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Microbial cell density and its environmental controls in 34 aquatic ecosystems across the U.S.

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Rational

Microbes are the ultimate drivers of the biogeochemical cycling of nutrients. Aquatic microbes are different from those in terrestrial systems mainly due to dispersal across habitats. The cell count of microbes in the water body may partially reflect the magnitude of microbial processes on carbon mineralization, nitrification, denitrification, etc. Meanwhile, microbial cell density can indicate the quality of the water body it inhabits. Therefore, understanding the microbial cell count in water bodies and its major controls at a regional scale can provide important information for understanding ecosystem health and functions. By examining the cell count and sampled water volume across the 34 aquatic core sites within the National Ecological Observatory Network (NEON), we examined the microbial cell density and its association with water temperature, conductance, and dissolved oxygen. The biogeographic pattern of microbial cell counts in water bodies and their environmental controls are vital information for better understanding microbial roles in carbon and nutrient cycling in aquatic ecosystems across the space under the changing climate.

Methodology – Site information

Figure 1. Location of sampling sites from the NEON Domain

Methodology - Data processing

NEON collect data at 34 aquatic sites, including 24 wadeable streams, 7 lakes, and 3 non-wadeable rivers that are located within 19 of the 20 Domains. The aquatic sites were chosen to be representative of aquatic features and habitats in the US within each NEON Domain. Core aquatic sites are located in areas that are not significantly influenced by built structures, e.g., bridges, or human activities that may impact water quality, such as urbanization, agriculture, or wastewater effluent. Gradient aquatic sites are located in order to capture environmental gradients, such as a hydrologic continuum from headwater stream to large river.

Surface water microbes are collected 12 times per year in wadeable streams and 6 times per year in lakes and non-wadeable streams (rivers) which can be accessed from the online NEON dataset (https://data.neonscience.org/data-products/DP1.20138.001). A Python mini program was coded and used to extracted the data from NEON dataset. Based on the reported cell count and sampled water volume, we calculated the microbial cell density in the water body. Due to the inconsistent data availability across sites, the data of 2021-2022 were used for investigating seasonal variability of microbial density and its controls; the annual average of microbial density was used to investigate biogeographic patterns of microbial density. Once the data was collected, we compiled the data and used a r script to analyze the relationship of microbial cell density with water temperature, dissolved oxygen, and specific conductance. Analysis with the structural equation model approach confirms the interplay of water temperature, dissolved oxygen, and specific conductance and their impacts on microbial density in water bodies.

Site	Coordinates	State Type	Site	Coordinates	State Type
HOPB	42.47194 -72.32953	Massachusetts Core	PRPO	47.12984 -99.25315	North Dakota Core
POSE	38.89431 -78.14726	Virginia Core	PRLA	47.15909 -99.11388	North Dakota Gradient
LEWI	39.09564 -77.98322	Virginia Gradient	ARIK	39.75821 -102.44715	Colorado Core
BARC	29.67598 -82.00841	Florida Core	PRIN	33.37852 -97.78231	Texas Core
SUGG	29.68778 -82.01775	Florida Core	BLUE	34.44422 -96.62420	Oklahoma Gradient
FLNT	31.18542 -84.43740	Georgia Gradient	BLDE	44.95011 -110.58715	Wyoming Core
CUPE	18.11352 -66.98676	Puerto Rico Core	COMO	40.03496 -105.54416	Colorado Core
GUIL	18.17406 -66.79868	Puerto Rico Gradient	WLOU	39.89137 -105.91540	Colorado Gradient
CRAM	46.20967 -89.47369	Wisconsin Core	SYCA	33.75099 -111.50809	Arizona Core
LIRO	45.99827 -89.70477	Wisconsin Gradient	REDB	40.78393 -111.79789	Utah Core
KING	39.10506 -96.60383	Kansas Core	MART	45.79084 -121.93379	Washington Core
MCDI	38.94586 -96.44302	Kansas Gradient	MCRA	44.25960 -122.16555	Oregon Gradient
WALK	35.95738 -84.27925	Tennessee Core	TECR	36.95593 -119.02736	California Core
LECO	35.69043 -83.50379	Tennessee Gradient	BIGC	37.05972 -119.25755	California Gradient
MAYF	32.96037 -87.40769	Alabama Core	OKSR	68.66975 -149.14302	Alaska Core
BLWA	32.54153 -87.79815	Alabama Gradient	TOOK	68.63069 -149.61064	Alaska Gradient
TOMB	31.85343 -88.15887	Alabama Gradient	CARI	65.15322 -147.50397	Alaska Core

Table 1. Description of sampling sites taken from the NEON Domain

Results

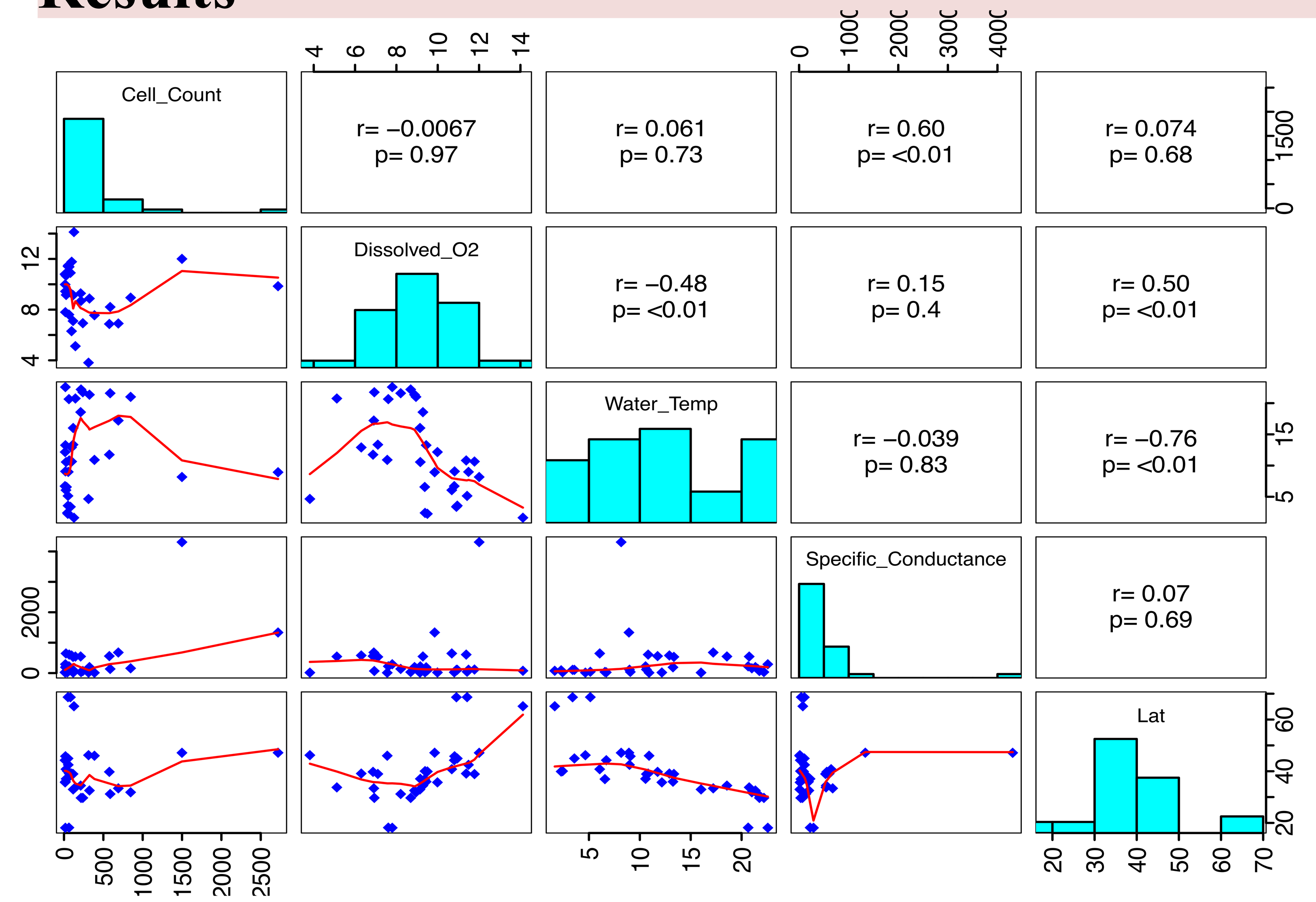


Figure 2. Correlation matrix of microbial cell density, dissolved O_2, water temperature, specific conductance, and latitude. Microbial cell count is not correlated with water temperature and latitude, indicating that temperature is not the dominant control across space. Specific conductance positively correlated with microbial cell count.

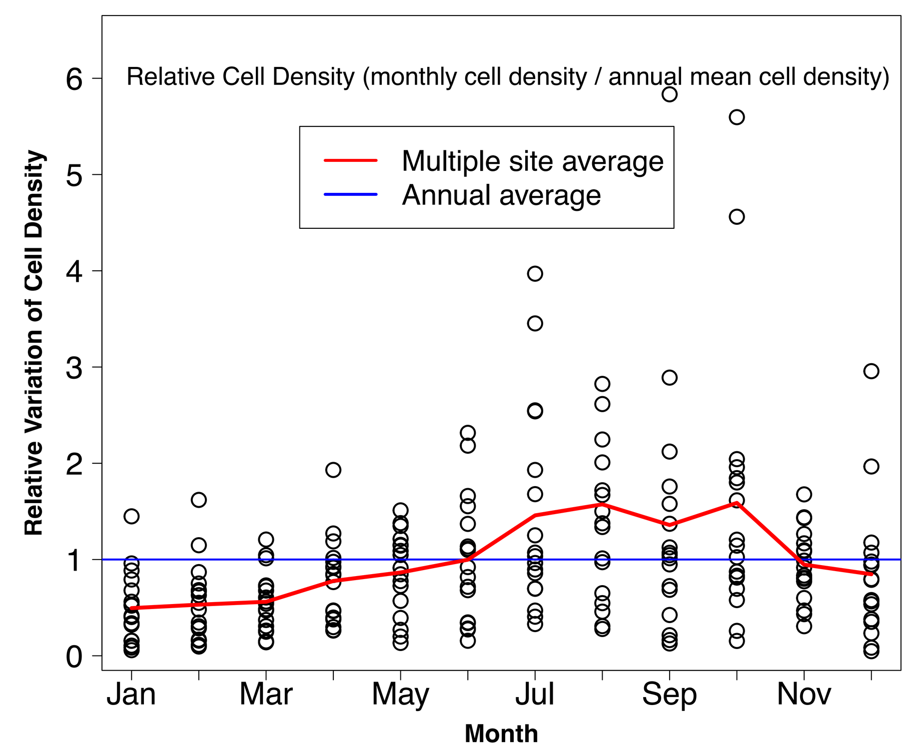
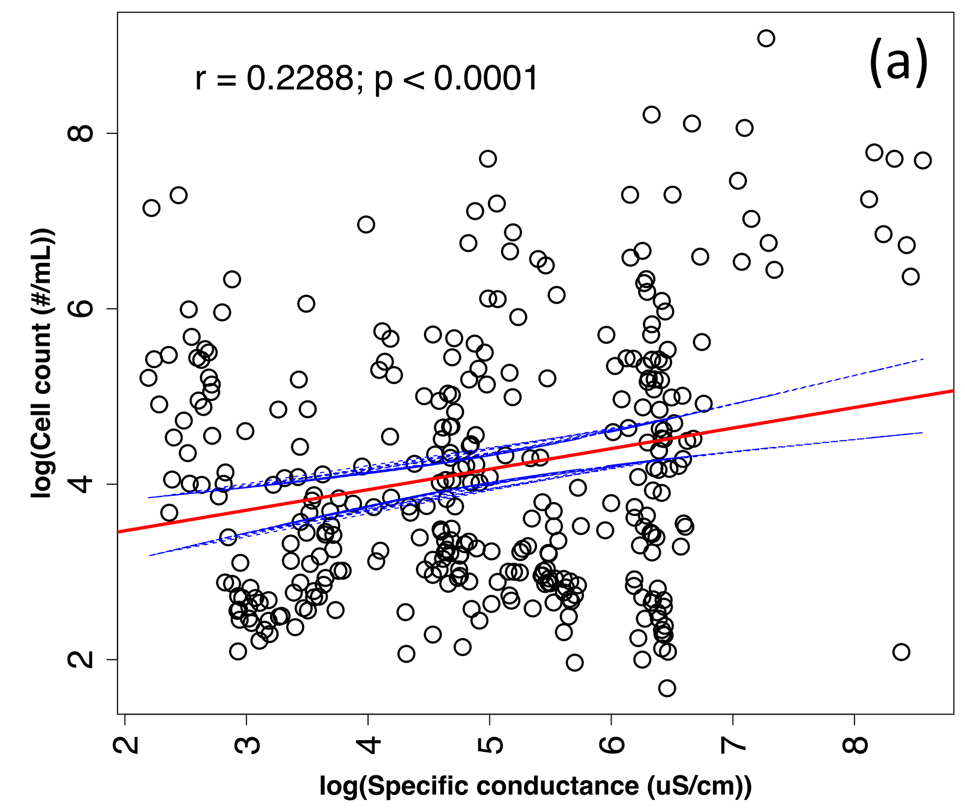
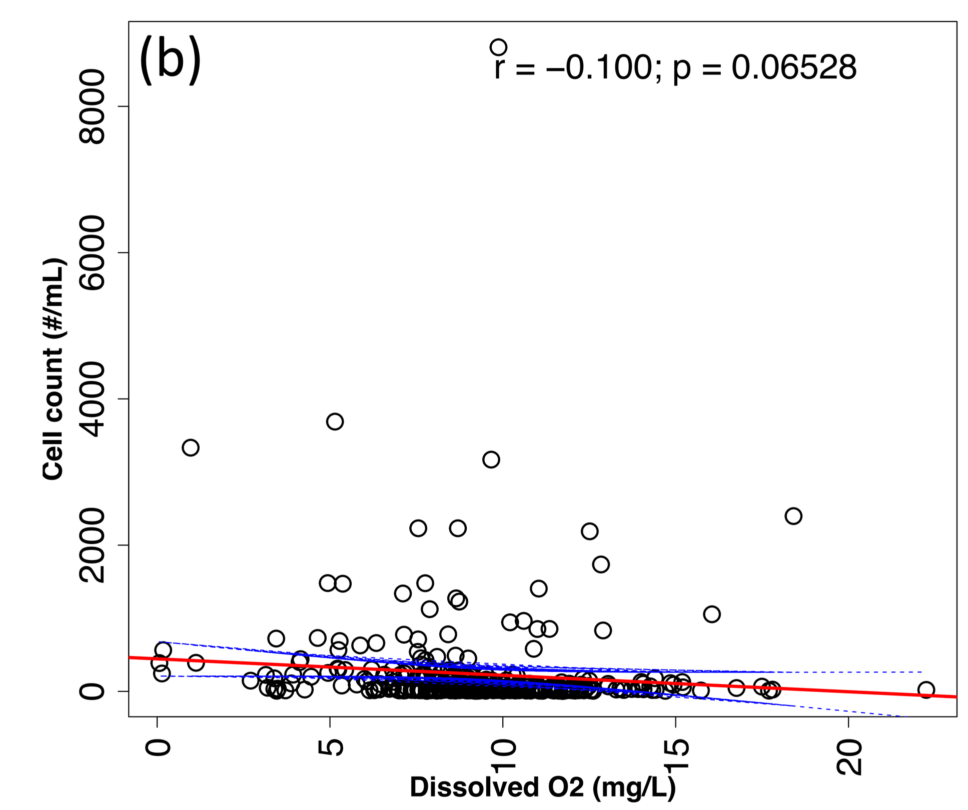


Figure 3. Relative variation of microbial cell count at monthly scale for all sites.

1) There is clear seasonality in microbial cell count in aquatic ecosystems across the 34 NEON sites across the U.S.
2) Large variation in microbial seasonality among sites.
3) The lowest microbial cell count was in January, February, and March. Recovery in microbial cell count from April, May, to June; highest in July, August, September, and October; decreases in November and December.
4) A strong association between monthly temperature and monthly microbial cell count suggests a strong temperature impact at the seasonal scale, which differs from the temperature impact across space.
5) Average 50% to 200% of microbial cell count in different months, relative to the annual mean (mean across all sites).





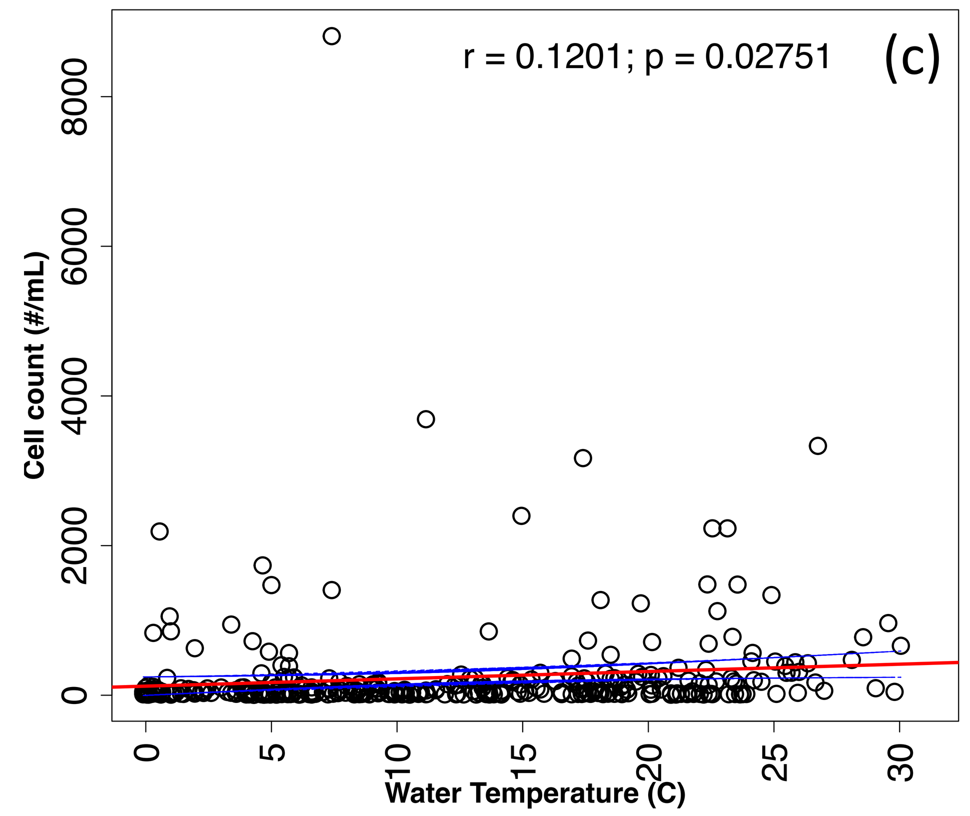


Figure 4. Correlation of microbial cell count with environmental factors, mainly specific conductance (a), dissolved oxygen (b), and water temperature (c). At a monthly scale, specific conductance and water temperature are major controlling factors on microbial cell count in aquatic ecosystems. Dissolved oxygen shows seasonality but is not correlated with microbial cell count, indicating dissolved oxygen has complicated impacts on microbial seasonality.

A negative correlation between dissolved oxygen and microbial cell count was found for a few sites (data now shown).

Take home message

1) Microbial cell density shows a pattern across space, but the spatial pattern is insignificant for the 34 sites in this study.
2) Across space, the water temperature and specific conductance are major controlling factors, with specific conductance being stronger than water temperature.
3) At a monthly scale, specific conductance and water temperature are major controlling factors on microbial cell count in aquatic ecosystems.
4) A negative correlation between dissolved oxygen and microbial cell count was found for a few sites (*data now shown*)
5) A relatively weak seasonal variation indicates microbial tolerance to environmental conditions over a season.
6) Research is needed to investigate the mechanism for these variations across space and over time.

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