Water Quality and Methane Emissions at Lake Roaming Rock

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1. Background:

The US Environmental Protection Agency (USEPA) is conducting an investigation of methane (CH₄) dynamics in reservoirs. CH₄ is a potent greenhouse gas that is produced by microorganisms in reservoir sediments. The objective is to estimate the magnitude of CH₄ emissions from reservoirs in the United States.

The USEPA measured CH₄ emissions from 32 reservoirs in Ohio, Indiana, and Kentucky during the summer of 2016. We designated a minimum of 15 sampling sites in each reservoir (depending on reservoir size), where we measured CH₄ emissions and several water quality indicators. CH₄ emissions were measured using a device which captures CH₄-rich bubbles as they rise through the water column toward the atmosphere. A sonde was used to measure chlorophyll a, dissolved oxygen, pH, specific conductivity, water temperature, and turbidity just below the water surface at each of the 15 sites. Additionally, nutrient chemistry was analyzed at one shallow and one deep site for each reservoir.

This preliminary report presents results from the USEPA 2016 measurement campaign relevant to Lake Roaming Rock. These data will be included in a formal peer-reviewed publication to be submitted for publication in early 2018. This preliminary report includes:

- 1. This background information
- 2. A map showing the location of the sampled sites
- 3. A 3D map of the reservoir showing the measurement results for : $\frac{1}{2}$
 - CH₄ emissions
 - Chlorophyll a
- 4. Figures showing how Lake Roaming Rock compared to the other 31 reservoirs in the study in terms of:
 - CH₄ emissions
 - Total phosphorus
 - Total nitrogen
 - Chlorophyll a
- 5. Tables summarizing the other measured water quality values at each site within Lake Roaming Rock

Thank you for your help in including Lake Roaming Rock in this project.

2. Map of Sampled Sites

We sampled Lake Roaming Rock on September $8^{\rm th}$ - $9^{\rm th}$ of 2016. The sampling sites were chosen using a generalized random tesselation stratified design ("GRTS"), an approach which combines elements of systematic and random survey designs which allows for the random allocation of sampling sites with maximum spatial coverage of the reservoir. We used a GPS and geographic information system (GIS) software to locate each sampling site (+/- 30 meters).

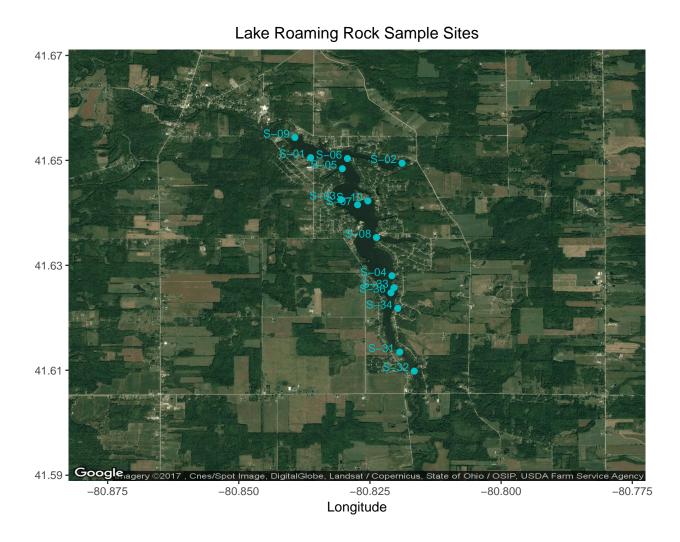


Figure 1: Location of the fifteen sample sites within Lake Roaming Rock. Satellite image from Google Maps.

3. Within-lake values of methane emissions and chlorophyll a concentrations

Previous studies have found a general pattern of higher CH₄ emissions in the river-reservoir transition (tributary) area, and lower emissions in the deeper downstream waters. Lake Roaming Rock dispalyed this pattern: the highest emissions were observed in the south tributary and near the northeast tributary inflow.

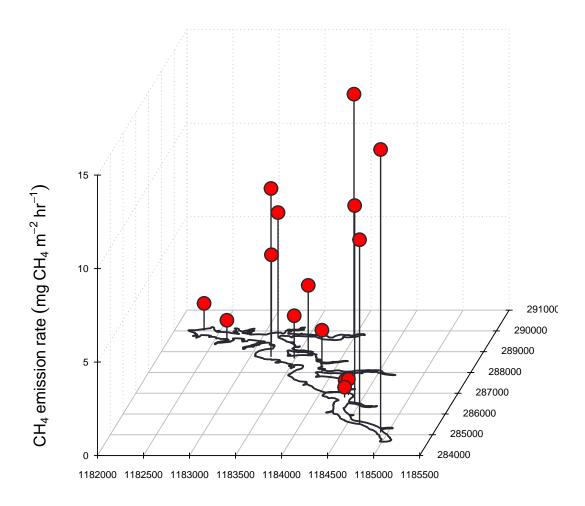


Figure 2: Methane emissions measured at the 15 sample sites within Lake Roaming Rock. The height of each "lollipop" corresponds to the emission rate shown on the vertical z-axis in units of milligrams CH_4 per square meter of lake surface per hour.

However, chlorophyll a concentrations in Lake Roaming Rock did not show a clear difference between upstream and downstream sites, and were relatively low overall (see Figure 5).

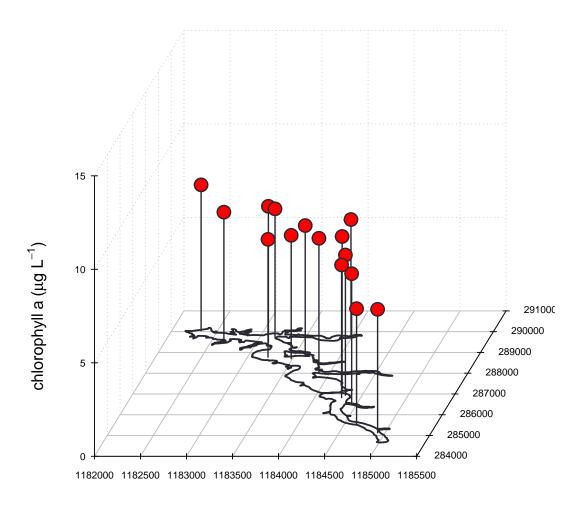


Figure 3: Chlorophyll a concentrations measured at the 15 sample sites within Lake Roaming Rock. The height of each "lollipop" corresponds to the concentration shown on the vertical z-axis in units of micrograms per liter of water.

4. Comparative plots

We used the results from the individual measurement sites to calculate mean values and an uncertainty range for the reservoir. The uncertainty measure we used is the 95% confidence interval (CI), which is similar to two standard deviations (sd) from the mean in a normally distributed data set (where 2*sd = 95.45%). In the case of this study, the majority of the uncertainty is due to the spatial variability of a given parameter within the reservoir, rather than uncertainty due to analytical errors.

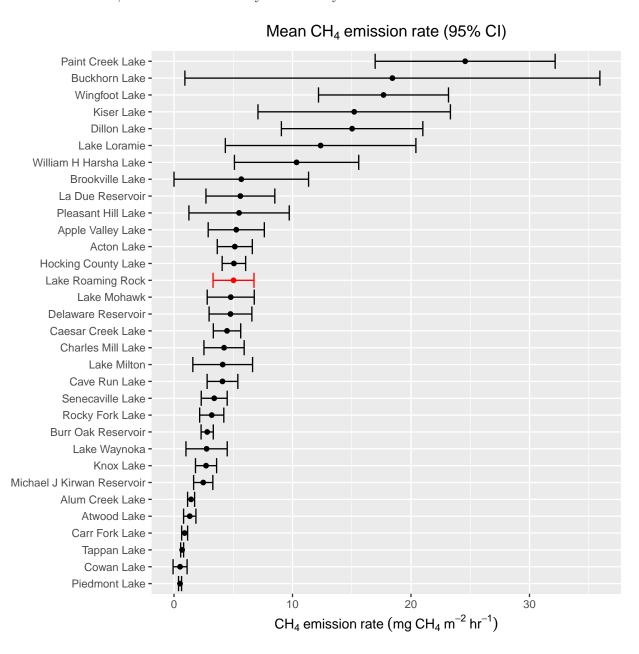


Figure 4: Mean and 95% confidence interval (CI) of the CH_4 emission rate for each reservoir in this study, calculated from the vaules measured at >=15 sites within each reservoir.

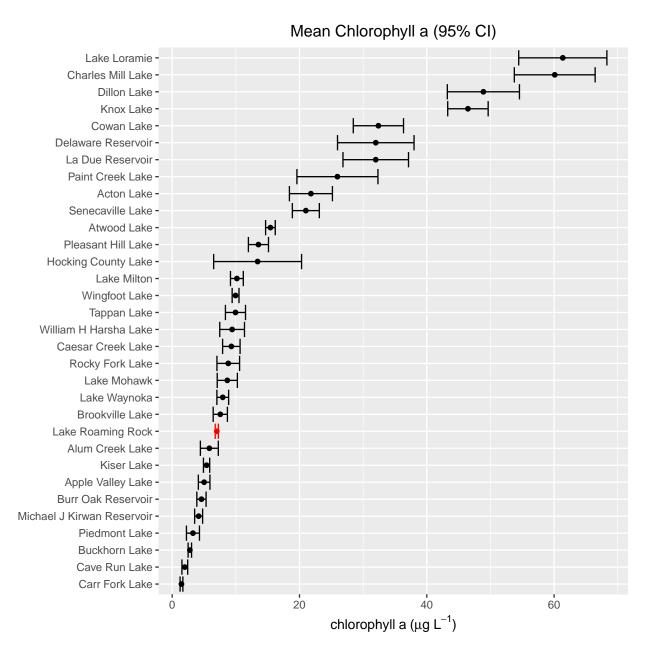


Figure 5: Mean and 95% confidence interval (CI) of the chlorophyll a concentration for each reservoir in this study, calculated from the vaules measured at >=15 sites within each reservoir.

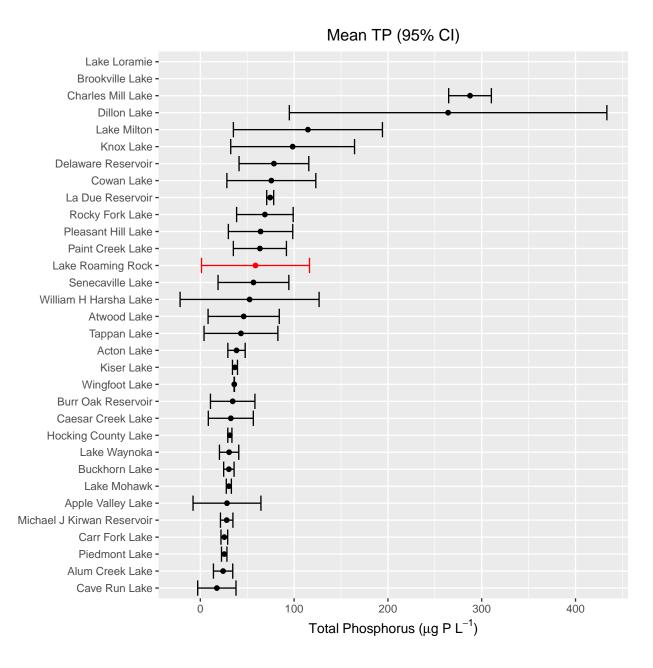


Figure 6: Mean and 95% confidence interval (CI) of the total phosphorus (TP) concentration for each reservoir in this study, calculated from the vaules measured at >=15 sites within each reservoir.

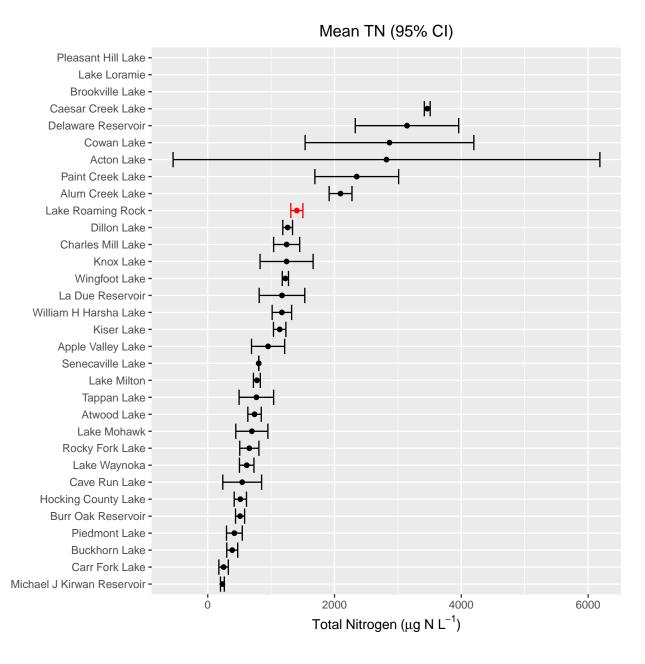


Figure 7: Mean and 95% confidence interval (CI) of the total nitrogen (TN) concentration for each reservoir in this study, calculated from the vaules measured at >=15 sites within each reservoir.

5. Tables of measured values at each site

Table 1: Water quality parameters measured via sonde at each site

5-0141.6505380.836353.16.811.59.3026.511.5S-0241.6494680.819001.56.311.49.2028.411.5S-0341.6494680.819001.56.311.49.2027.611.6S-0441.6425280.830527.07.312.09.2027.627.8S-0541.6484480.830257.07.312.09.2027.627.1S-0641.6403280.829313.46.611.99.3027.411.1S-0841.6416380.823732.77.210.39.3027.411.1S-0941.6524480.839137.17.811.79.2027.99S-1041.6422280.825375.87.011.49.2027.99S-3141.6134680.819251.26.29.29.1027.99S-3241.6097980.820383.47.58.88.9026.99S-3441.6218580.819691.87.08.48.8026.99S-3441.6218780.820381.87.08.88.9026.79S-3441.6218780.820381.87.08.88.9026.79S-3541.6247280.820391.87.08.8 <td< th=""><th>Site ID</th><th>Latitude</th><th>ite ID Latitude Longitude</th><th>Depth (m)</th><th>Chl a (ug/L)</th><th>DO (mg/L)</th><th>Hd</th><th>Sp. Cond</th><th>Water Temp (C)</th><th>Turbidity</th></td<>	Site ID	Latitude	ite ID Latitude Longitude	Depth (m)	Chl a (ug/L)	DO (mg/L)	Hd	Sp. Cond	Water Temp (C)	Turbidity
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41.6425280.830527.66.311.49.2027.641.6484480.820247.07.312.09.2027.641.6484480.830257.07.311.49.2027.141.6416380.829313.46.911.49.2027.141.6416380.823732.77.210.39.1027.441.6422280.825377.17.811.79.2027.941.6422480.819251.26.29.2027.941.6037980.816521.06.67.68.6026.941.6257080.820383.47.58.88.9026.141.6247280.820922.17.08.58.9026.7	S-02	41.64946		1.5	6.3	11.5	9.2	0	28.4	18.3
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41.6503280.829313.46.911.49.2027.141.6416380.827286.76.611.99.3027.441.6545480.823732.77.210.39.1027.441.6442280.825375.87.011.49.2027.941.6134680.819251.26.29.29.1027.041.6097980.820383.47.58.88.9026.141.6218580.819691.87.08.58.9026.141.6247280.820922.17.18.48.8025.9	S-05	41.64844		7.0	7.3	12.0	9.2	0	27.6	21.5
41.6416380.827286.76.611.99.3027.441.6352680.823732.77.210.39.1028.441.6454280.839137.17.811.79.2027.941.642280.819251.26.29.2027.041.6097980.816521.06.67.68.6026.941.6257080.820383.47.58.89026.141.6247280.820922.17.18.48.8025.9	90-S	41.65032		3.4	6.9	11.4	9.2	0	27.1	19.5
41.63526 80.82373 2.7 7.2 10.3 9.1 0 28.4 41.64524 80.83913 7.1 7.8 11.7 9.2 0 27.9 41.64225 80.82537 5.8 7.0 11.4 9.2 0 27.4 41.61346 80.81925 1.2 6.2 9.2 9.1 0 27.0 41.60570 80.82038 3.4 7.5 8.8 8.9 0 26.1 41.62472 80.82092 1.3 7.1 8.4 8.8 0 25.9	S-0.2	41.64163		6.7	9.9	11.9	9.3	0	27.4	15.7
41.65454 80.83913 7.1 7.8 11.7 9.2 0 27.9 41.64222 80.82537 5.8 7.0 11.4 9.2 0 27.4 41.61346 80.81925 1.2 6.2 9.2 9.1 0 27.0 41.60570 80.82038 3.4 7.5 8.8 8.9 0 26.1 41.62472 80.82092 2.1 7.1 8.4 8.8 0 25.9	S-08	41.63526		2.7	7.2	10.3	9.1	0	28.4	19.5
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41.61346 80.81925 1.2 6.2 9.2 9.1 0 27.0 41.60979 80.81652 1.0 6.6 7.6 8.6 0 26.9 41.62570 80.82092 3.4 7.5 8.8 8.9 0 26.1 41.62472 80.82092 2.1 7.1 8.4 8.8 0 25.9	S-10	41.64222		5.8	7.0	11.4	9.2	0	27.4	16.6
41.60979 80.81652 1.0 6.6 7.6 8.6 0 26.9 41.62570 80.82038 3.4 7.5 8.8 8.9 0 26.1 41.62472 80.82092 2.1 7.1 8.4 8.8 0 25.9	S-31	41.61346		1.2	6.2	9.2	9.1	0	27.0	6.2
41.62570 80.82038 3.4 7.5 8.8 8.9 0 26.1 41.62472 80.82092 2.1 7.1 8.4 8.8 0 26.7	S-32	41.60979		1.0	9.9	9.2	8.6	0	26.9	6.5
41.62185 80.81969 1.8 7.0 8.5 8.9 0 26.7 41.62472 80.82092 2.1 7.1 8.4 8.8 0 25.9	S-33	41.62570		3.4	7.5	8.8	8.9	0	26.1	9.7
41.62472 80.82092 2.1 7.1 8.4 8.8 0	S-34	41.62185		1.8	7.0	8.5	8.9	0	26.7	10.1
	S-36	41.62472		2.1	7.1	8.4	8.8	0	25.9	7.1

Table 2: Water chemistry parameters measured at one shallow and one deep site

(gP/L)		
Total P (ugP/L)	37	103
Reactive P (ug/L)	19	35
Total N (ugN/L)	1370	1480
NO2.3 (ugN/L)	14	43
NH4 (ugN/L)	12	130
Depth (m)	7.1	1.0
Longitude	80.83913	80.81652
Latitude	41.65454	41.60979
Site ID	8-06	S-32

6. EPA disclaimer

The U.S. Environmental Protection Agency, through its Office of Research and Development, participated in the research described herein. It has been subjected to the Agency's administrative review and has been approved for limited external distribution. Any opinions expressed in this article are those of the authors and do not necessarily reflect the views of the Agency, therefore, no official endorsement should be inferred. Any mention of trade names or commercial products does not constitute endorsement or recommendation for use.