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 (CH_4) dynamics in reservoirs. CH_4 is a potent greenhouse gas that is produced by microorganisms in reservoir sediments. The objective is to estimate the magnitude of CH_4 emissions from reservoirs in the United States.

The USEPA measured CH_4 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 CH_4 emissions and several water quality indicators. CH_4 emissions were measured using a device which captures CH_4-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 meausurement 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 :
    - CH_4 emissions
    - Chlorophyll a
4. Figures showing how Lake Roaming Rock compared to the other 31 reservoirs in the study in terms of:
    - CH_4 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^{th} - 9^{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).

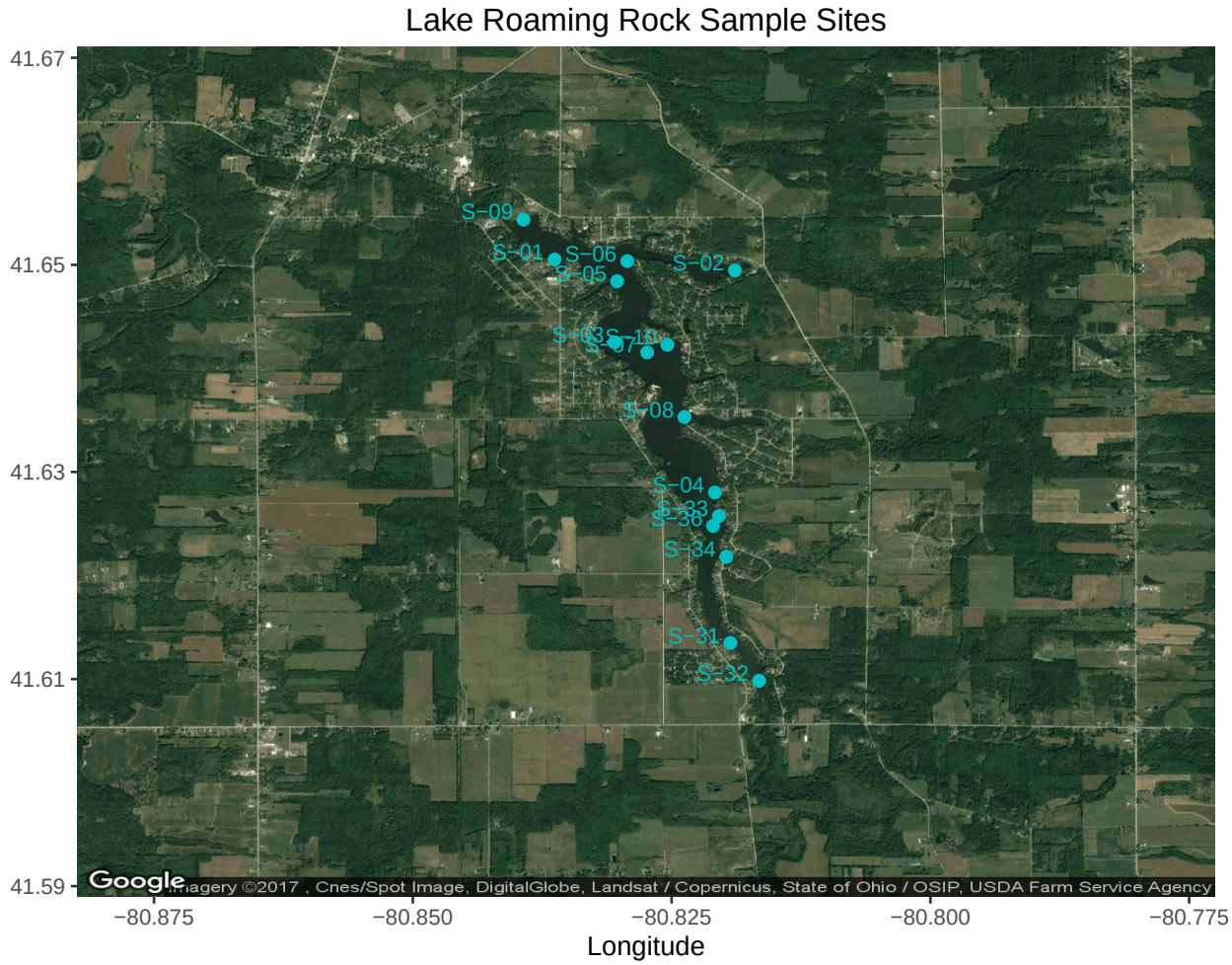

Figure 1: *Location of the fifteen sample sites within Lake Roaming Rock. Satellite image from Google Maps.*

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

Previous studies have found a general pattern of higher CH_4 emissions in the river-reservoir transition (tributary) area, and lower emissions in the deeper downstream waters. Lake Roaming Rock displayed this pattern: the highest emissions were observed in the south tributary and near the northeast tributary inflow.

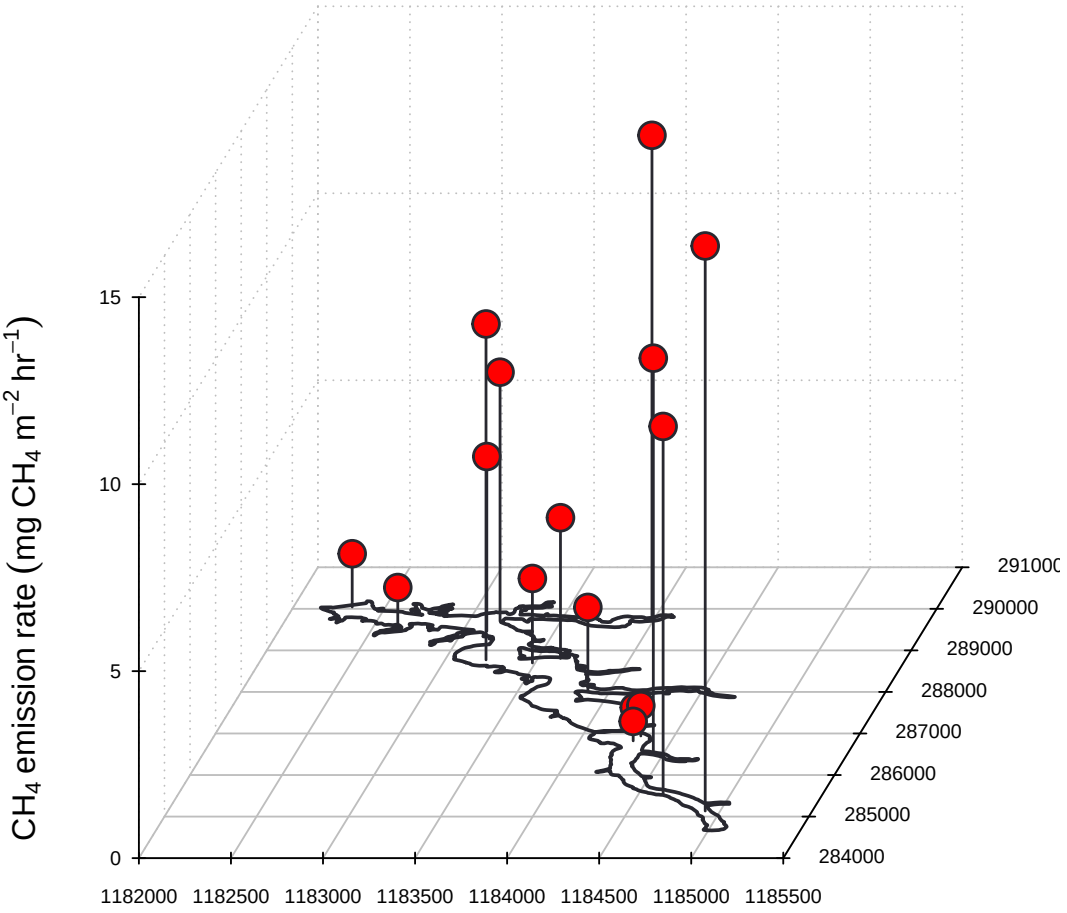

Figure 2: *Methane emissions measured at the 15 sample sites within Lake Roaming Rock. The height of each "lollipop" corresponds to the emission rate shown on the vertical z-axis in units of milligrams CH_4 per square meter of lake surface per hour.*

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).

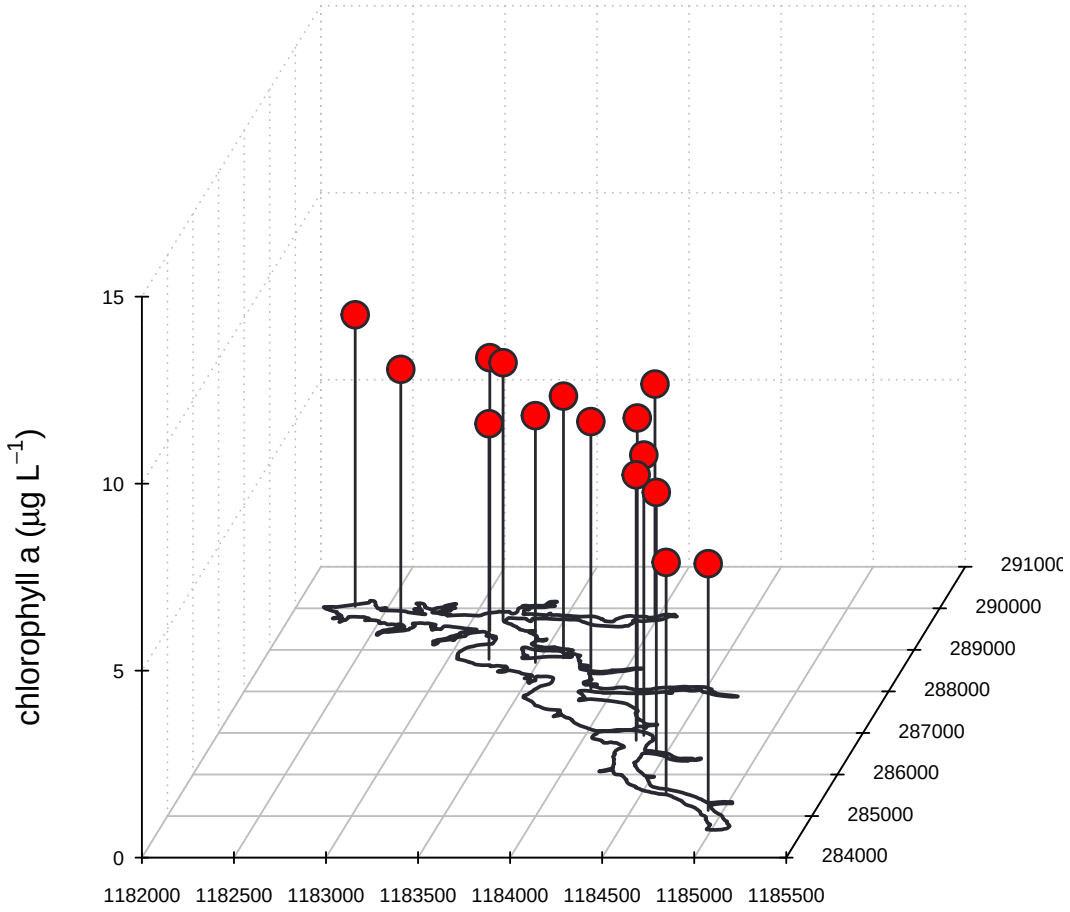

Figure 3: *Chlorophyll a concentrations measured at the 15 sample sites within Lake Roaming Rock. The height of each "lollipop" corresponds to the concentration shown on the vertical z-axis in units of micrograms per liter of water.*

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.

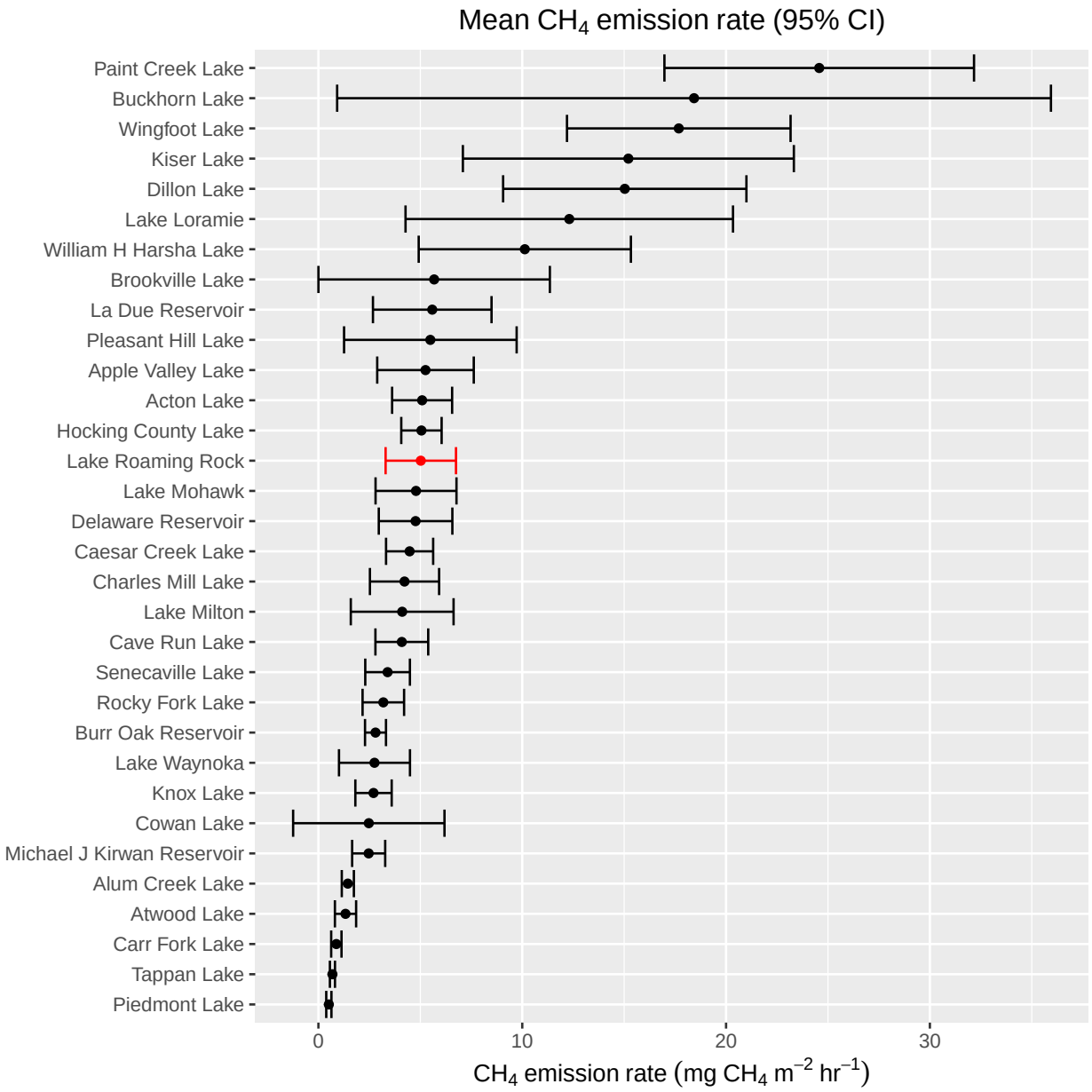

Figure 4: *Mean and 95% confidence interval (CI) of the CH_4 emission rate for each reservoir in this study, calculated from the vaules measured at >=15 sites within each reservoir.*

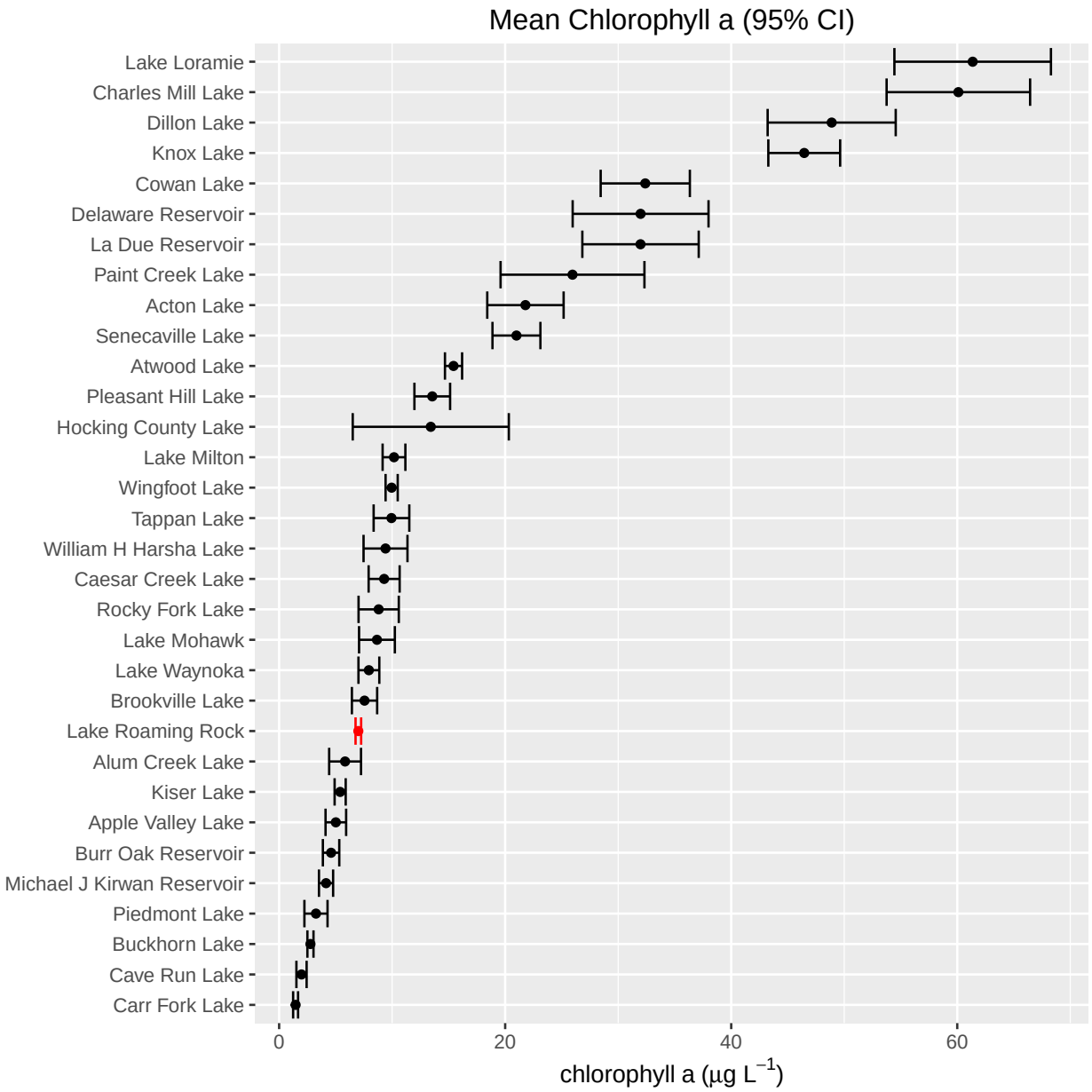

Figure 5: *Mean and 95% confidence interval (CI) of the chlorophyll a concentration for each reservoir in this study, calculated from the vaules measured at >=15 sites within each reservoir.*

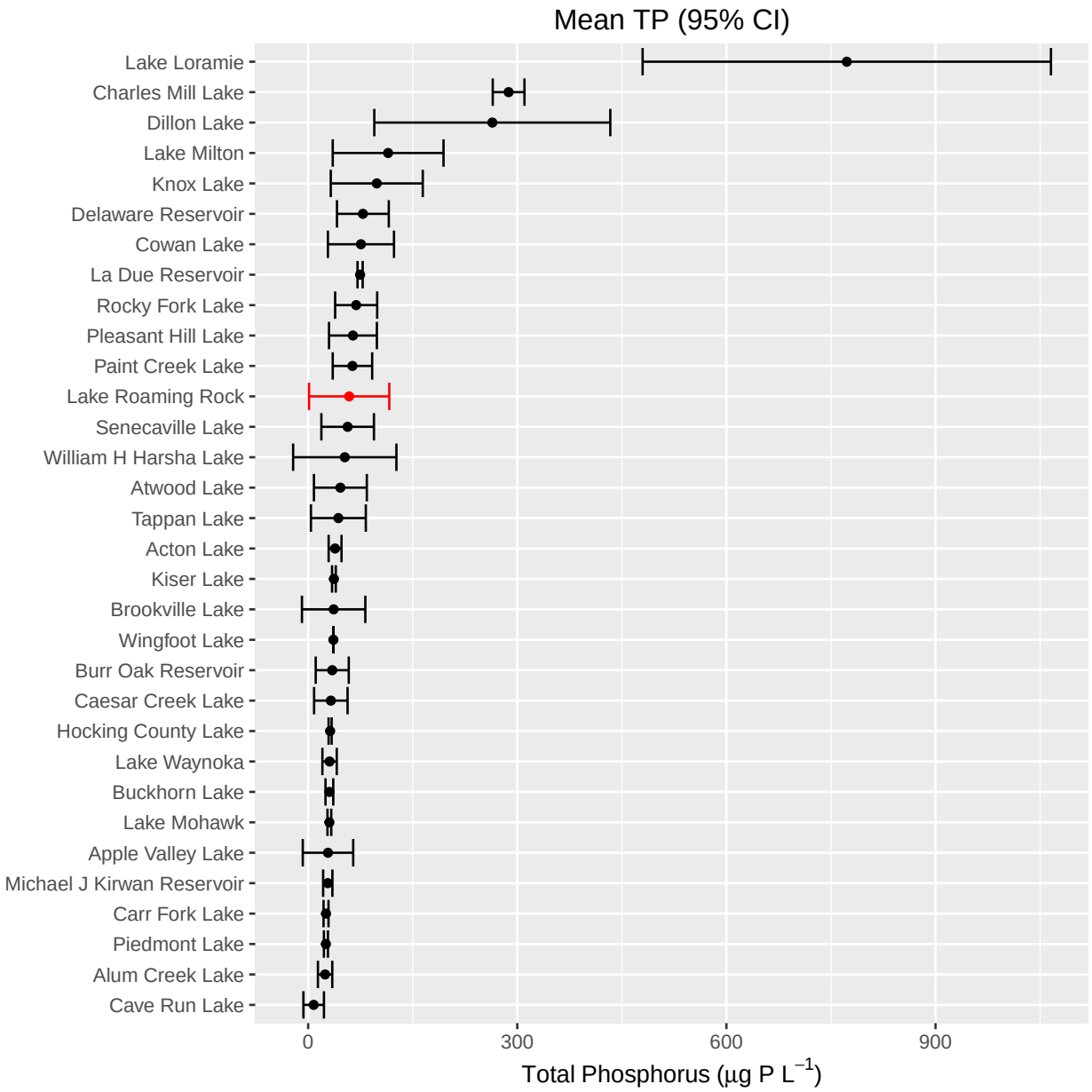

Figure 6: *Mean and 95% confidence interval (CI) of the total phosphorus (TP) concentration for each reservoir in this study, calculated from the vaules measured at >=15 sites within each reservoir.*

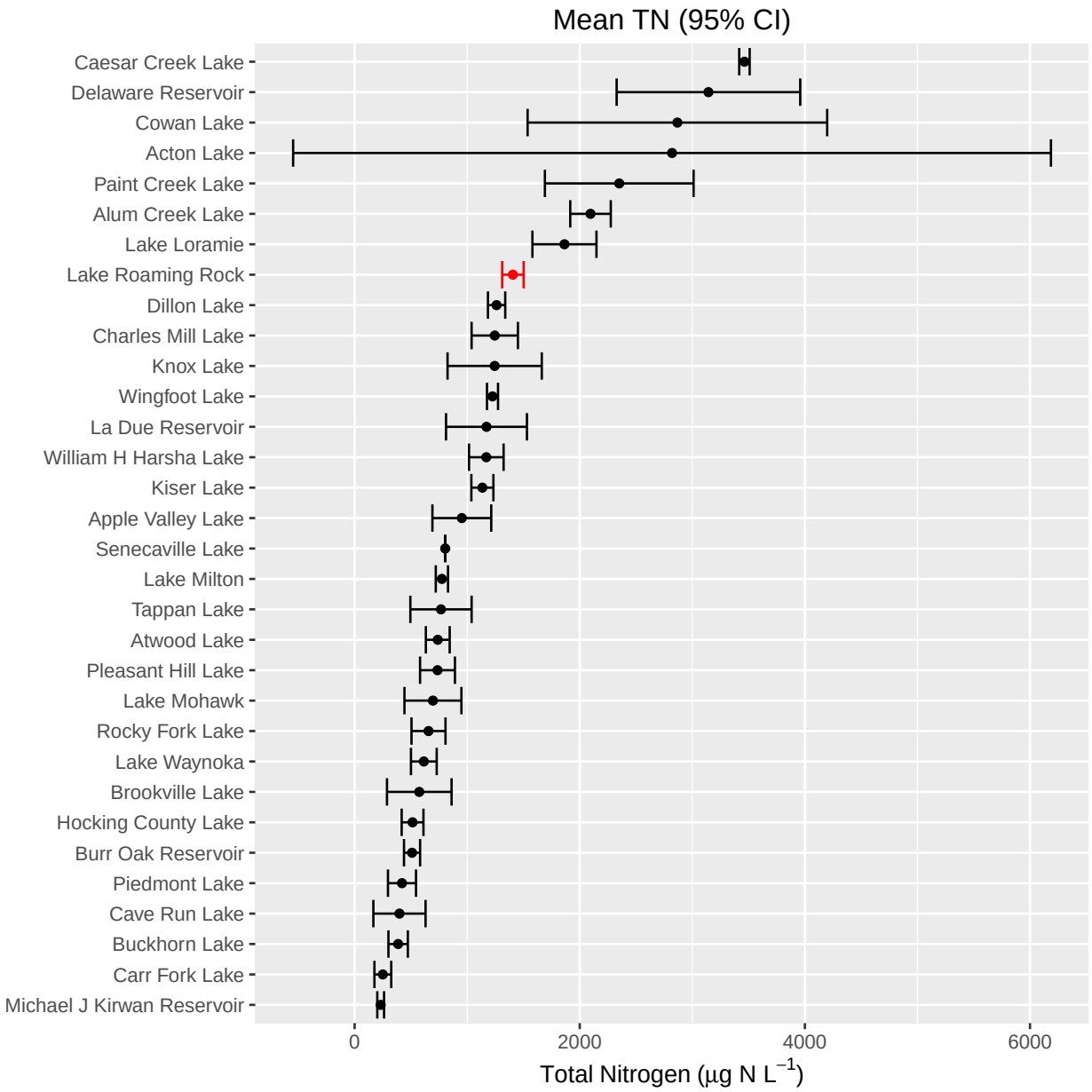

Figure 7: *Mean and 95% confidence interval (CI) of the total nitrogen (TN) concentration for each reservoir in this study, calculated from the vaules measured at >=15 sites within each reservoir.*

5. Tables of measured values at each site

Table 1: Surface (0.1 m) water quality parameters measured via sonde at each site. "Site Depth" is the measure of how deep the lake was at each site.

Site ID	Latitude	Longitude	Site Depth (m)	Chl a (ug/L)	DO (mg/L)	pH	Sp. Cond	Water Temp (C)	Turbidity
S-01	41.65053	80.83635	3.1	6.8	11.5	9.3	227	26.5	22.5
S-02	41.64946	80.81900	1.5	6.3	11.5	9.2	228	28.4	18.3
S-03	41.64252	80.83052	7.6	6.3	11.4	9.2	230	27.6	16.6
S-04	41.62803	80.82074	2.7	8.2	8.3	8.8	230	25.8	7.1
S-05	41.64844	80.83025	7.0	7.3	12.0	9.2	228	27.6	21.5
S-06	41.65032	80.82931	3.4	6.9	11.4	9.2	229	27.1	19.5
S-07	41.64163	80.82728	6.7	6.6	11.9	9.3	230	27.4	15.7
S-08	41.63526	80.82373	2.7	7.2	10.3	9.1	232	28.4	19.5
S-09	41.65454	80.83913	7.1	7.8	11.7	9.2	228	27.9	31.9
S-10	41.64222	80.82537	5.8	7.0	11.4	9.2	230	27.4	16.6
S-31	41.61346	80.81925	1.2	6.2	9.2	9.1	230	27.0	6.2
S-32	41.60979	80.81652	1.0	6.6	7.6	8.6	243	26.9	6.5
S-33	41.62570	80.82038	3.4	7.5	8.8	8.9	231	26.1	7.6
S-34	41.62185	80.81969	1.8	7.0	8.5	8.9	230	26.7	10.1
S-36	41.62472	80.82092	2.1	7.1	8.4	8.8	231	25.9	7.1

Table 2: Surface (0.1 m) water chemistry parameters measured at one shallow and one deep site. "Site Depth" is the measure of how deep the lake was at each site.

Site ID	Latitude	Longitude	Site Depth (m)	NH4 (ugN/L)	NO2.3 (ugN/L)	Total N (ugN/L)	Reactive P (ug/L)	Total P (ugP/L)
S-32	41.60979	80.81652	1.0	130	43	1480	35	103
S-09	41.65454	80.83913	7.1	12	14	1370	19	37

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.