

1 **Does allochthonous dissolved organic matter increase during**
2 **summer algal bloom conditions in an agricultural reservoir?**

3 Kyra M. Florea, Ruchi Bhattacharya, and Rebecca L. North

4 School of Natural Resources, University of Missouri, Columbia, MO 65201

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30 **Abstract**

31 Cyanobacterial harmful algal blooms (cyanoHABs) are increasing in frequency
32 worldwide. CyanoHABs can produce toxins (e.g., microcystin), which can be a contaminant in
33 recreational and drinking water reservoirs. Reservoirs have been increasing worldwide,
34 highlighting the importance of understanding their biogeochemical processes. Dissolved organic
35 matter (DOM) is a reactive and readily available source of nitrogen (N) and carbon (C) for
36 microbes in aquatic systems, however, the relationships between DOM and cyanoHABs remain
37 relatively unexplored in agricultural reservoirs. Our primary objective is to determine if an
38 increase in allochthonous DOM leads to an increase in autochthonous DOM during a summer
39 cyanobacterial bloom event in a warm monomictic agricultural reservoir. Water samples were
40 collected two to three times per week from June 21st until October 5th, 2018 and analyzed for
41 algal biomass and community composition, DOM quality and quantity. A variety of spectral
42 parameters were used to determine DOM quality. One cyanobacterial bloom event was detected
43 on July 16th. Maximum microcystin concentration for the sampling period was 0.68 μgL^{-1} which
44 is well under the EPA recommended recreational limit (8 μgL^{-1}). Dissolved organic carbon
45 (DOC) concentrations were positively correlated with high amounts of terrestrial DOM. DOC
46 concentrations and a_{350} also correlated positively with microcystin concentrations. Specific UV
47 absorbance at 254nm (SUVA₂₅₄) correlated positively with Chl-*a* ($r=0.37$, $p=0.033$). Our
48 findings indicate that high DOM quantity has a significant relationship to microcystin
49 concentration, which has negative implications for recreation and drinking water quality.

50 **Introduction**

51 Over the past several decades, cyanobacterial harmful algal blooms (cyanoHABs) have
52 been increasing in frequency worldwide (Huisman et al. 2018). Reservoirs are a primary
53 drinking water and recreation source which can be contaminated by cyanobacteria and lead to the
54 deaths of fish, birds, and even mammals (Chen et al. 2016). As such, it is important that we fully
55 understand the biogeochemical processes that may lead to the formation of toxin producing
56 cyanoHABs.

57 Dissolved organic matter (DOM) is a reactive, readily available source of carbon (C) and
58 nitrogen (N) for microbes in aquatic systems (Jaffé et al. 2008). Excessive nutrient inputs can
59 lead to eutrophication in aquatic systems (Jones and Bachmann 1975). Previous studies have
60 shown a relationship between nutrients such as phosphorus (P) and N and the formation of algal
61 blooms (Jones et al., 2004; Paerl et al. 2011; Xu et al. 2015). Although there is extensive
62 literature about the effects of N and P on algal blooms (Levine and Schindler 1998; Smith et al.
63 2006; Jankowiak et al. 2019,), the impacts of dissolved organic matter (DOM) cycling and its
64 relationship to cyanoHABs and toxin concentrations in reservoirs remains relatively unexplored.
65 High concentrations of DOM can lead to serious water quality issues including the formation of
66 algal blooms and fish kills as a result of low oxygen concentrations (Creed et al. 2018). DOM
67 may also be contributing to a shift in phytoplankton communities that favors potentially toxin
68 producing cyanobacteria (Creed et al. 2018), though more research is needed to establish the
69 relationship. Current knowledge about DOM and C cycling comes largely from studies in coastal
70 and marine systems (Zhao et al. 2009, Osburn and Stedmon 2011, Dixon et al. 2014). Those
71 conducted in freshwater have focused on natural systems such as large rivers and natural lakes
72 (Green and Blough 1994, Cole et al. 2007). It is important to understand inland reservoir

73 biogeochemistry and C cycling, as reservoirs contribute significantly to the global C cycle
74 (Downing et al. 2006) and have been increasing in number globally (Zarfl et al., 2014).

75 Small reservoirs have been identified as important sites for C burial (Cole et al. 2007) and
76 efflux (Jones et al. 2016, Pittman et al. 2013); however, DOM cycling has not been thoroughly
77 investigated in small agricultural reservoirs in regards to cyanotoxin concentrations. The water
78 quality implications of DOM have been studied in a small subtropical reservoir (Liu et al. 2014);
79 however, possible links with algal blooms, and more specifically with algal toxins, have not been
80 thoroughly explored in small, agricultural reservoirs. Small farm reservoirs make up a significant
81 portion of freshwater water bodies in the United States (Downing et al. 2006). Agricultural
82 reservoirs are particularly vulnerable to eutrophication and cyanobacterial blooms (Downing et
83 al. 1999, Wang et al. 2005). The state of Missouri, USA alone has over 190,000 reported small
84 farm ponds (Smith et al. 2002). Missouri waterbodies are primarily man-made reservoirs and
85 63% of Missouri land use is classified as agricultural (Jones and Knowlton, 1993) which
86 highlights the importance of understanding the biogeochemistry of these systems.

87 Previous research has established a positive relationship between high amounts of
88 precipitation events and frequent bloom formation. This is largely due to the influx of nutrients
89 (N and P) into water bodies during a rain event (Michalak et al., 2013). There is also a positive
90 relationship between high amounts of terrestrial DOM and high amounts of precipitation Dixon
91 et al., 2014). This research highlights the importance of understanding how rainfall may be
92 affecting DOM influx into reservoirs.

93 The optical properties of DOM have been found to be useful in identifying DOM quality
94 (Helms et al., 2008). Our study uses a range of spectrophotometric parameters to determine the
95 source and reactivity of DOM in an agricultural reservoir. Our primary objective is to determine

96 if an increase in allochthonous DOM leads to an increase in autochthonous DOM during a
97 summer cyanobacterial bloom event in a warm monomictic agricultural reservoir. Therefore, we
98 also examine precipitation patterns during the sampling period to determine if changes in DOM
99 are also impacted by precipitation in small agricultural systems.

100 **Methodology**

101 *Study Site*

102 An observational study was conducted on Dairy Farm Lake #1, a reservoir in Boone
103 County, Missouri, USA (38°99'38"N, 92°48'90"S). Dairy Farm Lake is located on the University
104 of Missouri Experimental Foremost Dairy Farm and is in an agricultural watershed co-managed
105 by the University of Missouri and the Missouri Department of Conservation (MDC). MDC
106 manages the fish populations and the lake is open to the public for recreational fishing. Dairy
107 Farm Lake has a surface area of 56,160 m² (~15 acres) and a total water volume of 123,920 m³.
108 The 639,997 m² watershed is 62.94% crop land and 31.85% pasture. The mean depth for Dairy
109 Farm Lake is 2.21 m with a maximum of 4.62 m. All water samples were collected in front of the
110 earthen dam at a depth of 4.3 m.

111 Dairy Farm Lake has been monitored annually by the University of Missouri Limnology
112 Laboratory as part of the Statewide Lake Assessment Program since 2006, excluding 2015.
113 Annual monitoring includes analysis of Total Phosphorus (TP), Total Nitrogen (TN), Total
114 Suspended Solids (TSS), and Chlorophyll-*a* (Chl-*a*) concentrations (Table 1; Eaton et al. 1995).
115 TP and TN are measured using a digestion and spectrophotometric method (APHA 4500-P E;
116 Crumpton et al. 1992). Dairy Farm lake is hypereutrophic, based on nutrient criteria of Chl-*a* >40

117 μgL^{-1} , $\text{TP}>100 \mu\text{g L}^{-1}$, and $\text{TN}>1200 \text{ mg L}^{-1}$ (Jones et al 1993). The average historical Chl-*a*
118 concentration for Dairy Farm Lake from 2006-2017 is $106.6 \mu\text{gL}^{-1}$ ($9.2\text{--}772.6 \mu\text{gL}^{-1}$; Table 1).

119 *Sampling*

120 Samples were collected three times per week from June 21st until October 5th, 2018.
121 Temperature profiles were measured each sampling day using a YSI EXO 3 temperature probe.
122 Profiles were examined in the field to determine the depth of the thermocline. Mixing depth was
123 later calculated using the Lake Analyzer package in R (Winslow et al., 2018); the lake was
124 stratified for the duration of the sampling season. Photosynthetically Active Radiation (PAR)
125 was measured using a Li-Cor LI-1500 cosine sensor in quarter meter increments at the water
126 collection site. The light attenuation coefficient (K_d) was later calculated as described in Kirk
127 (1994). Secchi disk depth and water level changes were also measured each sampling day. A
128 meter stick was placed in the water next to the dam and changes were monitored each sampling
129 day. Precipitation data was collected from the Sanborn Field Weather Station located in
130 Columbia, MO, USA.

131 Samples for analysis of DOM, DOC, and Chl-*a* were collected from both the epilimnion
132 and hypolimnion in 2L polycarbonate bottles. Bottles were previously acid washed and triple
133 rinsed with lake water at the sample site before sample collection. Epilimnetic samples were
134 collected using an integrated sampler from the surface to 0.5 m depth. Discrete hypolimnetic
135 samples were taken one meter off the bottom of the reservoir (~ 3 m from surface) using a Van
136 Dorn sampler. Whole water samples were stored away from light and taken back to the lab for
137 processing on the same day. Water samples to be used for cyanotoxin analysis were collected in
138 polyethylene terephthalate glycol (PETG) bottles to prevent contamination (Kamp et al. 2016).

139 *Chlorophyll-a, phytoplankton community composition and biovolumes, and cyanotoxin analyses*

140 Three freeze-thaw cycles were conducted on the toxin samples. Algal toxin samples were
141 filtered through 0.45µm filters and concentrations were then analyzed using Abraxis® ELISA
142 kits with a detection limit of 0.15 µgL⁻¹ and an ELISA Microplate Reader (Carmichael and An,
143 1999). Phytoplankton samples were collected from the epilimnion and preserved with Lugols
144 solution. Chlorophyll-*a* (Chl-*a*) concentrations were measured as a proxy for algal biomass. The
145 seasonal mean for Dairy Farm Lake is based on annual samples collected four times per summer
146 from 2006 to 2018 as part of the Statewide Lake Assessment program. Whole water samples
147 were filtered through 0.7 µm GF/F filters. Chl-*a* concentration was determined via extraction
148 with ethanol and fluorometry using a Turner Designs TD-700 Fluorometer and was corrected for
149 pheophytin (Phe-*a*; Knowlton and Jones 1995).

150 *Dissolved organic carbon*

151 Whole-water samples from both the epilimnion and hypolimnion were filtered through
152 pre-combusted 0.7 µm GF/F filters. The filtrate was used for DOM analysis and absorbance
153 spectroscopy. To determine DOM quantity, we measured dissolved organic carbon concentration
154 (DOC). Prior to analysis, water samples were acidified (pH < 3) with 1 M H₂SO₄ to convert
155 inorganic carbon to CO₂ gas. DOC was measured using a high temperature combustion method
156 (APHA 5310 B) on a Shimadzu TOC-V_{CPH}; detection limit 0.2 mgL⁻¹. Samples were air sparged
157 for 7.5 minutes to remove the inorganic carbon. Each sample was measured in two pre-
158 combusted vials, and each of the two vials were measured twice (quadruplicate). Reported DOC
159 concentrations are the average of these four measurements. If the coefficient of variance (CV) of
160 the four measurements was greater than 5, the sample was re-analyzed.

161 *DOM absorbance spectra*

162 An indicator of DOM quantity (a_{350}) was also determined using UV absorbance
163 spectroscopy on an Agilent Cary 60 UV-Vis spectrophotometer. Each sample was scanned from
164 200 to 800 nm in a 1 cm quartz cuvette. All samples were blank corrected by subtracting the
165 absorbance of UltraPure DI water. Absorption was converted to Napierian absorption coefficient
166 with the equation $a_{\lambda} = 2.303A_{\lambda} L^{-1}$ (Osburn and Stedmon, 2011), where a is the absorption
167 coefficient, A is measured absorbance at wavelength λ , and L is the pathlength of the cuvette in
168 meters.

169 DOM quality (i.e., source and reactivity) was also determined using UV absorbance
170 spectroscopy. Specific UV Absorbance (SUVA), normalized for DOC concentration, was
171 calculated at 254nm ($a_{254}/[\text{DOC}]$). SUVA_{254} provides an indication of molecular weight and
172 aromaticity (Weishaar et al. 2003). Higher SUVA_{254} values are associated with aromatic and
173 allochthonous terrestrially derived DOM (Dixon et al. 2014). The spectral slope ratio was used to
174 characterize both molecular weight and DOM source. Slope ratio (S_R) was calculated as the ratio
175 of the slopes from wavelengths 275–295 to 350–400 nm ($S_{275-295}/S_{350-400}$ where S is the slope of
176 the absorbance fitted to a single exponential decay function via non-linear regression; Helms et
177 al. 2008). S_R values greater than one are indicative of autochthonous organic matter with a low
178 molecular weight, while S_R values less than one indicate allochthonous organic matter with a
179 high molecular weight (Helms et al. 2008). A definition of all measured parameters can be found
180 in Table 2.

181 *Statistics and Data Analysis*

182 Prior to conducting parametric statistics, the data were confirmed to be normal using a
183 Shapiro-Wilk Test ($p > 0.05$; Base R). All parameters were analyzed for differences between the
184 epilimnion and hypolimnion using a one-way analysis of variance test (ANOVA; multcomp)

185 with the data aggregated into weekly groups. ANOVA was also used to determine differences in
186 each parameter between weeks. Correlation coefficients were calculated using the Pearson
187 method (Hmisc). Correlations were determined to be significant at $p < 0.05$.

188 **Results**

189 *Limnological variables and precipitation*

190 The reservoir was stratified for the duration of the sampling period (June 21st to October
191 5th) with an average mixing depth of 2.21 m (range 1.0–4.2). Mean Secchi disk depth for the
192 sampling period was 0.4 m (range 0.3–0.7). The water level did not change during the sampling
193 period as it was a relatively dry season with two significant precipitation events that preceded the
194 detected algal blooms. There was 8.4 mm of rainfall two days before the first bloom occurred on
195 July 16th. Similarly, there was 11.9 mm of rainfall four days before the second bloom on
196 September 12th.

197 There were significant differences between the epilimnion and hypolimnion for all
198 measured parameters excluding microcystin. The mean Chl-*a* for the epilimnion during the
199 sampling season was 87.0 $\mu\text{g Chl-}a \text{ L}^{-1}$ (Table 3). Mean dissolved organic carbon (DOC)
200 concentration in the epilimnion was 9.7 mg C L^{-1} with a maximum of 10.9 mg C L^{-1} and a
201 minimum of 8.8 mg C L^{-1} . DOC concentration in the hypolimnion was significantly lower than
202 that of the epilimnion (Table 4) with a mean 9.4 mg C L^{-1} , a maximum of 10.9 mg C L^{-1} and a
203 minimum was 8.4 mg C L^{-1} .

204 *Cyanobacterial bloom detection*

205 We define a bloom as any deviation from established seasonal Chl-*a* means for the
206 system (Carstensen and Henriksen 2007). The seasonal Chl-*a* mean for Dairy Farm Lake was

207 106.6 $\mu\text{g Chl-}a \text{ L}^{-1}$ (Table 1). We captured two bloom events during our sampling period which
208 had significantly higher concentrations of Chl-*a* than the seasonal mean (Figure 1). The first
209 occurred on July 16th, with a peak Chl-*a* value of 162.5 $\mu\text{g Chl-}a \text{ L}^{-1}$. This bloom was dominated
210 by cyanobacteria (counts; Figure 2) and had a peak microcystin concentration of 0.6 $\mu\text{g MC L}^{-1}$.
211 A second bloom event occurred on September 12th with a peak Chl-*a* value of 135.6 $\mu\text{g Chl-}a \text{ L}^{-1}$.
212 This bloom had a microcystin concentrations half that of the first bloom (0.3) $\mu\text{g MC L}^{-1}$
213 (Figure 3, A). Unlike the first bloom event, the second bloom (September 12th) was not
214 dominated by cyanobacteria (counts; Figure 2). Microcystin concentrations in the hypolimnion
215 were not significantly different than in the epilimnion, however, the mean for the sampling
216 period was 0.4 $\mu\text{g MC L}^{-1}$ (0.15 $\mu\text{g MC L}^{-1}$ to 0.78 $\mu\text{g MC L}^{-1}$).

217 *Algal community composition*

218 Preliminary data from phytoplankton counts show that the initial bloom (July 16, 2019)
219 was *Dolichospermum* (formerly known as *Anabaena*). After this bloom collapsed, there was a
220 second bloom of *Raphidiopsis* (formerly known as *Cylindrospermopsis*). It is interesting that
221 these genera were in such high abundance in the reservoir despite the microcystin concentration
222 never being below the detection limit (0.15 $\mu\text{g MC L}^{-1}$) in any of our samples. It is surprising
223 that microcystin producing species were not the highest in abundance. Further study should
224 include toxins produced by these genera of algae.

225 *Relationship between DOM, Chl-*a*, and microcystin concentrations*

226 There were significant correlations between the measured DOM parameters and Chl-*a*
227 concentrations. There was no relationship between DOC and Chl-*a*; however, DOM quality
228 assessed by a_{350} and SUVA_{254} were positively correlated with Chl-*a* (Figure 4). The mean

229 microcystin concentration in the epilimnion was $0.3\mu\text{g L}^{-1}$ ($0.15\mu\text{g MC L}^{-1}$ to $0.68\mu\text{g MC L}^{-1}$;
230 Table 3).

231 There were significant correlations between DOM quantity and quality and microcystin
232 concentrations. In the epilimnion, DOC correlated positively with microcystin concentrations
233 (Figure 5). A significant correlation between these two parameters was also found in the
234 hypolimnion, though the correlation in the hypolimnion was stronger ($r=0.63$, $p<0.0005$) than in
235 the epilimnion. Significant positive correlations were also found between a_{350} and microcystin;
236 however, it was stronger in the hypolimnion ($r=0.49$, $p<0.003$) than in the epilimnion ($r=0.34$,
237 $p=0.047$). There was no relationship between SUVA_{254} and microcystin in the epilimnion;
238 however, there was a significant positive correlation between the two in the hypolimnion
239 ($r=0.35$, $p=0.040$). There were also significant correlations between S_R and a_{350} ($r=0.65$,
240 $p<0.0005$), and S_R and SUVA_{254} ($r=0.51$, $p=0.002$). S_R was greater than one for the duration of
241 the sampling period indicating high amounts of algal DOM consistently throughout the summer.
242 S_R did not significantly change during the sampling period.

243 Discussion

244 The goal of this project was to determine how DOM quantity and quality changes
245 summer algal bloom in an agricultural reservoir. While we saw significant decreases in
246 allochthonous DOM during bloom conditions, there were no significant increases in
247 autochthonous DOM during the bloom event. S_R , the index used for autochthonous DOM did not
248 significantly change during the bloom events; however, values were greater than 1 for the
249 duration of the sampling period, indicating consistently high amounts of autochthonous DOM
250 (Dixon et al. 2014).

251 *Did terrestrial DOM quantity decrease during bloom conditions?*

252 High a_{350} and $SUVA_{254}$ values for the duration of the study indicate that this reservoir
253 contains high amounts of terrestrial and aromatic DOM. $SUVA_{254}$ was significantly lower in the
254 hypolimnion during the cyanobacterial bloom than much of the sampling period (Figure 3B).
255 Phytoplankton degradation is known to be a major source of DOM during algal blooms and
256 terrestrially derived DOM has more influence on DOM composition during non-bloom
257 conditions (Zhao et al. 2009). This seems to be the case in our data as well; however, the
258 significant decrease in $SUVA_{254}$ during the bloom occurred only in the hypolimnion. There was
259 also a significant increase in S_R in the hypolimnion, which may indicate phytoplankton
260 degradation and accumulation in bottom waters. We would also expect to see a decrease in
261 $SUVA_{254}$ in the epilimnion as well as the hypolimnion, since the bloom is occurring in the
262 epilimnion. It is not clear what would cause such a sharp decrease in $SUVA_{254}$ only in the
263 hypolimnion while there was no significant change in the epilimnion during the bloom.

264 Significant positive relationships were observed between DOC concentrations, Chl-*a*, and
265 microcystin. This suggests that there is a relationship between the amount of DOM in an aquatic
266 system and algal abundance. This is supported by previous research that has shown DOM to be a
267 source of nitrogen and carbon for algae (Jaffé et al. 2008). However, research to support a
268 relationship between DOM quantity and microcystin concentration is lacking.

269 There was a decrease in DOC from the beginning to the end of the sampling period in
270 both the epilimnion and the hypolimnion. It is possible that this occurred because the algae were
271 taking up C. In a mesocosm study, a decrease in DOC was documented during an algal bloom.
272 The authors concluded that it was likely because algae were using the DOC which is likely what
273 happened in this study as well. It is also possible that C assimilation by phytoplankton may have

274 played a role in sustaining the cyanobacterial bloom (Bai et al. 2017; Morales-Williams et al.
275 2017). At the beginning of the bloom, we saw an increase of allochthonous DOM. As the first
276 bloom progressed, these values decreased, indicating that the algae were using this as a source of
277 nutrients. As the bloom subsided, we saw allochthonous DOM increase again in both the
278 epilimnion and hypolimnion. This suggests a sustained input of allochthonous DOM. This may
279 be the result of runoff from precipitation events as such events were recorded several days before
280 each bloom. Research from under ice algal blooms also supports a relationship between DOM
281 quantity and cyanobacterial biomass (Roiha et al. 2016). It is possible that in this system as well
282 that there is a positive relationship between DOM quantity and algal biomass.

283 *Does DOM quality and quantity correlate with toxin concentration?*

284 We found a significant positive relationship between DOM quantity and microcystin
285 concentration. To our knowledge, no other studies have looked for a relationship between DOM
286 and toxin concentrations. The relationship observed between DOM quantity and cyanobacterial
287 biovolume suggests that there is an interesting dynamic between DOM and algal community
288 structure. DOM has implications for microcystin concentration during bloom events as well.
289 Microcystin concentrations during first the bloom event exceeded $0.3 \mu\text{gL}^{-1}$, the EPA 10-day
290 drinking water health advisory limit for young children (U.S. EPA 2015), but were well under
291 $8.0 \mu\text{gL}^{-1}$, the EPA recommended swimming advisory limit (U.S. EPA 2019). While our
292 measurements come from raw water, this does highlight concern for the relationships between
293 DOM and toxin concentrations. We did not find any indication of a relationship between DOM
294 quality and toxin concentration. While we tested for relationships between all previously
295 mentioned DOM quality parameters and microcystin, none of them were significant.

296 It is notable that there was no significant difference in microcystin concentrations
297 between the epilimnion and hypolimnion. Since blooms occur in the epilimnion in shallow
298 systems such as this one, it is interesting that microcystin in the hypolimnion were never below
299 the detection limit. This may indicate that microcystin is accumulating in the bottom waters as
300 the bloom crashes or that it is being released from sediments (Zastepa et al. 2015).

301 **Conclusion**

302 The results of this study show that there is a relationship between DOM quantity and
303 quality, cyanobacterial bloom formation, and toxin concentration. However, it begs the question:
304 are changes in DOM facilitating cyanobacteria bloom formation and toxin concentrations or did
305 the bloom itself drive the changes in DOM? Unfortunately, we are unable to parse out this
306 distinction with our data. To do this would likely require mesocosm experiments with additions
307 of known quantities and known types of DOM (Rochelle-Newall et al. 1999).

308 Our results highlight the importance of understanding the relationships between DOM,
309 cyanobacterial blooms, and toxin concentrations. There remains much to learn about DOM
310 cycling and its relationship with toxin concentration, particularly in man-made systems. Harmful
311 algal blooms and reservoirs are both increasing worldwide; however, to our knowledge no
312 studies resolving the relationships between DOM and cyanotoxin concentration in reservoirs
313 have been published. As cyanobacterial blooms and reservoirs continue to increase, the
314 importance of understanding what factors cause increases in algal biomass and toxin
315 concentration will become essential to finding potential solutions. Reservoirs are increasing
316 worldwide and are an important source of freshwater for much of the population. As such, it is
317 important that we fully understand the implications of DOM for cyanoHABs and algal toxicity.

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454 **Tables and Figures**

455 Table 1. Characterization table of Dairy Farm Lake #1 from 2006 to 2018 for Total Phosphorous (TP),
 456 Total Nitrogen (TN), Chlorophyll-*a* (Chl-*a*), Total Suspended Solids (TSS), and Secchi disk depth
 457 (Secchi Transparency).

Year	TP ($\mu\text{g L}^{-1}$)	TN ($\mu\text{g L}^{-1}$)	Chl- <i>a</i> ($\mu\text{g L}^{-1}$)	TSS (mg L^{-1})	Secchi depth (m)
2006	118	2137	69.9	3.7	0.5
2007	105	1645	70.1	4.5	0.6
2008	249	1928	100.4	6.1	0.4
2009	191	2576	108.2	5.8	0.4
2010	218	2781	100.4	3.9	0.4
2011	291	2768	83.8	7.7	0.3
2012	127	1589	54.2	4.3	0.6
2013	148	1544	56.8	6.1	0.6
2014	100	1629	73.3	2.2	0.7
2016	103	1238	55.8	3.6	0.6
2017	95	1463	51.4	1.3	0.6
2018	101	1580	44.7	13.3	0.4

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475 Table 2. Abbreviations, units, and definition of each parameter measured or calculated.

Parameter	Units	Definition
Chl- <i>a</i>	$\mu\text{g L}^{-1}$	Chlorophyll- <i>a</i> is used as an indicator of algal biomass.
Microcystin	$\mu\text{g L}^{-1}$	Hepatotoxin released by cyanobacteria and contained within their cells.
DOC	Mg L^{-1}	Dissolved organic carbon. Used as a measurement of DOM quantity.
a_{350}	m^{-1}	Napierian absorbance coefficient at 350 nm. a_{350} is an indicator of terrestrially derived dissolved organic matter.
SUVA ₂₅₄	$\text{Lmg}^{-1}\text{Cm}^{-1}$	Specific UV absorbance (SUVA) at 254nm. SUVA is calculated as the Napierian absorption coefficient at 254nm divided by DOC concentration. High SUVA ₂₅₄ indicates high molecular weight and high aromaticity.
S_R	unitless	Slope Ratio. S_R values lower than one are indicative of allochthonous organic matter with a high molecular weight. S_R values greater than one are indicative of autochthonous organic material with high molecular weight.

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490 Table 3. Summary table of parameters from 2018 sampling season (June 21-October 5) of Dairy Farm
 491 Lake #1 including mean, minimum, and maximum values from the epilimnion and hypolimnion.
 492 Definitions of each parameter and units can be found in Table 2.

	Epilimnion			Hypolimnion		
	Mean	Minimum	Maximum	Mean	Minimum	Maximum
DOC	9.7	8.7	10.9	9.4	8.4	10.9
Chl- <i>a</i>	87.0	40.6	162.5	142.9	25.8	384.2
a_{254}	39.0	34.9	42.9	48.3	35.1	63.2
SUVA ₂₅₄	4.0	3.8	4.4	5.1	3.9	6.7
S_R	23.1	4.7	168.5	12.0	3.1	32.2
Microcystin	0.3	0.2	0.7	0.4	0.2	0.8

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511 Table 4. One-way ANOVA results for parameters grouped by week measured both in the epilimnion and
 512 hypolimnion. All parameters had significant changes ($p < 0.05$) during the sampling period except for a_{350}
 513 in the epilimnion. A definition of each parameter can be found in Table 2.

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Parameter	Epilimnion		Hypolimnion	
	$F_{(df1, df2)}$	p	$F_{(df1, df2)}$	p
Chl-a	3.3 _(15,18)	0.0083	-	-
Microcystin	5.24 _(15, 18)	0.0006	4.5 _(15, 17)	0.002
DOC	8.4 _(15, 19)	<0.0005	3.6 _(15, 18)	0.0057
a_{350}	2.1 _(15, 19)	0.0657	7.6 _(15, 18)	<0.0005
SUVA254	5.4 _(15, 19)	<0.0005	8.6 _(15, 18)	<0.0005
SR	3.3 _(15, 17)	0.0101	2.8 _(15, 16)	0.0253

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535 Table 5: Correlation matrix for DOM quantity and quality parameters and their relation to the
 536 concentration of microcystin. Values represent correlation coefficients (r). Bolded values indicate
 537 correlations that were significant ($p < 0.05$). Definitions for all parameters can be found in Table 2.

	DOC		a ₃₅₀		SUVA ₂₅₄		S _R		Chl _a	Microcystin
	Epi	Hypo	Epi	Hypo	Epi	Hypo	Epi	Hypo	Epi	Epi
DOC	1									
a ₃₅₀	0.51	-0.27	1	1						
SUVA ₂₅₄	-0.51	0.06	0.31	0.91	1	1				
S _R	-0.12	-0.12	0.65	0.41	0.51	0.18	1	1		
Chl- <i>a</i>	0.07	-	0.44	-	0.37	-	0.36	-	1	
Microcystin	0.5	0.63	0.34	0.49	0.12	0.35	0.04	-0.05	0.6	1

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556 Figure 1: Epilimnetic chlorophyll-*a* concentrations from June 21st to October 5th divided into
557 weekly aggregates. The first Chl-*a* peak (162.47 $\mu\text{g L}^{-1}$) occurred on July 16th, 2018. The second
558 Chl-*a* peak (135.61 $\mu\text{g L}^{-1}$) occurred on September 12th, 2018. Both values were significantly
559 higher than historical seasonal means indicating that our observational study included two
560 distinct algal blooms. The dotted line represents the historical Chl-*a* mean in Dairy Farm Lake
561 #1. The x-axis indicates the first day of each sampling week. Different letters indicate
562 statistically significant differences between each week.

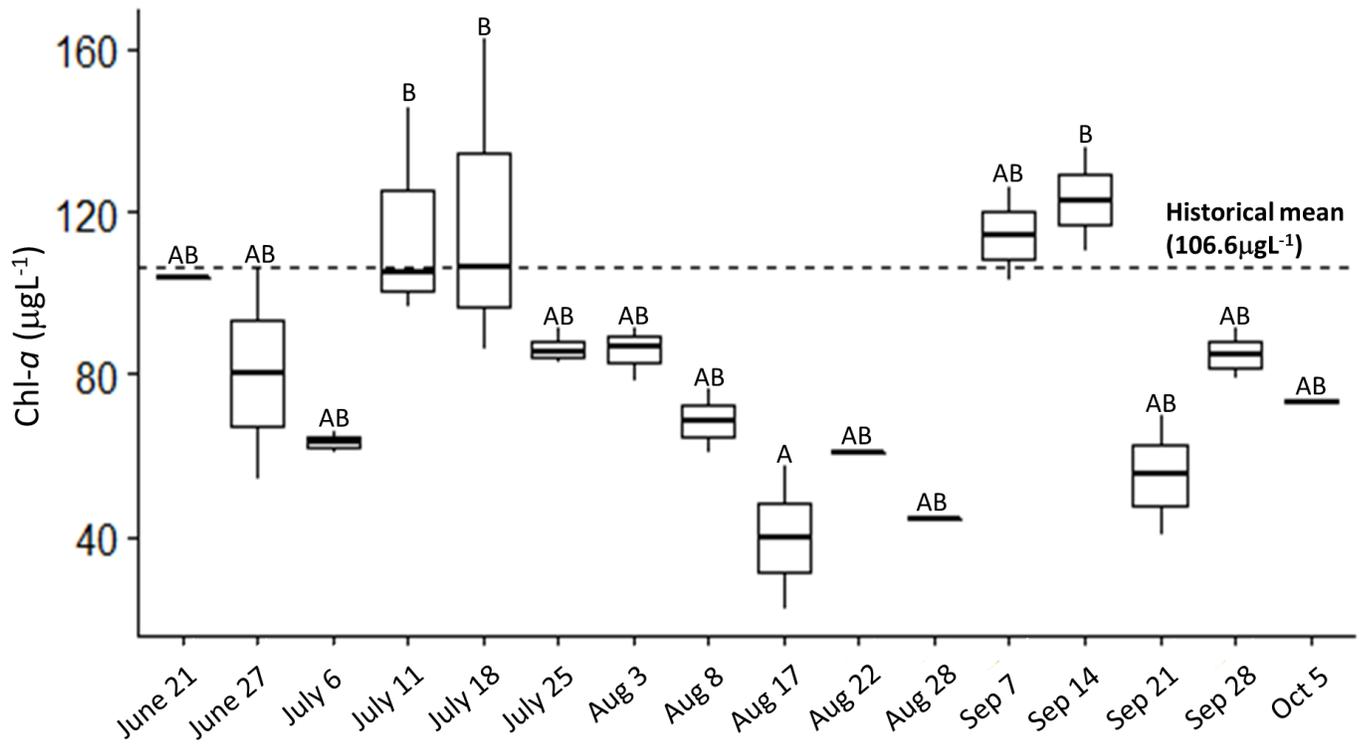
563 Figure 2: A: Cyanobacterial biovolume (mg/m^3) throughout the sampling period. B: Percent
564 cyanobacteria during the sampling period. The highlighted portion in mid-July indicates where
565 the algal community was dominated by cyanobacteria (>80% cyanobacteria).

566 Figure 3: Timeseries of microcystin, DOC concentration, SUVA_{254} , a_{350} , and S_R from June 21st to
567 October 5th, 2018 in the epilimnion. A definition of each parameter can be found in Table 2. A:
568 Microcystin concentration, B: DOC concentration, C: SUVA_{254} , D: a_{350} , E: S_R . The highlighted
569 portion in mid-July indicates where the algal community was dominated by cyanobacteria. Each
570 box represents one week of sampling. The x-axis indicates the first day of each sampling week.
571 Different letters indicate statistically significant differences between each week.

572 Figure 4: Timeseries of measured parameters from June 21st to October 5th in the hypolimnion. A
573 definition of each parameter can be found in Table 2. A: Microcystin concentration, B: DOC
574 concentration, C: SUVA_{254} , D: a_{350} , E: S_R . The highlighted portion in mid-July indicates
575 where the algal community was dominated by cyanobacteria. Each box represents one week of
576 sampling. The x-axis indicates the first day of each sampling week. Different letters indicate
577 statistically significant differences between each week.

578 Figure 5: Correlations DOC and microcystin. A: DOC and microcystin in the epilimnion,
579 $r=0.50$, $p<0.05$; B: DOC and microcystin in the hypolimnion, $r=0.50$, $p<0.05$.

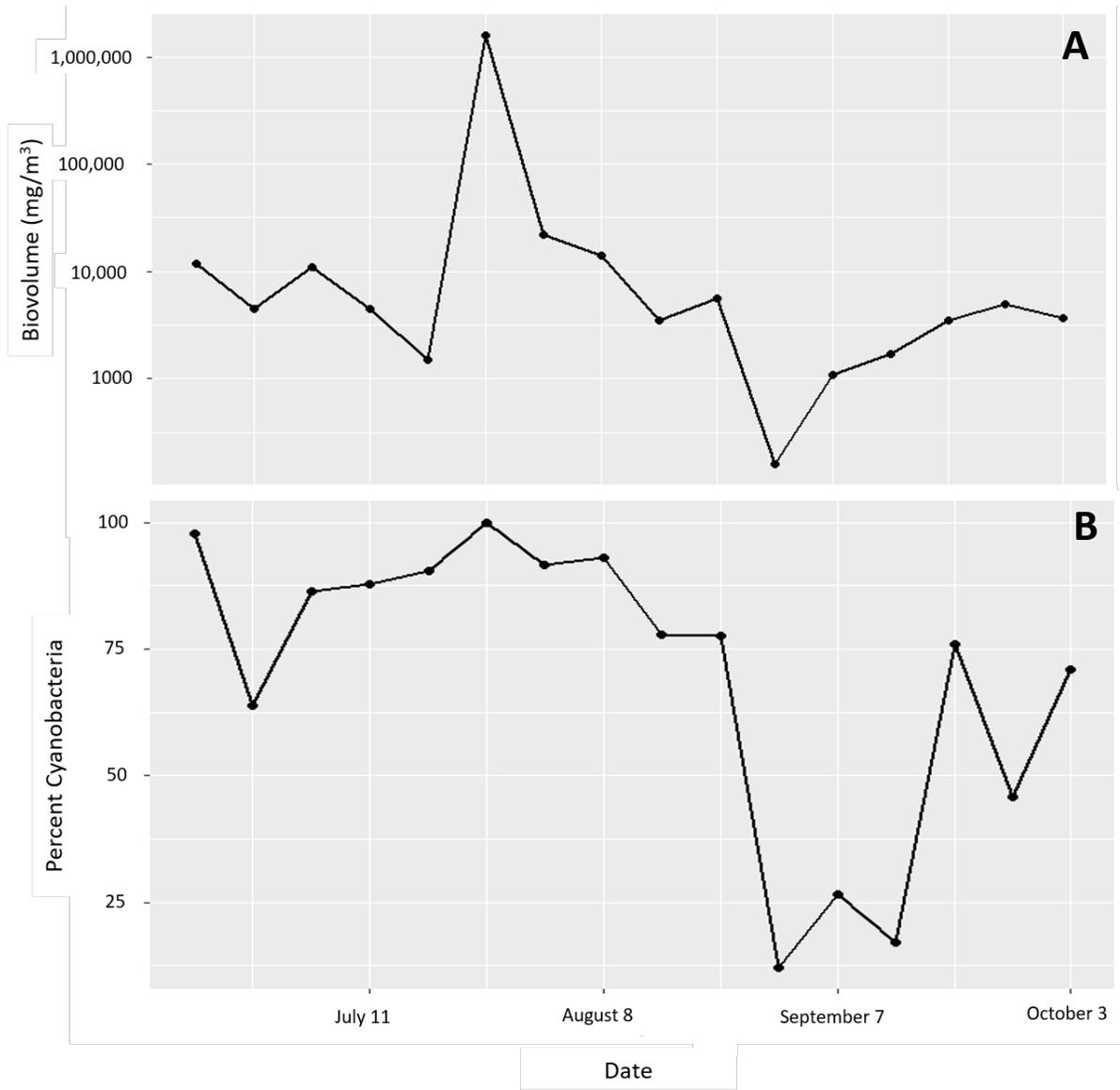
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595 Figure 2

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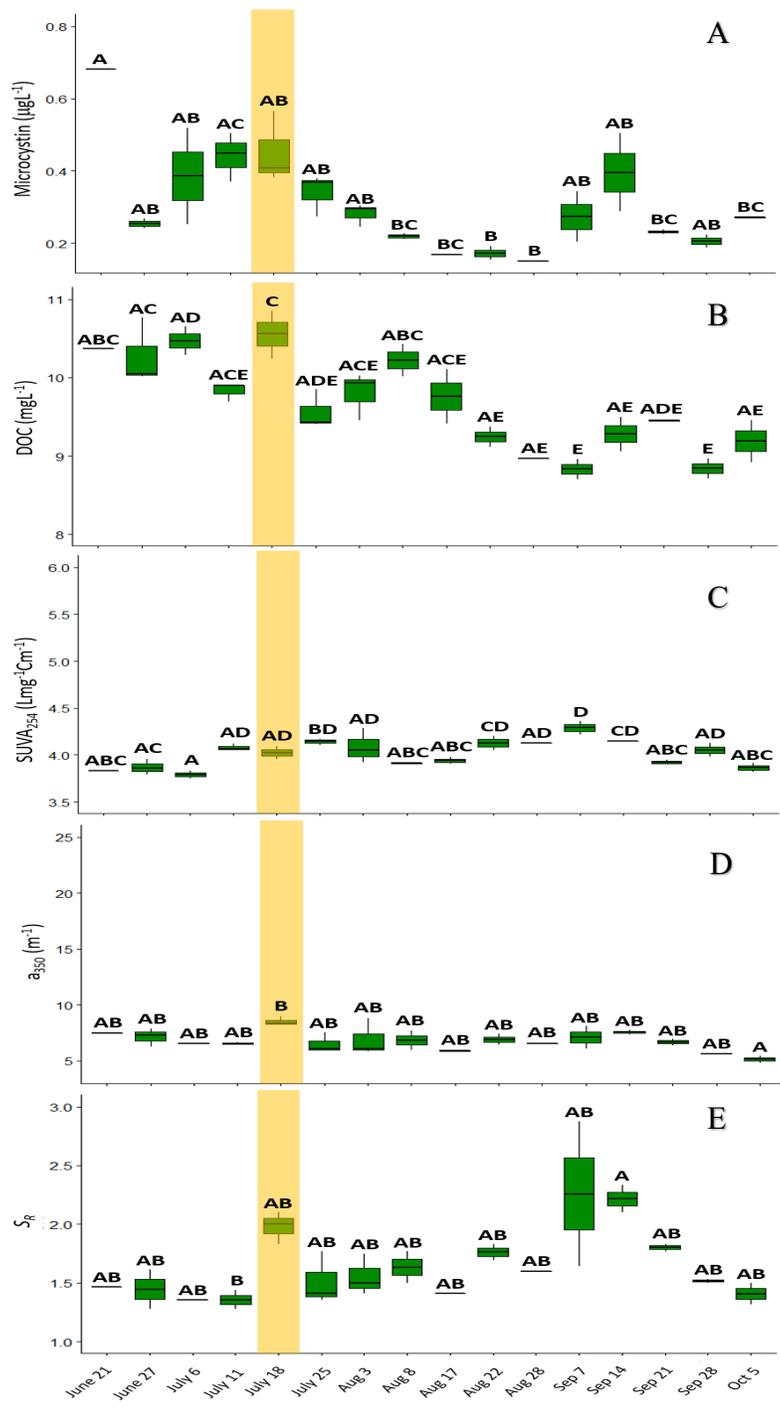
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633 Figure 4

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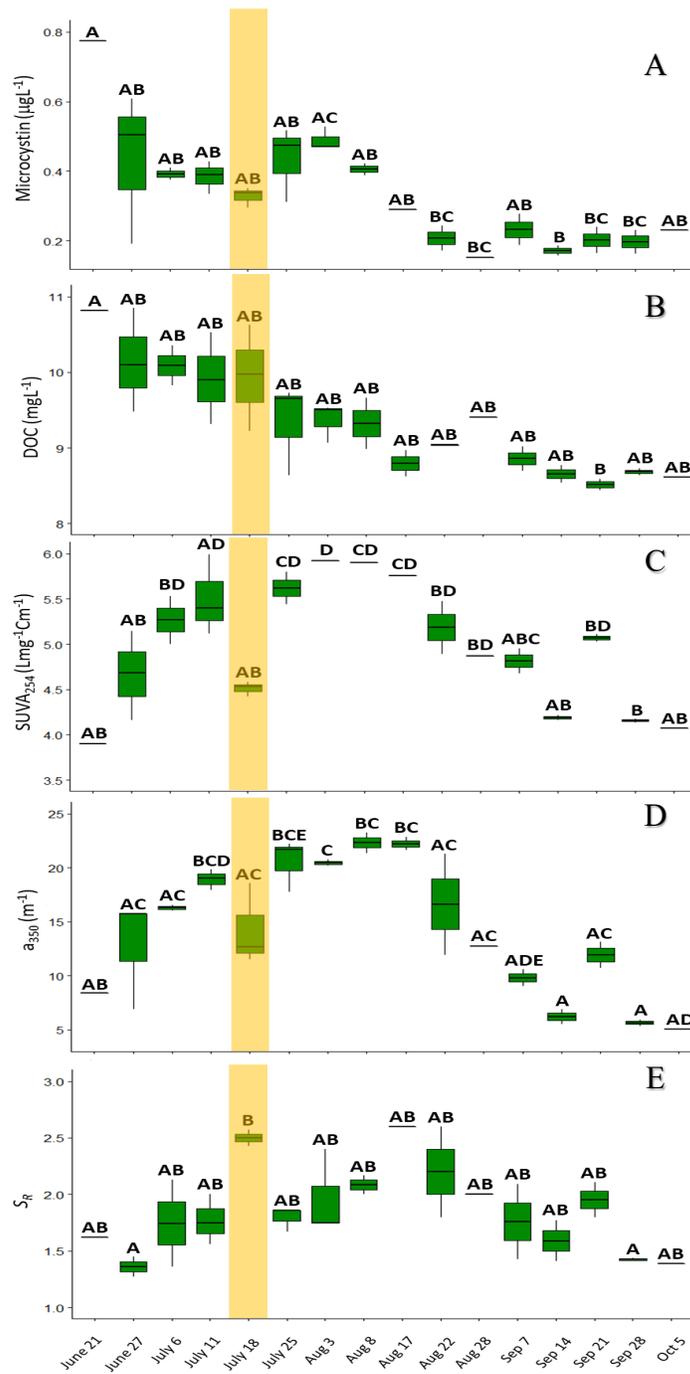
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661 Figure 5

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