	0	1.6	0.04	0.20
8/11/2010	SA	0	PH	Salmon River	OC	0	0	0	NT	0.00	
8/11/2010	SC	0	PH	Scott River	OC	0	0	0	NT	0.00	
8/11/2010	SH	0	PH	Shasta River	OC	0	0	0	ND	0.00	0.00
8/11/2010	OR	59.1	PH	Orleans	OC	0	0	59	ND	0.00	0.00
8/11/2010	OR	59.1	PH	Orleans	SG	0	0	0	ND	0.00	0.00
8/11/2010	HC	108.4	PH	Happy Camp	OC	0	0	0	1.6	0.00	0.20
8/11/2010	HC	108.4	PH	Happy Camp	SG	0	0	976	ND	0.00	0.00
8/11/2010	SV	128.5	PH	Seiad Valley	OC	0	0	0	ND	0.00	0.00
8/11/2010	SD	128.5	PH	Seiad Valley Dup	OC	0	0	0	ND	0.00	0.00
8/11/2010	SV	128.5	PH	Seiad Valley	SG	0	0	0	ND	0.00	0.00
8/11/2010	BB	150	PH	Brown Bear	SG	0	0	72	ND	0.00	0.00
8/11/2010	WA	157	PH	Walker Bridge	OC	0	99[P]	0	ND	0.00	0.00
8/11/2010	IB	176	PH	IB (I5 Bridge)	SG	928	0	0	ND	0.02	0.00
8/18/2010	OR	59.1	PH	Orleans	SG	0	0	0	0.15	0.00	0.02
8/18/2010	HC	108.4	PH	Happy Camp	SG	0	0	0	0.18	0.00	0.02
8/18/2010	SV	128.5	PH	Seiad Valley	SG	0	176 [P]	0	0.26	0.00	0.03
8/18/2010	BB	150	PH	Brown Bear	SG	455	364 [G]	0	0.18	0.02	0.02
8/18/2010	IB	176	PH	IB (I5 Bridge)	SG	362	0	0	1.1	0.01	0.14
8/18/2010	SD	176	PH	IB (I5 Bridge) Dup	SG	1,992	0	0	0.86	0.05	0.11
8/25/2010	SA	0	PH	Salmon River	OC	0	0	0	NT	0.00	
8/25/2010	SC	0	P	Scott River	OC	0	0	0	NT	0.00	
8/25/2010	SH	0	PH	Shasta River	OC	0	0	0	ND	0.00	0.00
8/25/2010	OR	59.1	PH	Orleans	OC	0	0	1,187	ND	0.00	0.00
8/25/2010	OR	59.1	PH	Orleans	SG	0	0	0	0.15	0.00	0.02
8/25/2010	HC	108.4	PH	Happy Camp	SG	9,139	198 [P]	0	1.5	0.23	0.19
8/25/2010	SV	128.5	PH	Seiad Valley	OC	18,690	0	2,438	2.9	0.47	0.36
8/25/2010	SV	128.5	PH	Seiad Valley	SG	19,559	0	0	2.4	0.49	0.30
8/25/2010	BB	150	PH	Brown Bear	SG	13,041	0	0	3.2	0.33	0.40

Date	Station Name	RM	Sample Event	Station Description	Depth	Microcystis aeruginosa (cells/ml)	Planktothrix (Oscillatoria) or Gloeotrichia echinulata (cells/ml)	Anabaena sp. (cells/ml)	Microcystin Total (µg/L)	Exceedance of SWRCB[1] risk level of 40,000 cells/ml Microcystis or Planktothrix (x greater than 4[5] cells/ml)	Exceedance of microcystin TDI of 0.04 µg/kg/day for a 20kg (44lb) child ingesting 100 mls[2] (x greater than TDI)
8/25/2010	WA	157	PH	Walker Bridge	OC	11,121	0	0	2.4	0.28	0.30
8/25/2010	IB	176	PH	IB (I5 Bridge)	SG	25,925	0	0	3.8	0.65	0.48
8/25/2010	IG	189.7	PH	Below Iron Gate	OC	17,044	0	0	4.2	0.43	0.53
8/30/2010	HC	108.4	PH	Happy Camp	SG	40,194	0	0	10	1.00	1.25
8/30/2010	BB	150	PH	Brown Bear	SG	24,138	0	0	6.9	0.60	0.86
9/1/2010	OR	59.1	PH	Orleans	SG	24,805	0	0	5.6	0.62	0.70
9/1/2010	HC	108.4	PH	Happy Camp	SG	34,888	0	0	10	0.87	1.25
9/1/2010	SV	128.5	PH	Seiad Valley	SG	31,075	0	0	12	0.78	1.50
9/1/2010	SD	128.5	PH	Seiad Valley Dup	SG	36,656	0	0	19	0.92	2.38
9/1/2010	BB	150	PH	Brown Bear	SG	33,427	0	0	7.9	0.84	0.99
9/1/2010	IB	176	PH	IB (I5 Bridge)	SG	42,893	0	0	10	1.07	1.25
9/8/2010	SA	0	PH	Salmon River	OC	0	0	0	NT	0.00	
9/8/2010	SC	0	PH	Scott River	OC	0	0	0	NT	0.00	
9/8/2010	SH	0	PH	Shasta River	OC	0	0	0	0.17	0.00	0.02
9/8/2010	OR	59.1	PH	Orleans	OC	19,973	0	0	9.6	0.50	1.20
9/8/2010	OR	59.1	PH	Orleans	SG	35,243	0	0	8.8	0.88	1.10
9/8/2010	HC	108.4	PH	Happy Camp	OC	32,249	0	0	8.3	0.81	1.04
9/8/2010	HC	108.4	PH	Happy Camp	SG	33,162	0	0	7.4	0.83	0.93
9/8/2010	SV	128.5	PH	Seiad Valley	OC	41,718	0	0	7.4	1.04	0.93
9/8/2010	SV	128.5	PH	Seiad Valley	SG	31,819	0	0	5.7	0.80	0.71
9/8/2010	BB	150	PH	Brown Bear	SG	37,550	0	0	9.3	0.94	1.16
9/8/2010	WA	157	PH	Walker Bridge	OC	38,522	0	0	6.6	0.96	0.83
9/8/2010	IB	176	PH	IB (I5 Bridge)	SG	56,329	0	0	11	1.41	1.38
9/15/2010	OR	59.1	PH	Orleans	SG	37,447	0	0	9.1	0.94	1.14
9/15/2010	HC	108.4	PH	Happy Camp	SG	56,202	0	0	12	1.41	1.50
9/15/2010	SV	128.5	PH	Seiad Valley	SG	37,503	0	0	11	0.94	1.38
9/15/2010	SD	128.5	PH	Seiad Valley Dup	SG	66,447	0	0	8.9	1.66	1.11
9/15/2010	BB	150	PH	Brown Bear	SG	295,272	0	0	85	7.38	10.63
9/15/2010	IB	176	PH	IB (I5 Bridge)	SG	140,812	0	0	26	3.52	3.25
9/22/2010	SA	0	PH	Salmon River	OC	0	0	0	NT	0.00	

Date	Station Name	RM	Sample Event	Station Description	Depth	Microcystis aeruginosa (cells/ml)	Planktothrix (Oscillatoria) or Gloeotrichia echinulata (cells/ml)	Anabaena sp. (cells/ml)	Microcystin Total (µg/L)	Exceedance of SWRCB[1] risk level of 40,000 cells/ml Microcystis or Planktothrix (x greater than 4[5] cells/ml)	Exceedance of microcystin TDI of 0.04 µg/kg/day for a 20kg (44lb) child ingesting 100 mls[2] (x greater than TDI)
9/22/2010	SC	0	PH	Scott River	OC	0	0	0	NT	0.00	
9/22/2010	SH	0	PH	Shasta River	OC	0	0	0	ND	0.00	0.00
9/22/2010	OR	59.1	PH	Orleans	OC	16,014	0	0	4.8	0.40	0.60
9/22/2010	OR	59.1	PH	Orleans	SG	30,724	0	0	4.5	0.77	0.56
9/22/2010	HC	108.4	PH	Happy Camp	SG	8,693	0	0	2.5	0.22	0.31
9/22/2010	SV	128.5	PH	Seiad Valley	OC	25,771	0	0	5.1	0.64	0.64
9/22/2010	SV	128.5	PH	Seiad Valley	SG	39,780	0	0	4.2	0.99	0.53
9/22/2010	SD	128.5	PH	Seiad Valley Dup	OC	31,707	0	0	4.5	0.79	0.56
9/22/2010	BB	150	PH	Brown Bear	SG	45,444	0	0	7.5	1.14	0.94
9/22/2010	WA	157	PH	Walker Bridge	OC	57,763	354[P]	0	5.8	1.45	0.73
9/22/2010	IB	176	PH	IB (I5 Bridge)	SG	21,404	0	0	6.5	0.54	0.81
9/22/2010	IG	189.7	PH	Below Iron Gate	OC	51,225	0	0	6.2	1.28	0.78
9/29/2010	OR	59.1	PH	Orleans	SG	34,850	0	0	12	0.87	1.50
9/29/2010	HC	108.4	PH	Happy Camp	SG	35,078	0	0	14	0.88	1.75
9/29/2010	SV	128.5	PH	Seiad Valley	SG	15,481	0	0	8.6	0.39	1.08
9/29/2010	SD	128.5	PH	Seiad Valley Dup	SG	17,476	0	0	9.4	0.44	1.18
9/29/2010	BB	150	PH	Brown Bear	SG	19,336	0	0	22	0.48	2.75
9/29/2010	IB	176	PH	IB (I5 Bridge)	SG	36,640	0	0	15	0.92	1.88
10/6/2010	SA	0	PH	Salmon River	OC	0	0	0	NT	0.00	
10/6/2010	SC	0	PH	Scott River	OC	0	0	0	NT	0.00	
10/6/2010	OR	59.1	PH	Orleans	OC	10,895	0	0	5.4	0.27	0.68
10/6/2010	OR	59.1	PH	Orleans	SG	16,097	0	0	6	0.40	0.75
10/6/2010	HC	108.4	PH	Happy Camp	OC	20,080	0	0	3.9	0.50	0.49
10/6/2010	HC	108.4	PH	Happy Camp	SG	12,869	0	0	4.2	0.32	0.53
10/6/2010	SV	128.5	PH	Seiad Valley	OC	41,592	0	0	15	1.04	1.88
10/6/2010	SV	128.5	PH	Seiad Valley	SG	56,359	0	0	12	1.41	1.50
10/6/2010	SD	128.5	PH	Seiad Valley Dup	OC	37,208	0	0	8.2	0.93	1.03
10/6/2010	BB	150	PH	Brown Bear	SG	46,808	0	0	17	1.17	2.13
10/6/2010	WA	157	PH	Walker Bridge	OC	39,087	0	0	16	0.98	2.00
10/6/2010	IB	176	PH	IB (I5 Bridge)	SG	78,339	0	0	25	1.96	3.13

Date	Station Name	RM	Sample Event	Station Description	Depth	Microcystis aeruginosa (cells/ml)	Planktothrix (Oscillatoria) or Gloeotrichia echinulata (cells/ml)	Anabaena sp. (cells/ml)	Microcystin Total (µg/L)	Exceedance of SWRCB[1] risk level of 40,000 cells/ml Microcystis or Planktothrix (x greater than 4[5] cells/ml)	Exceedance of microcystin TDI of 0.04 µg/kg/day for a 20kg (44lb) child ingesting 100 mls[2] (x greater than TDI)
10/20/2010	SA	0	PH	Salmon River	OC	0	0	0	NT	0	
10/20/2010	SC	0	PH	Scott River	OC	0	0	0	NT	0	
10/20/2010	SH	0	PH	Shasta River	OC	0	0	0	ND	0	
10/20/2010	OR	59.1	PH	Orleans	OC	8,829	0	0	11	0.22	1.38
10/20/2010	OR	59.1	PH	Orleans	SG	70,832	0	0	12	1.77	1.50
10/20/2010	HC	108.4	PH	Happy Camp	SG	14,451	0	0	5.6	0.36	0.70
10/20/2010	SV	128.5	PH	Seiad Valley	OC	11,336	0	0	5.9	0.28	0.74
10/20/2010	SV	128.5	PH	Seiad Valley	SG	12,748	0	0	5.4	0.32	0.68
10/20/2010	SD	128.5	PH	Seiad Valley Dup	SG	22,566	0	0	5.4	0.56	0.68
10/20/2010	BB	150	PH	Brown Bear	SG	12,027	0	0	11	0.30	1.38
10/20/2010	WA	157	PH	Walker Bridge	OC	27,103	0	0	8.7	0.68	1.09
10/20/2010	IB	176	PH	IB (I5 Bridge)	SG	19,819	0	0	13	0.50	1.63
10/20/2010	IG	189.7	PH	Below Iron Gate	OC	1,504	0	0	11	0.04	1.38
11/17/2010	SA	0	PH	Salmon River	OC	0	0	0	NT	0.00	
11/17/2010	SC	0	PH	Scott River	OC	0	0	0	NT	0.00	
11/17/2010	SH	0	PH	Shasta River	OC	0	0	0	NT	0.00	
11/17/2010	OR	59.1	PH	Orleans	OC	0	0	0	ND	0.00	
11/17/2010	HC	108.4	PH	Happy Camp	OC	0	0	0	ND	0.00	
11/17/2010	SV	128.5	PH	Seiad Valley	OC	0	0	0	ND	0.00	
11/17/2010	SD	128.5	PH	Seiad Valley Dup	OC	0	0	0	NT	0.00	
11/17/2010	WA	157	PH	Walker Bridge	OC	0	0	0	ND	0.00	
12/15/2010	SA	0	PH	Salmon River	OC	0	0	0	NT	0.00	
12/15/2010	SC	0	PH	Scott River	OC	0	0	0	NT	0.00	
12/15/2010	SH	0	PH	Shasta River	OC	0	0	0	NT	0.00	
12/15/2010	OR	59.1	PH	Orleans	OC	0	0	0	NT	0.00	
12/15/2010	HC	108.4	PH	Happy Camp	OC	0	0	0	NT	0.00	
12/15/2010	SV	128.5	PH	Seiad Valley	OC	0	0	0	NT	0.00	
12/15/2010	SD	128.5	PH	Seiad Valley Dup	OC	0	0	0	NT	0.00	
12/15/2010	WA	157	PH	Walker Bridge	OC	0	0	0	NT	0.00	

NT= not tested NT*= not tested-samples were received broken or empty ND= non detect
[P]= Planktothrix [G]=Gloeotrichia

APPENDIX II: Cell Density and cyanotoxin concentration for Copco and Iron Gate Reservoirs and KRBI-SG provided by PacifiCorp, 2010.

Date	Station Name	Station Description	Depth	Microcystis aeruginosa (cells/ml)	Anabaena sp. (cells/ml)	Microcystin Total (µg/L)	Exceedance of SWRCB[1] risk level of 40,000 cells/ml Microcystis or Planktothrix (x greater than 4[5] cells/ml)	Exceedance of microcystin TDI of 0.04 µg/kg/day for a 20kg (44lb) child ingesting 100 mls[2] (x greater than TDI)
5/27/2010	CRCC	Copco Reservoir at Copco Cove ramp	SG	0	124		0.00	0.00
5/27/2010	CRMC	Copco Reservoir at Mallard Cove ramp	SG	0	0		0.00	0.00
5/27/2010	IRCC	Iron Gate Reservoir at Camp Creek ramp	SG	0	0		0.00	0.00
5/27/2010	IRJW	Iron Gate Reservoir at Williams campground	SG	0	0		0.00	0.00
5/27/2010	KRBI	Klamath River below Iron Gate dam near hatchery bridge	SG	0	0		0.00	0.00
6/7/2010	CRCC	Copco Reservoir at Copco Cove ramp	SG	0	70	0.47	0.00	0.06
6/7/2010	CRMC	Copco Reservoir at Mallard Cove ramp	SG	0	0	0.25	0.00	0.03
6/7/2010	IRCC	Iron Gate Reservoir at Camp Creek ramp	SG	0	0	0.00	0.00	0.00
6/7/2010	IRJW	Iron Gate Reservoir at Williams campground	SG	0	0	0.00	0.00	0.00
6/7/2010	KRBI	Klamath River below Iron Gate dam near hatchery bridge	SG	0	0	0.26	0.00	0.03
6/21/2010	CRCC	Copco Reservoir at Copco Cove ramp	SG	0	110,582	0.46	0.00	0.06
6/21/2010	CRMC	Copco Reservoir at Mallard Cove ramp	SG	0	54,809	0.44	0.00	0.06
6/21/2010	IRCC	Iron Gate Reservoir at Camp Creek ramp	SG	0	1,611	0.21	0.00	0.03
6/21/2010	IRJW	Iron Gate Reservoir at Williams campground	SG	0	6,305	0.16	0.00	0.02
6/21/2010	KRBI	Klamath River below Iron Gate dam near hatchery bridge	SG	0	164		0.00	0.00
7/6/2010	CRCC	Copco Reservoir at Copco Cove ramp	SG	0	568	0.00	0.00	0.00
7/6/2010	CRMC	Copco Reservoir at Mallard Cove ramp	SG	0	111	0.00	0.00	0.00
7/6/2010	IRCC	Iron Gate Reservoir at Camp Creek ramp	SG	0	9,849	0.00	0.00	0.00
7/6/2010	IRJW	Iron Gate Reservoir at Williams campground	SG	0	8,187	0.00	0.00	0.00
7/6/2010	KRBI	Klamath River below Iron Gate dam near hatchery bridge	SG	256	3,494	0.00	0.01	0.00
7/6/2010	KRBI (dup)	Klamath River below Iron Gate dam near hatchery bridge	SG	227	2,487	0.00	0.01	0.00
7/19/2010	CRCC	Copco Reservoir at Copco Cove ramp	SG	160	1,359	0.51	0.00	0.06
7/19/2010	CRMC	Copco Reservoir at Mallard Cove ramp	SG	2,260	504	1.00	0.06	0.13
7/19/2010	IRCC	Iron Gate Reservoir at Camp Creek ramp	SG	4,411	22,364	1.70	0.11	0.21

Date	Station Name	Station Description	Depth	Microcystis aeruginosa (cells/ml)	Anabaena sp. (cells/ml)	Microcystin Total (µg/L)	Exceedance of SWRCB[1] risk level of 40,000 cells/ml Microcystis or Planktothrix (x greater than 4^5 cells/ml)	Exceedance of microcystin TDI of 0.04 µg/kg/day for a 20kg (44lb) child ingesting 100 mls[2] (x greater than TDI)
7/19/2010	IRJW	Iron Gate Reservoir at Williams campground	SG	0	620	0.50	0.00	0.06
7/19/2010	KRBI	Klamath River below Iron Gate dam near hatchery bridge	SG	0	0	0.25	0.00	0.03
8/2/2010	CRCC	Copco Reservoir at Copco Cove ramp	SG	321,713	151,536	200.00	8.04	25.00
8/2/2010	CRMC	Copco Reservoir at Mallard Cove ramp	SG	2,346	719	0.68	0.06	0.09
8/2/2010	IRCC	Iron Gate Reservoir at Camp Creek ramp	SG	26,187	4,001	4.70	0.65	0.59
8/2/2010	IRJW	Iron Gate Reservoir at Williams campground	SG	834,609	193,878	280.00	20.87	35.00
8/2/2010	KRBI	Klamath River below Iron Gate dam near hatchery bridge	SG	0	0	0.82	0.00	0.10
8/2/2010	KRBI (dup)	Klamath River below Iron Gate dam near hatchery bridge	SG	0	602	0.97	0.00	0.12
8/9/2010	KRBI	Klamath River below Iron Gate dam near hatchery bridge	SG	465	51	1.30	0.01	0.16
8/16/2010	CRCC	Copco Reservoir at Copco Cove ramp	SG	80,178	0	28.00	2.00	3.50
8/16/2010	CRMC	Copco Reservoir at Mallard Cove ramp	SG	7,779,750	239,030	1,500.00	194.49	187.50
8/16/2010	IRCC	Iron Gate Reservoir at Camp Creek ramp	SG	90,200	727	21.00	2.26	2.63
8/16/2010	IRJW	Iron Gate Reservoir at Williams campground	SG	32,214	1,174	4.00	0.81	0.50
8/16/2010	KRBI	Klamath River below Iron Gate dam near hatchery bridge	SG	4,997	171	0.00	0.12	0.00
8/16/2010	KRBI (dup)	Klamath River below Iron Gate dam near hatchery bridge	SG	9,120	200	1.90	0.23	0.24
8/23/2010	KRBI	Klamath River below Iron Gate dam near hatchery bridge	SG	37,511	0	7.00	0.94	0.88
8/30/2010	CRCC	Copco Reservoir at Copco Cove ramp	SG	551,863	0	230.00	13.80	28.75
8/30/2010	CRMC	Copco Reservoir at Mallard Cove ramp	SG	1,471,223	0	670.00	36.78	83.75
8/30/2010	IRCC	Iron Gate Reservoir at Camp Creek ramp	SG	37,554	0	12.00	0.94	1.50
8/30/2010	IRJW	Iron Gate Reservoir at Williams campground	SG	5,280,000	0	2,300.00	132.00	287.50
8/30/2010	KRBI	Klamath River below Iron Gate dam near hatchery bridge	SG	33,436	0	8.40	0.84	1.05
8/30/2010	KRBI (dup)	Klamath River below Iron Gate dam near hatchery bridge	SG	18,743	0	12.00	0.47	1.50
9/7/2010	KRBI	Klamath River below Iron Gate dam near hatchery bridge	SG	55,967	0	8.20	1.40	1.03
9/13/2010	CRCC	Copco Reservoir at Copco Cove ramp	SG	12,702,077	0	7,200.00	317.55	900.00
9/13/2010	CRMC	Copco Reservoir at Mallard Cove ramp	SG	2,976,600	0	2,100.00	74.42	262.50
9/13/2010	IRCC	Iron Gate Reservoir at Camp Creek ramp	SG	112,750	0	24.00	2.82	3.00
9/13/2010	IRJW	Iron Gate Reservoir at Williams campground	SG	334,116	0	120.00	8.35	15.00
9/13/2010	KRBI	Klamath River below Iron Gate dam near hatchery bridge	SG	64,474	0	23.00	1.61	2.88
9/13/2010	KRBI (dup)	Klamath River below Iron Gate dam near hatchery bridge	SG	98,695	0	25.00	2.47	3.13

Date	Station Name	Station Description	Depth	Microcystis aeruginosa (cells/ml)	Anabaena sp. (cells/ml)	Microcystin Total (µg/L)	Exceedance of SWRCB[1] risk level of 40,000 cells/ml Microcystis or Planktothrix (x greater than 4[5] cells/ml)	Exceedance of microcystin TDI of 0.04 µg/kg/day for a 20kg (44lb) child ingesting 100 mls[2] (x greater than TDI)
9/20/2010	KRBI	Klamath River below Iron Gate dam near hatchery bridge	SG	58,139	0	13.00	1.45	1.63
9/27/2010	CRCC	Copco Reservoir at Copco Cove ramp	SG	7,206,796	0	5,400.00	180.17	675.00
9/27/2010	CRMC	Copco Reservoir at Mallard Cove ramp	SG	4,025,614	0	2,300.00	100.64	287.50
9/27/2010	IRCC	Iron Gate Reservoir at Camp Creek ramp	SG	53,358	0	11.00	1.33	1.38
9/27/2010	IRJW	Iron Gate Reservoir at Williams campground	SG	1,329,220	0	420.00	33.23	52.50
9/27/2010	KRBI	Klamath River below Iron Gate dam near hatchery bridge	SG	55,865	0	16.00	1.40	2.00
9/27/2010	KRBI (dup)	Klamath River below Iron Gate dam near hatchery bridge	SG	58,533	0	16.00	1.46	2.00
10/6/2010	CRCC	Copco Reservoir at Copco Cove ramp	SG	40,214	562	21.00	1.01	2.63
10/6/2010	CRMC	Copco Reservoir at Mallard Cove ramp	SG	3,157,000	0	5,700.00	78.93	712.50
10/6/2010	IRCC	Iron Gate Reservoir at Camp Creek ramp	SG	128,905	370	55.00	3.22	6.88
10/6/2010	IRJW	Iron Gate Reservoir at Williams campground	SG	966,156	1,397	570.00	24.15	71.25
10/6/2010	KRBI	Klamath River below Iron Gate dam near hatchery bridge	SG	137,806	491	23.00	3.45	2.88
10/6/2010	KRBI (dup)	Klamath River below Iron Gate dam near hatchery bridge	SG	67,716	614	21.00	1.69	2.63
10/18/2010	CRCC	Copco Reservoir at Copco Cove ramp	SG	745,130	13,236	790.00	18.63	98.75
10/18/2010	CRMC	Copco Reservoir at Mallard Cove ramp	SG	2,386,137	0		59.65	0.00
10/18/2010	IRCC	Iron Gate Reservoir at Camp Creek ramp	SG	5,022,838	0	3,700.00	125.57	462.50
10/18/2010	IRJW	Iron Gate Reservoir at Williams campground	SG	172,883	0	26.00	4.32	3.25
10/18/2010	KRBI	Klamath River below Iron Gate dam near hatchery bridge	SG	55,487	0		1.39	0.00
10/18/2010	KRBI (dup)	Klamath River below Iron Gate dam near hatchery bridge	SG	40,256	0		1.01	0.00

Page intentionally left blank