Integrating Temperature to Improve Nutrient-based Algal Predictions Across the US

Theme 3

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Introduction

- Excess phosphorus (P) and nitrogen (N) enter water bodies through runoff increasing the concentration of nutrients.
- High nutrient levels correspond with increased algae (chlorophyll-a) measurements, producing algal blooms and degrading water quality.
- Predicting chlorophyll-a from only the total P and N levels in lakes can suffer uncertainty.
- **Project Goal: Utilize lake water temperature to improve the accuracy of algal predictions.**

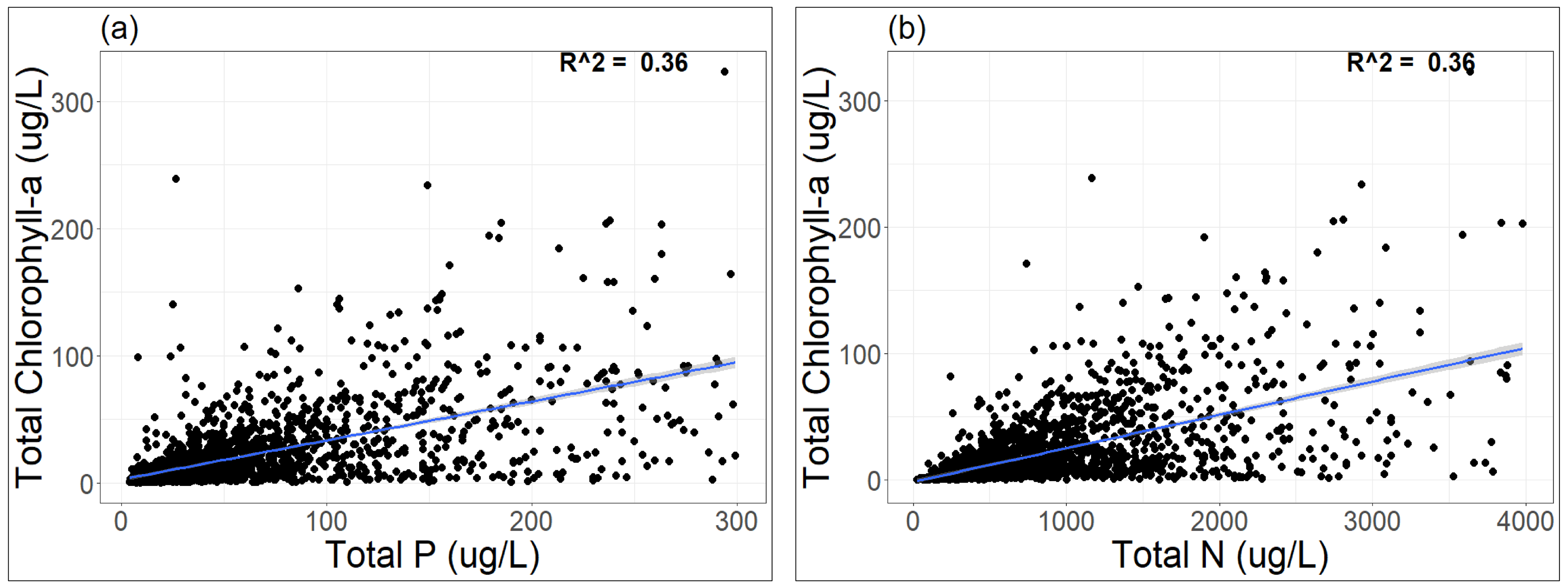

Figure 1 (a) Relationship between total P levels and total chlorophyll-a levels plotted from all NLA data. (b) Relationship between total N levels and total chlorophyll-a levels plotted from all NLA data.

Data

- **NLA** date from the years 2007-2022
  - National Lakes Assessment
  - Conducted every 5 years by the EPA
  - Gathers hydrographic and water chemistry data from over 1,000 lakes across the continental US
- Average temperature was calculated from the temperatures recorded within the first meter from the lake's surface where measurements for total P, total N, and chlorophyll were also recorded.

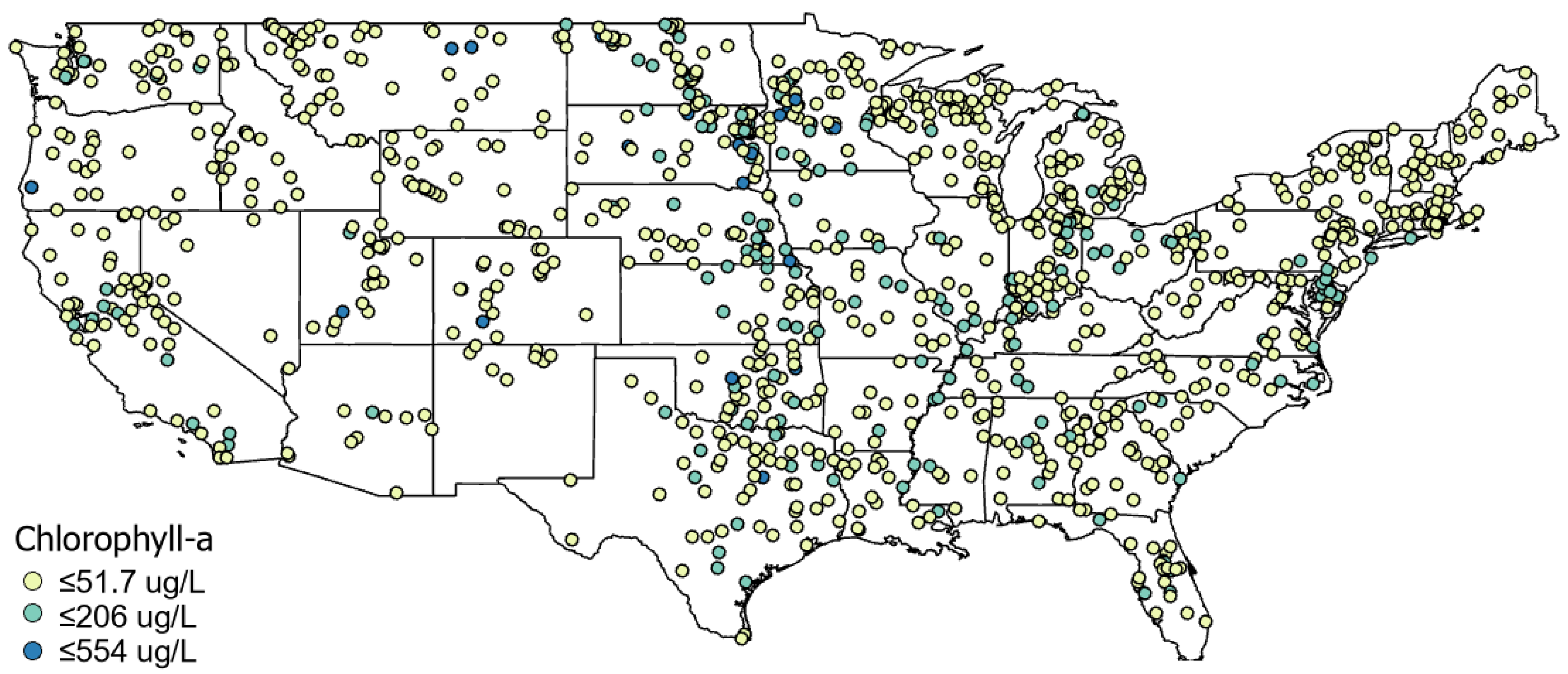

Figure 2 Chlorophyll-a concentration dispersion for the 2022 NLA data.

Methods

Table 1 Utilized NLA data and their variable representation.

NLA Data	Variable	Units
Chlorophyll-a	*chl*	µg/L
Total P	*tp*	µg/L
Total N	*tn*	µg/L
Average water temperature	*T*	°C
Limiting nutrient	*N*	µg/L
Critical ratio	*R*	

- Created multiple models using the variables from Table 1 to predict chlorophyll-a.
- Used R coding language to run the models and summarize their statistics.
- Compared R^2 value, residual standard error (RSE) and p-values.
- R = 15.33 was used to test the initial significance of the models. This value was calculated for all NLA data using the methods discussed in a paper written by Dolman and Wiedner (Dolman and Wiedner 2015)

$$N = min(\frac{tn}{R}, tp)$$

Results

1. Formulate models to test with R = 15.3

Table 2 The three initial models and their correlating RSE values, which were used to determine their significance.

Model Number	Model Structure	RSE
Model (1)	$chl = b_N \cdot N + b_0$	21.89 µg/L
Model (2)	$chl = b_N \cdot N + b_T \cdot T + b_0$	21.58 µg/L
★ Model (3)	$chl = b_N \cdot N \cdot (\frac{T}{(b_T+T)}) + b_0$	21.43 µg/L

2. Parametrize R in chosen model

Model (2b)

$$chl = b_N \cdot [min(\frac{tn}{R}, tp)] \cdot (\frac{T}{(b_T+T)}) + b_0$$

RSE = 21.34 µg/L

Table 3 The parameter estimates and p-values for model (2b).

Parameter	Estimate	P-value
b_N	1.07	< 0.001
b_T	28.72	< 0.001
b_0	-1.79	0.013
R	12.82	< 0.001

3. Analyze nutrient limitation and chlorophyll change with adjusted temperature

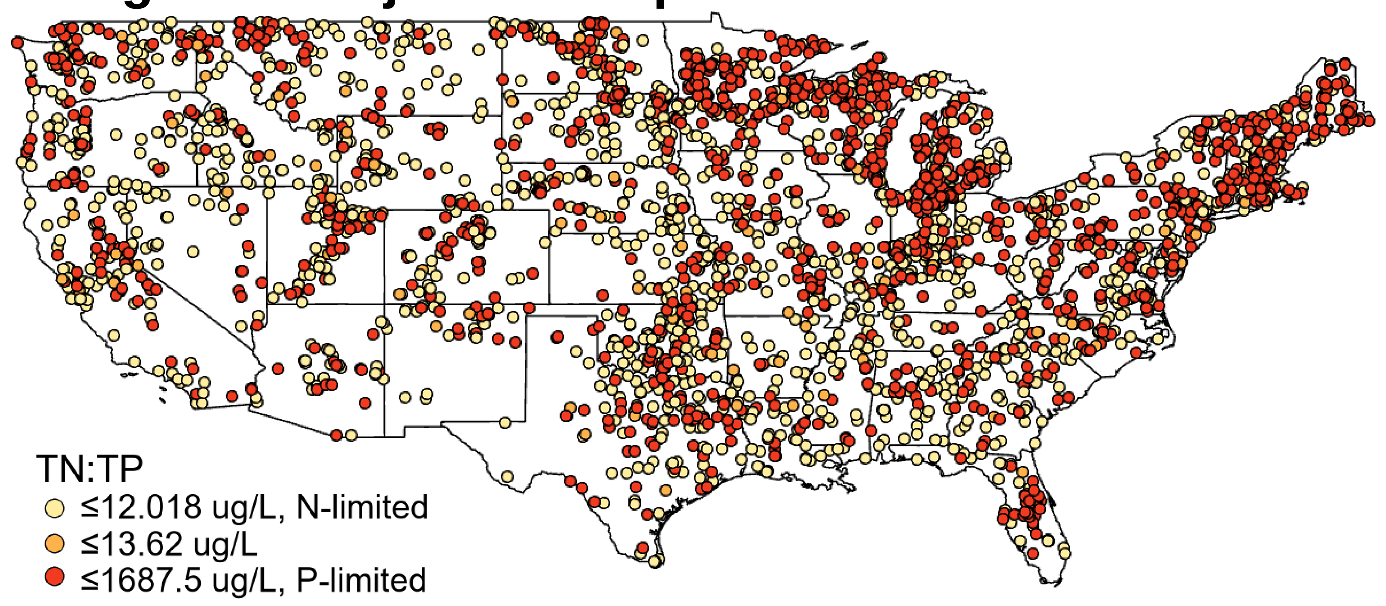

Figure 3 Nutrient limitation of all NLA data calculated from estimated critical ratio.

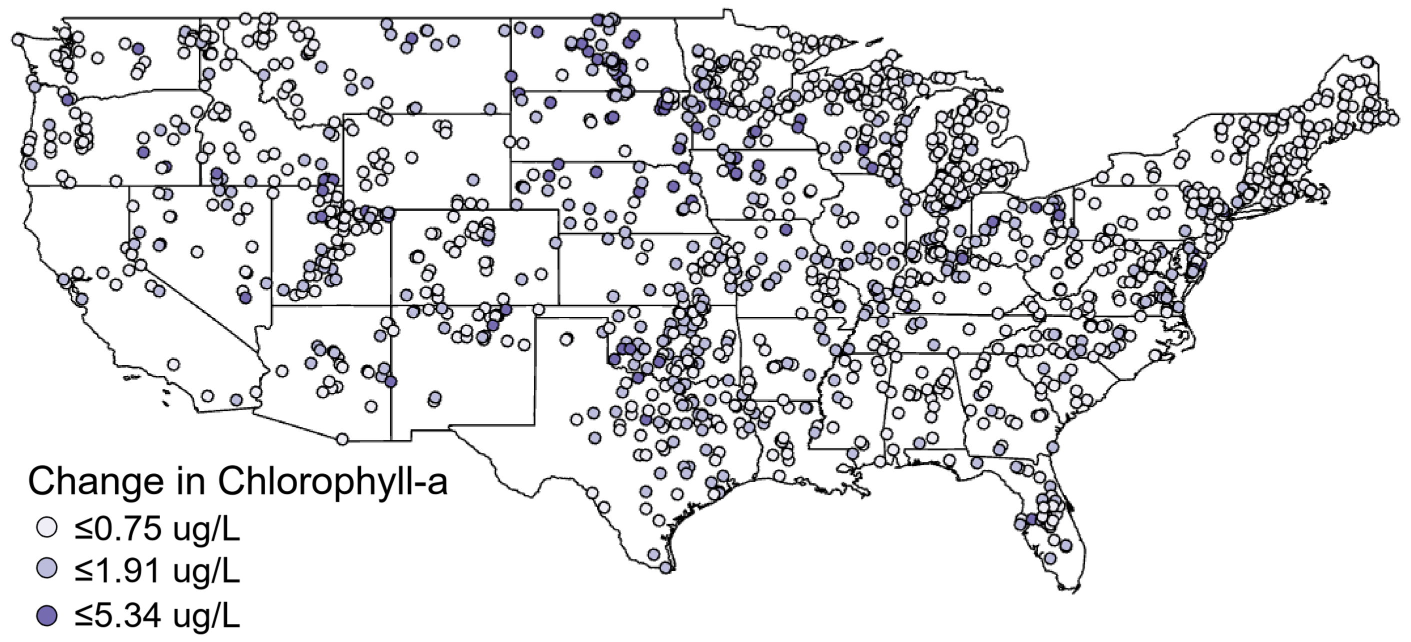

Figure 4 Change in chlorophyll between the chlorophyll concentration calculated using model 2b and chlorophyll calculated using model 2b with temperature values raised by 1.5 °C.

Next Steps

- Replacing temperature as the independent variable with other lake characteristics (depth, eutrophication level, ecoregion)
- Determine which lakes are most susceptible to changes in P concentration.

References

Dolman, Andrew M., and Claudia Wiedner. 2015. "Predicting Phytoplankton Biomass and Estimating Critical N:P Ratios with Piecewise Models That Conform to Liebig's Law of the Minimum." *Freshwater Biology* 60 (4): 686–97. https://doi.org/10.1111/fwb.12518.

US EPA, OW. 2015. "National Lakes Assessment." Overviews and Factsheets. April 13, 2015. https://www.epa.gov/national-aquatic-resource-surveys/nla.

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