BIOL 806 Final project: Spatial and seasonal analysis of chlorophyll a and phytoplankton abundance at two coastal sites in New Hampshire

Natalie Danek

Github_link

Introduction

While many of them may be too small to see with the naked eye, phytoplankton play huge roles in the marine environment. They are the base of the food web and provide food for a wide range of marine life including whales, fish and shellfish (Suthers et al., 2019). They also help filter the water, cycle nutrients, and produce oxygen. Phytoplankton concentrations can change based on the conditions of their environment. They respond to changes in parameters including light, nutrients, sediment, and pollution (Suthers et al., 2019). Phytoplankton biomass, especially picophytoplankton, have been seen to increase with temperature (Moran et al. 2010) and their average cell size tends to be smaller in warmer waters (Sommer et al., 2017). Nutrient supply and grazing also play a large role in phytoplankton size distribution (Sommer et al., 2017). Chlorophyll is the pigment that give plants and algae their green color, and allows them to capture light for photosynthesis. It is found inside of phytoplankton, therefore analyzing chlorophyll a concentrations in aquatic environments can be good indicators of phytoplankton concentrations. Analyzing trends in size and abundance of phyotplankton over time can provide insight into how that ecosystem may be changing over time.

The Jackson Estuarine Lab (JEL) is located in Durham, NH and is part of the Great Bay Estuary, which is one of the largest estuaries in New England. The Coastal Marine Lab (CML), also known as the Judd Gregg Marine Research Center, is in New Castle, NH and sits at the mouth of the Portsmouth harbor. These sites are both salt water, tidal sites but differ in how protected they are.

Objectives:

1. Compare chlorophyll a concentrations between CML and JEL in 2024.
2. Visualize the overall yearly trends in chlorophyll a concentrations at both CML and JEL in 2024.
3. See how chlorophyll a concentrations vary seasonally at CML and JEL in 2024.
4. Compare the abundance of picoeukaryotes, nanoeukaryotes, and cyanobacteria between CML and JEL in 2024.
5. Analyze how picoeukaryote, nanoeukaryote, and cyanobacteria concentrations vary seasonally at CML and JEL in 2024.

Methods

Data collection

Water samples were taken at CML and JEL off the end of the dock within thirty minutes of high tide once every week. These were brought back to the lab and analyzed for chlorophyll a, picoeukaryote, nanoeukaryote, and cyanobacteria concentrations. This work was done by members of Dr. Liz Harvey's UNH lab.

Data cleaning and organizing

To process the data I first loaded in the packages I needed to be able to organize, visualize, and statistically analyze the data (R version 4.4.0 (2024-04-24 ucrt)). I then loaded in the csv file of the data. I combined the day, month, and year columns into one "date" column. I only kept data for the two locations I was interested in - CML and JEL. I also made a new column called "Season" where I grouped months accordingly into the four seasons to be able to do seasonal analysis with the data. I focused on 2024 for this paper as that is the year with the most complete data, so I filtered the data for only that year.

Analysis of chlorophyll a data

To compare 2024 chlorophyll a concentrations between the two sites I found the mean for each site and graphed these as a bar graph. I did a t test to see if they were significantly different from each other. I then made a line graph of the raw chlorophyll a concentrations throughout the year to visualize the trends over the course of the year, faceted by site. Next I wanted to visualize and compare chlorophyll a counts by season for each site. I started with CML and made a boxplot to visualize chlorophyll a by season. I also visualized the chlorophyll a data with a histogram and qqplot to check for normality. Once I saw that the data were normally distributed, I did an ANOVA test to see if any of the seasons were significantly different. When I got a significant p value I then did a Tukey test to figure out which season was significantly different from which. I then followed this same process for the JEL data.

Analysis of cyanobacteria, picoeukaryote, nanoeukaryote data

Next, I did analysis with the cyanobacteria, picoeukaryote and nanoeukaryote data. I calculated means for each at each site and did t tests to see if each was higher on average at CML or at JEL. Next I wanted to visualize and compare these abundances by season. For each of the two sites, I grouped by season and made a boxplot of the concentrations. I then did MANOVA tests to be able to compare all three groups across the four seasons at once. Whenever I got a significant p value I then ANOVA tests and then Tukey tests to figure out which season was significantly different from which for each type of phytoplankton.

Results

Objective 1

A t test showed that there was a significant difference in chlorophyll a concentration at CML compared to JEL in 2024 (t = -6.87, p = 8.137e-11). Chlorophyll a concentrations were significantly higher at JEL compared to CML (Figure 1).

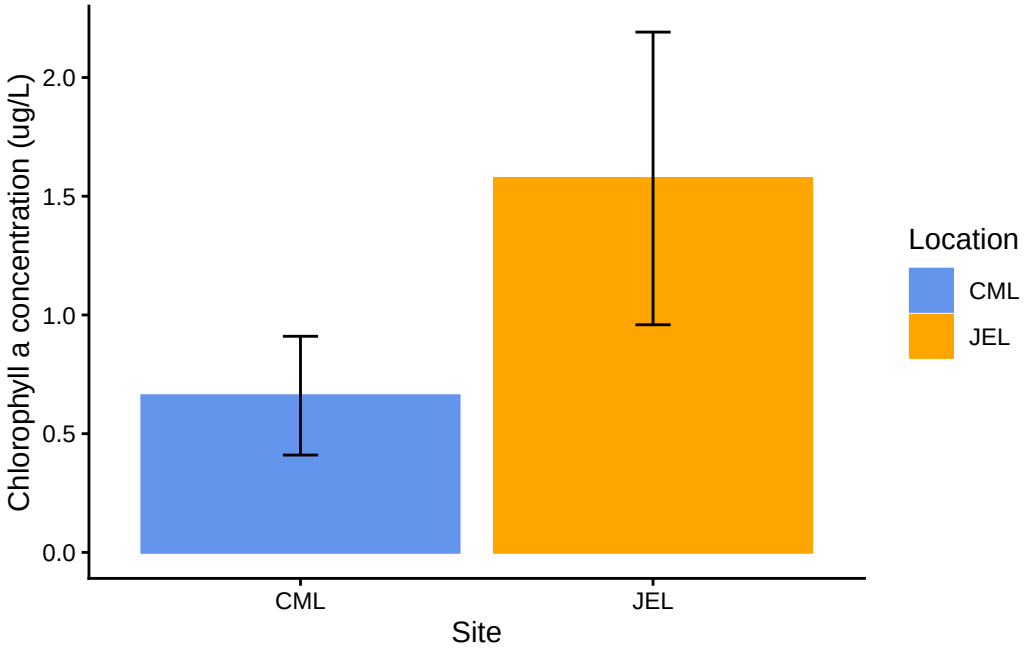

Figure 1: Bar graph of average chlorophyll a concentrations (ug/L) at CML and JEL in 2024. Error bars represent standard deviation

Objective 2

Chlorophyll a concentrations varied more at JEL than at CML, but they generally followed the same yearly trends at both sites. Both sites had a spike in May and August and some other similar, smaller spikes (Figure 2). JEL had a large spike at the end of the year, but CML did not (Figure 2).

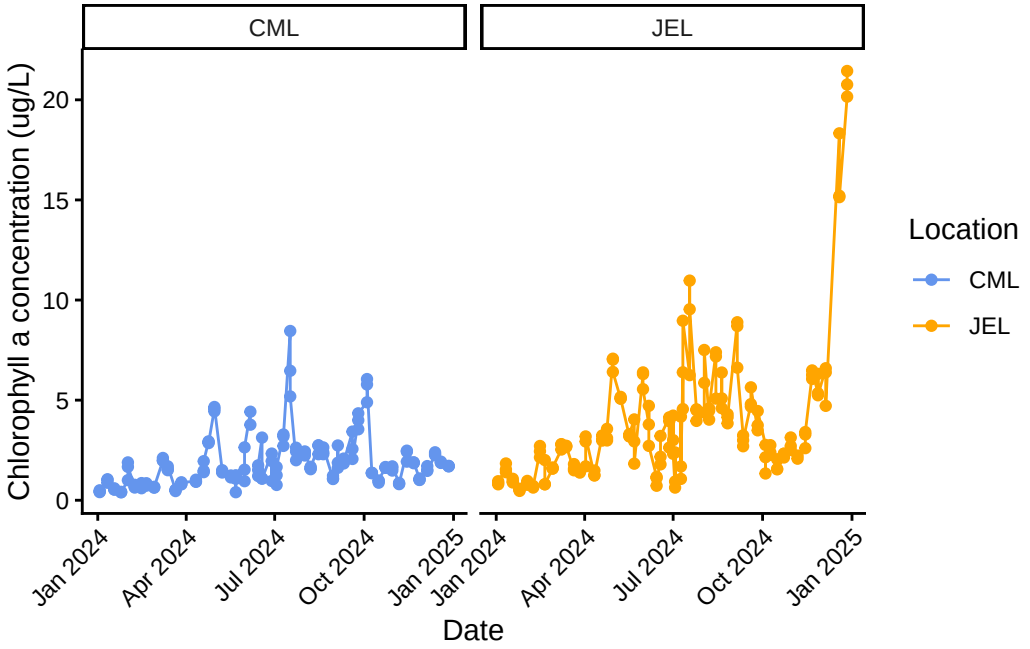

Figure 2: Line graph of weekly chlorophyll a concentrations (ug/L) at CML and JEL throughout 2024

Objective 3

Analysis of seasonal trends in chlorophyll a concentrations at CML throughout 2024 demonstrated that winter had the lowest average chlorophyll a concentrations while summer had the highest (Figure 3). A Tukey test demonstrated that winter chlorophyll a concentrations were significantly different than fall ($p = 0.0010$) as well as summer (p 0.0093 E-3), but no other seasonal comparison was significantly different. At JEL, winter also had the lowest average concentration while summer had the higher mean concentrations (Figure 4) but an ANOVA test showed that none of these seasonal comparisons were significant for that site ($p=0.495$).

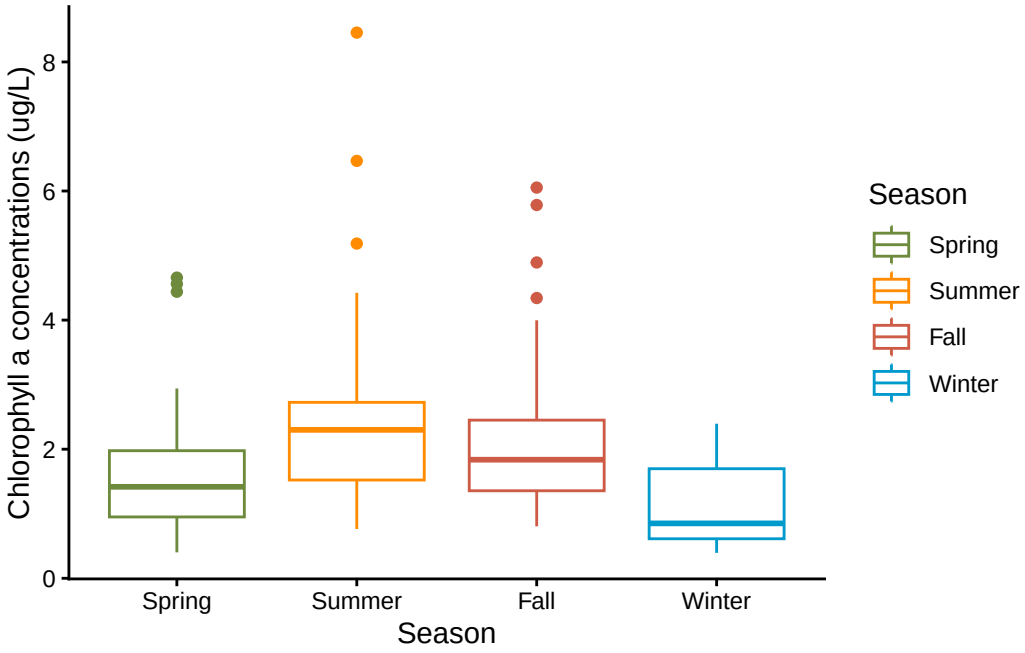

Figure 3: Boxplot of weekly chlorophyll a concentrations, grouped by season, at CML in 2024

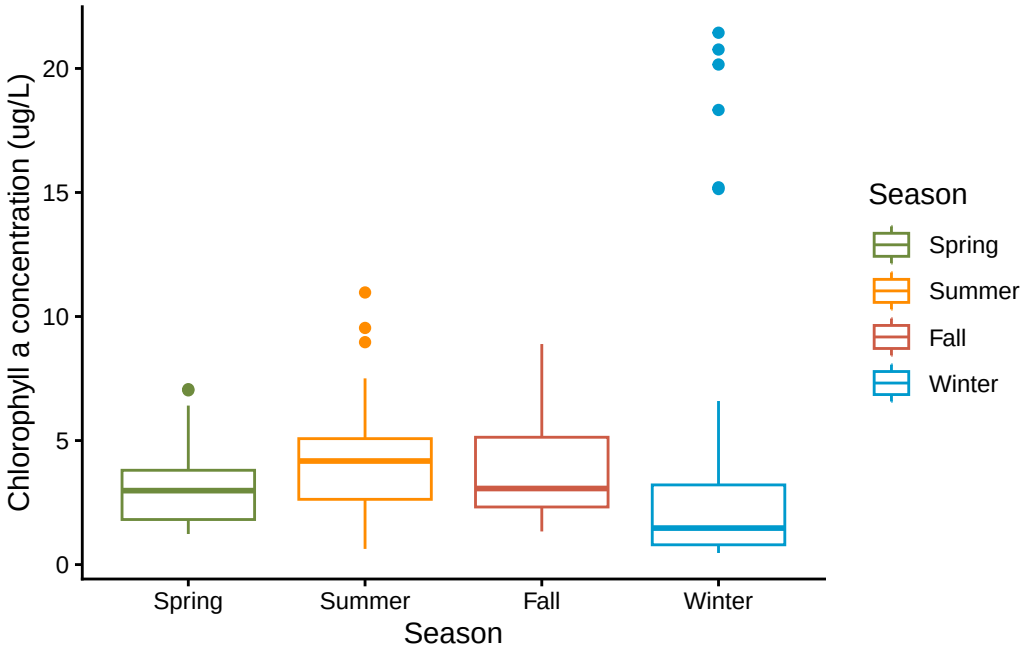

Figure 4: Boxplot of weekly chlorophyll a concentrations, grouped by season, at JEL in 2024

Objective 4

A t test to compare average cyanobacteria concentrations between CML and JEL in 2024 showed no significant difference between the sites (p = 0.7774). There was a significant difference in nanoeukaryote concentrations between the two sites (p = 0.0004), with JEL having a higher concentration (Figure 5). There was also a significant difference in picoeukaryote concentrations between the two sites in 2024 (p = 0.0105), with JEL having higher concentrations (Figure 5).

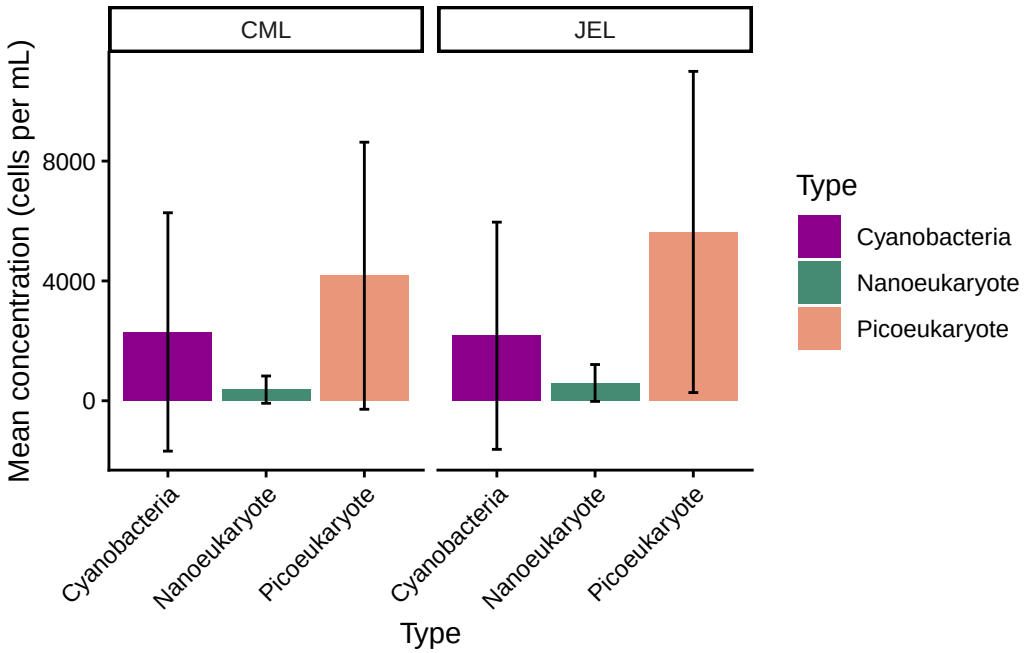

Figure 5: Bar graph of mean cyanobacteria, nanoeukaryote and picoeukaryote concentrations at CML and JEL in 2024. Error bars represent standard deviation

Objective 5

At CML, average cyanobacteria concentrations were highest in the winter and lowest in the fall (Figure 6). A Tukey test showed that winter was significantly different from spring (p = 0.0058) and fall (p = 0.0004). Nanoeukaryote concentrations were highest in the summer and lowest in the winter (Figure 6). A Tukey test showed that summer was significantly different from fall (p = 0.0024) and winter (p = 0.0007). Picoukaryote concentrations were highest in the spring and summer and lowest in the fall (Figure 6). Fall was significantly different from spring (p = 0.0006), summer (p = 0.0010) and winter (p = 0.0025 E -3).

At JEL, cyanobacteria concentrations were highest in the winter and lowest in the fall (Figure 6).An Tukey test was used to show that winter was significantly different from summer (p

= 0.0022) and from fall (p = 0.0016E-2) . Nanoeukaryote concentrations were highest in the summer and lowest in the fall and winter (Figure 6) but an ANOVA test showed that none of the seasons were significantly different from one another (p = 0.1258). Picoeukaryote concentrations were highest in the winter and lowest in the fall (Figure 6). A Tukey test showed that fall was significantly different from summer (p = 0.0004) and from winter (p = 0.0008).

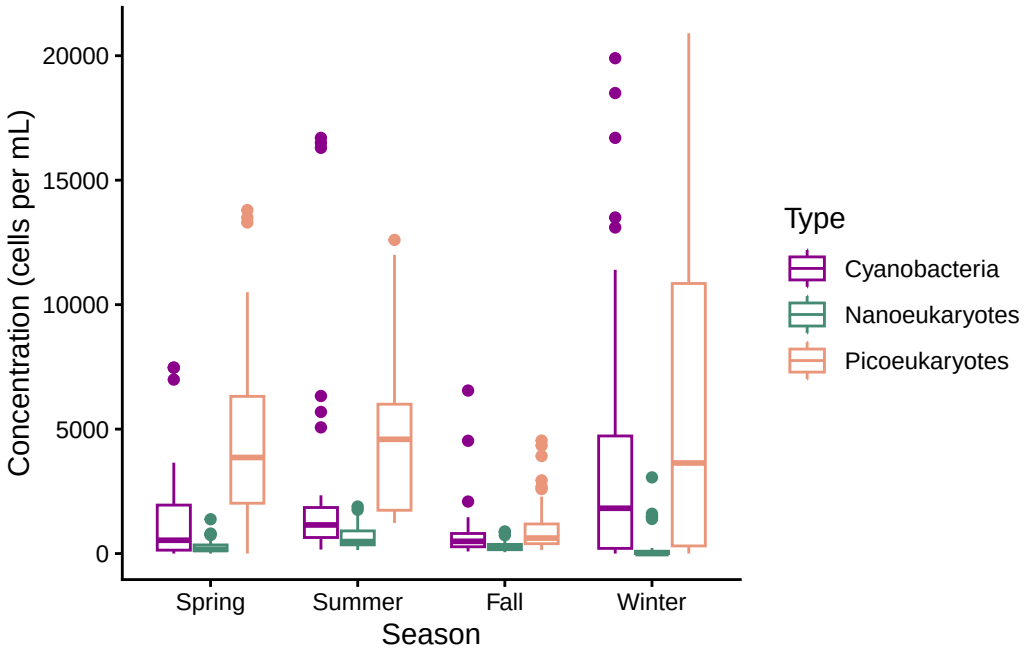

Figure 6: Boxplot of weekly picoeukaryote, nanoeukaryote, and cyanobacteria concentrations, grouped by season, at CML in 2024

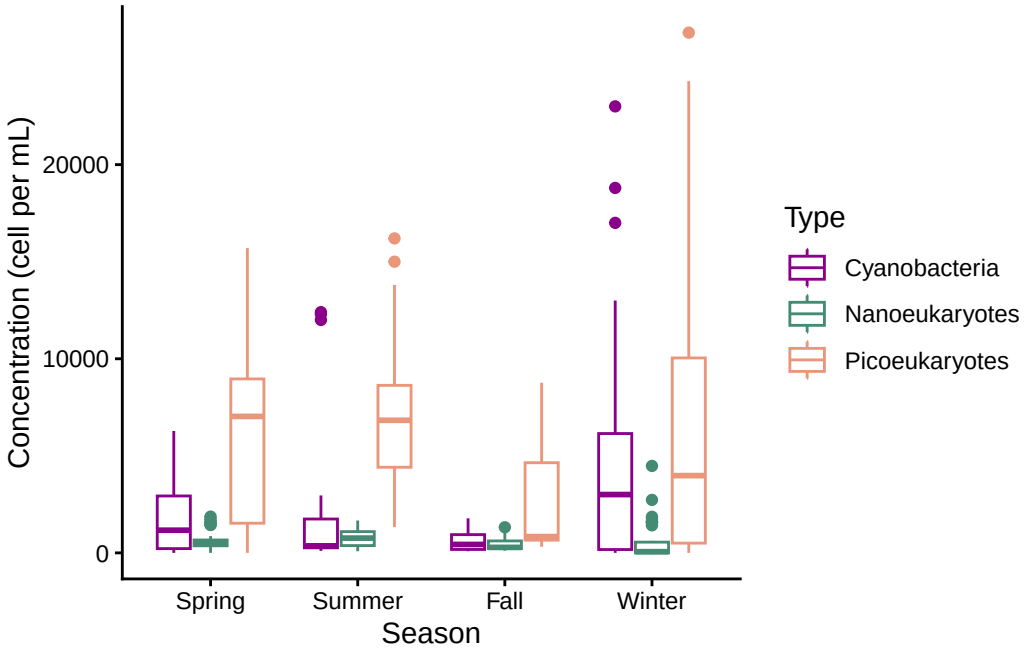

Figure 7: Boxplot of weekly picoeukaryote, nanoeukaryote, and cyanobacteria concentrations, grouped by season, at JEL in 2024

Discussion

Throughout 2024, chlorophyll a concentrations showed some similar trends at CML and JEL. There were spikes at similar times of the year, likely due to some environmental factor that affected both sites. This could be a heavy rainfall event or change in temperature. JEL had significantly higher concentrations overall. A large spike at the end of the year contributed to this difference; this spike was not observed at CML. So, there was some environmental factor that effected JEL but not CML in December. Since these sites are only about twenty miles apart they experience very similar weather and climate so this difference is not likely due to be one of those. This difference may be due to some input from local runoff that affects one site and not the other. This could have affected the nutrient load in that area, and therefore the chlorophyll a concentrations. Average chlorophyll a concentrations were lowest in the winter and highest in the summer at both sites. This suggests a correlation with temperature, which follows a very similar seasonal pattern.

Cyaanobacteria concentrations and seasonal trends were very similar at both sites. They were significantly highest in the winter so they may do better in colder water temperatures, or low nutrient waters. Both sites also had similar seasonal trends in nanoeukaryote concentrations, with them being highest in the summer and lowest in the fall and winter. So these may do better in warmer water temperatures. Both sites had the lowest picoeukaryote concentrations

in the fall. This could be due to lower amounts of runoff happening in the fall, therefore lower nutrients being added to the water then. Picoeukaryote and nanoeukaryote concentrations were both higher at JEL than at CML. This could be related to JEL having higher chlorophyll a concentrations.

This analysis is limited to just one year of data, so further analysis could include a longer timespan. It would be interesting to see if there are any other major spikes in chlorophyll a concentration like what was seen in December at JEL, and to see how long that spike stayed elevated into the beginning of 2025. It would be useful to pair this data with water quality parameters such as temperature, salinity, and nutrient loads to see which are correlated with these trends in phytoplankton abundance.

References

Garrett Grolemund, Hadley Wickham (2011). Dates and Times Made Easy with lubridate. Journal of Statistical Software, 40(3), 1-25. URL https://www.jstatsoft.org/v40/i03/.

Oksanen J, Simpson G, Blanchet F, Kindt R, Legendre P, Minchin P, O'Hara R, Solymos P, Stevens M, Szoecs E, Wagner H, Barbour M, Bedward M, Bolker B, Borcard D, Borman T, Carvalho G, Chirico M, De Caceres M, Durand S, Evangelista H, FitzJohn R, Friendly M, Furneaux B, Hannigan G, Hill M, Lahti L, Martino C, McGlinn D, Ouellette M, Ribeiro Cunha E, Smith T, Stier A, Ter Braak C, Weedon J (2025). *vegan: Community Ecology Package*. R package version 2.7-2, https://CRAN.R-project.org/package=vegan.

R Core Team (2024). *R: A Language and Environment for Statistical Computing*. R Foundation for Statistical Computing, Vienna, Austria. https://www.R-project.org/.

Sommer, U., Peter, K. H., Genitsaris, S., & Moustaka-Gouni, M. (2017). Do marine phytoplankton follow Bergmann's rule sensu lato? *Biological Reviews*, *92*(2), 1011–1026. https://doi.org/10.1111/brv.12266

Suthers, I., Rissik, D., & Richardson, A. (2019). *Plankton: A Guide to Their Ecology and Monitoring for Water Quality*. Csiro Publishing. Google-Books-ID: e8uPDwAAQBAJ

Wickham H, Averick M, Bryan J, Chang W, McGowan LD, François R, Grolemund G, Hayes A, Henry L, Hester J, Kuhn M, Pedersen TL, Miller E, Bache SM, Müller K, Ooms J, Robinson D, Seidel DP, Spinu V, Takahashi K, Vaughan D, Wilke C, Woo K, Yutani H (2019). "Welcome to the tidyverse." *Journal of Open Source Software*, *4*(43), 1686. doi:10.21105/joss.01686 https://doi.org/10.21105/joss.01686.

Wickham H, ggplot2: Elegant Graphics for Data Analysis. Springer-Verlag New York, 2016.

Wickham H, François R, Henry L, Müller K, Vaughan D (2023). *dplyr: A Grammar of Data Manipulation*. R package version 1.1.4, https://CRAN.R-project.org/package=dplyr.

Wickham H, Vaughan D, Girlich M (2024). *tidyr: Tidy Messy Data*. R package version 1.3.1, https://CRAN.R-project.org/package=tidyr.