Examining the Relationship between Flow and Nutrient Levels at Upstream and Downstream Locations along Ellerbe Creek, North Carolina

https://github.com/rml41/EDA_2020_Project.git

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1 Rationale and Research Questions

Ellerbe Creek runs into the Falls Lake Resovoir, through the city of Durham, North Carolina. Falls Lake serves as the source of drinking water for the City of Raleigh and does not meet North Carolina standards for *chlorophyll a*, which is found in algae (SOURCE: https://durhamnc.gov/716/Falls-Lake). Algal blooms generally come from excess nutrients such as phosphorus and nitrogen. Ellerbe Creek is one of the sources of excess nutrients and contaminents in Falls Lake. The Ellerbe Creek Watershed has the highest population density of Durham's watersheds, with an estimated 22% impervious surface (SOURCE: https://files.nc.gov/ncdeq/Water%20Quality/Planning/BPU/BPU/Neuse/Neuse%20Plans/2009%20Plan/Chapter%201.pdf). It is impacted by both point and nonpoint sources and was found to deliver the highest nutrient loads to Falls Lake (SOURCE: https://files.nc.gov/ncdeq/Water%20Quality/Planning/BPU/BPU/Neuse/Neuse%20Plans/2009%20Plan/Chapter%201.pdf). Ellerbe Creek and Falls Lake are both on the state's impaired water bodies list (303(d) list) (SOURCE https://durhamnc.gov/711/Ellerbe-Creek-Watershed, https://www.usgs.gov/centers/sa-water/science/groundwatersurface-water-interaction-near-ellerbe-creek-durham-nc?qt-science_center_objects=0#qt-science_center_objects). Ellerbe Creek was first listed on the 303(d) list in 1998 (SOURCE: https://files.nc.gov/ncdeq/Water%20Quality/Planning/BPU/BPU/Neuse/Neuse%20Plans/2009%20Plan/Chapter%201.pdf)

**This analysis and report will aim to answer the following questions: 1. Are Nitrogen and Phosphorus levels in Ellerbe Creek above recommended levels? 2. Is there a relationship between flow and Nitrogen or Phosphorus levels? 3. How does location, upstream vs. downstream, impact nutrient levels? 4. Is there a significant difference between discharge at the upstream and downstream gages? 5. Is time of year, specifically month a predictor forflow or nutrient levels?

2 Dataset Information

Nutrient data for this project were downloaded from the the Water Quality Portal, a coorperative service sponsered by the United States Geological Survey (USGS), the Environmental Protection Agency (EPA), and the National Water Quality Monitoring Council (NWQMC) on February 27, 2020. Discharge data were downloaded for two stream gages along Ellerbe Creek, HUC code 030202010403, from USGS using the data dataRetrieval package in R. The dataset analyzed contains 21 monitoring locations with measurments for nitrogen and phosphorus levels from 1982 to 2018 and daily discharge data from 2008 to 20202. Not all locations had data for each nutrient. Nitrogen and Phosphorus concentrations are recorded as mg/L of Nitrogen or Phosphorus in various compounds including, nitrate, nitrite, ammonia, ammonium, organic nitrogen, phosphate, and organic phosphorus. The USGS gage locations are Club Blvd (0208675010), upstream, and Gorman (02086849), downstream.

Variable	Units	Range	Mean	Median	Source
Nitrogen	mg/L N	0.37 - 33.00	7.18	2.82	NC DENR and USGS
Phosphorus	mg/L P	0.039 - 17.00	1.091	0.157	NC DENR and USGS
Discarge Club	ft^3/s	0.20 - 781.00	9.39	1.28	USGS
Discharge Gorman	ft^3/s	7.52 - 1750.00	48.84	20.50	USGS

2.1 Discharge Data Wrangling

Flow data from the two USGS stream gages were combined in two data sets, one as a long format with all discharge in one column and one in wide format, with two seperate columns for discharge based on location.

2.2 Nutrient Data Wrangling

The nutrient data set from the water quality portal was cleans to remove all irrelevant information and retain just characterstics of interest, Nitrogen and Phosphorus. Nitrogen and Phosphorus values for many samples were recorded as both mg/L of N and P, and of NO3 and PO4 respectively. Data were downloaded in long format and were converted to wide format in order to convert Nitrogen and Phosphorus values to mg/L of N or P. Relevant columns such as data, location, hydrologic event, variable name, measured value, and units were selected and processed data were saved as both long and wide format.

3 Exploratory Analysis

3.1 Initial Exploration

Explored raw data from the water quality portal to determine potential variables for analysis and time period of data. Examined a summary of all the characteristics in the dataset to determine the count for each variable. Selected Nitrogen, mixed forms (NH3), (NH4), organic, (NO2) and (NO3) and Phosphorus as the two variables to analyze. Explored discharge data to determine date range of data.

Table 2. Sample of summary results from raw data

Variable	Count
Dissolved Oxygen	636
Nitrate	128
Nitrogen, mixed forms (NH3), (NH4), organic, (NO2) and (NO3)	209
Phosphorus	286
RBP Stream Width	14
Temperature, water	1146
Total Dissolved Solids	278

3.2 Location of Monitoring Sites

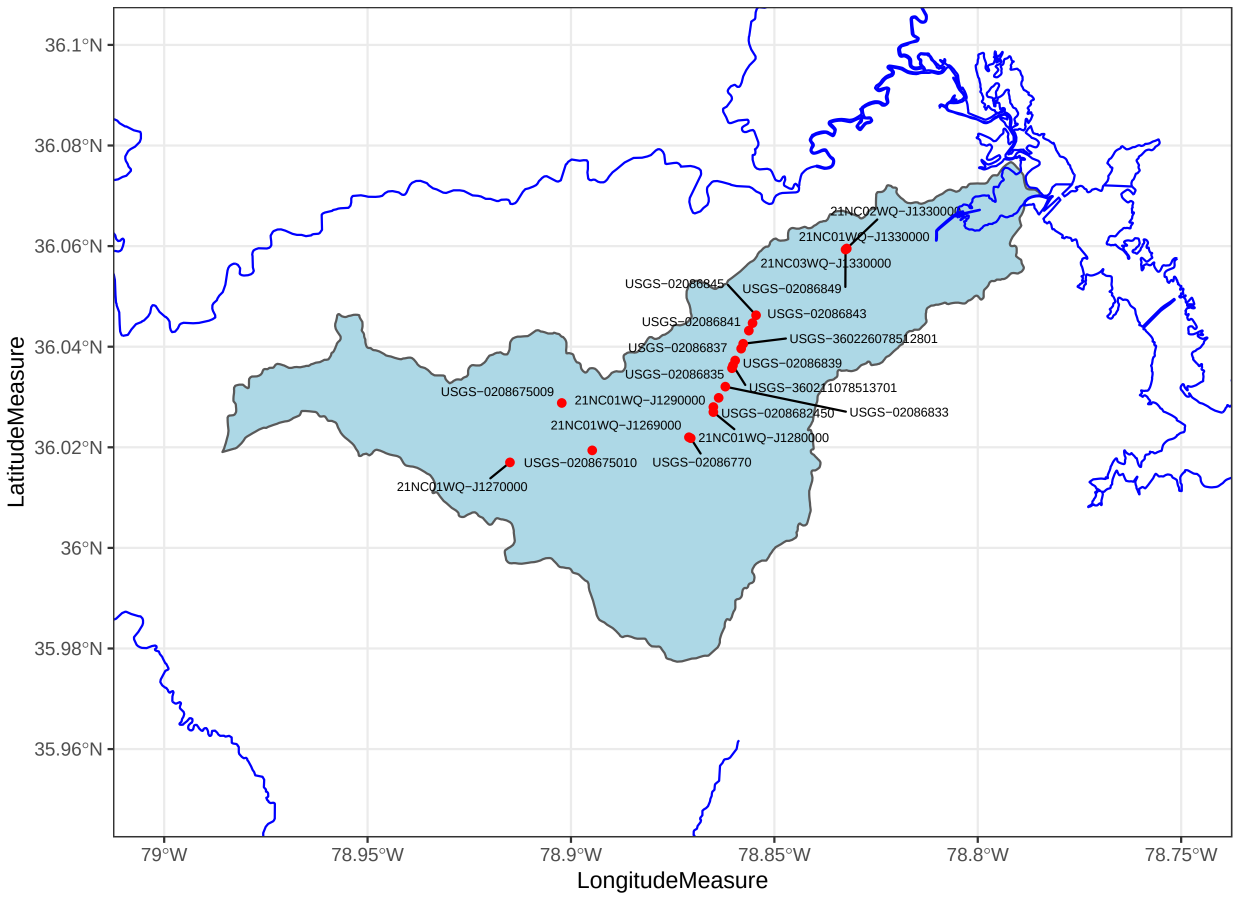

Figure 1: Map of the Ellerbe Creek Watershed and Monitoring Locations along Ellerbe Creek

3.3 Discharge Data Exploration

A boxplot was made to visualize the range of discharge at each site (Fig. 2). The distribution shows that the max discharge from 2008-2020 is higher at the downstream location (2086849) than the upstream location (208675010), but it is not obvious if the mean is different. This led to running statistical analysis to determine if the difference in average discharge is significant. If there is a significant difference in discharge between upstream and downstream, that could influence the nutrient levels at each site.

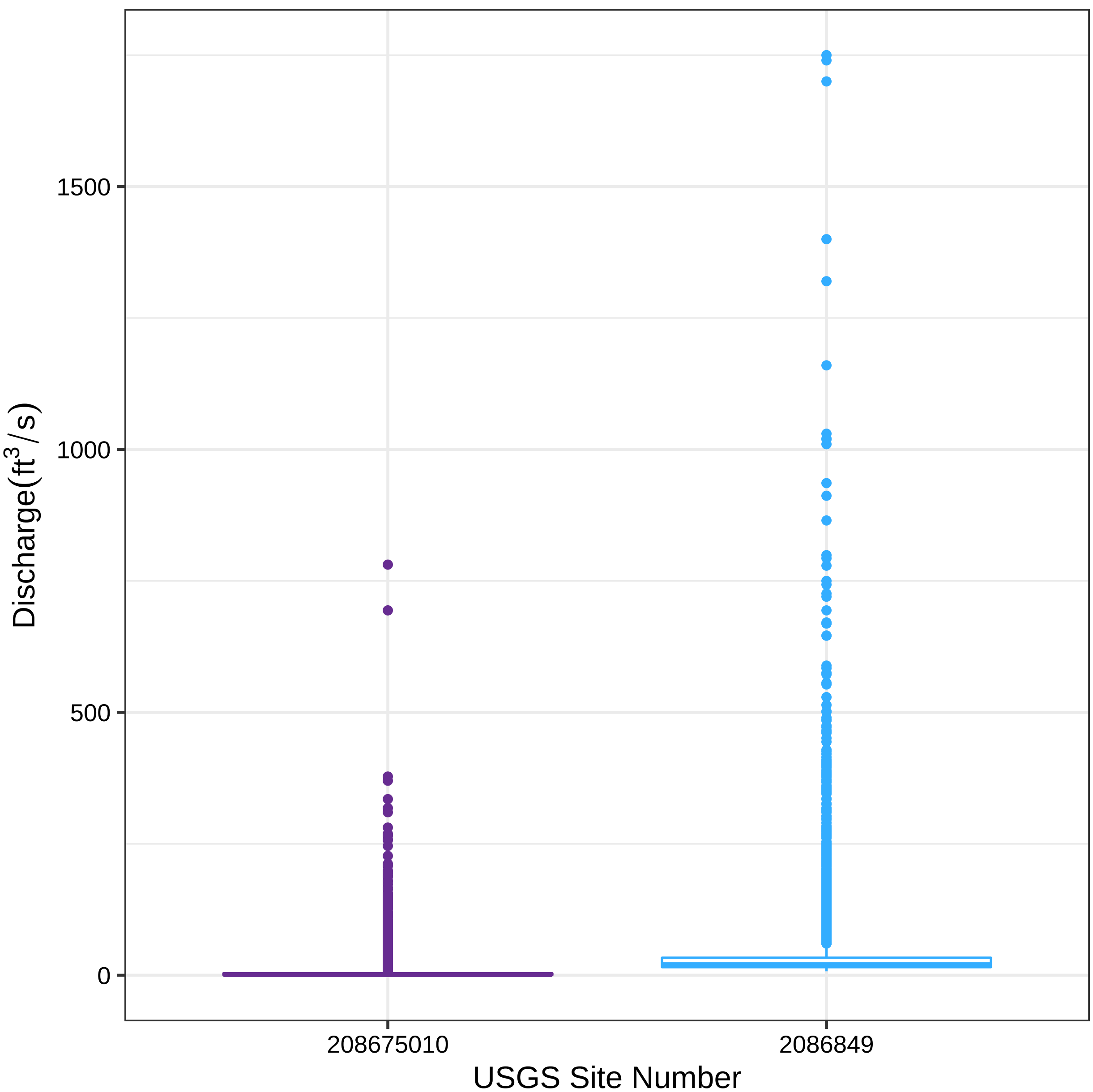

Figure 2: Distribution of discharge at two sites, upstream (208675010) and downstream (2086849) along Ellerbe Creek from January 1, 2008 to April 17, 2020

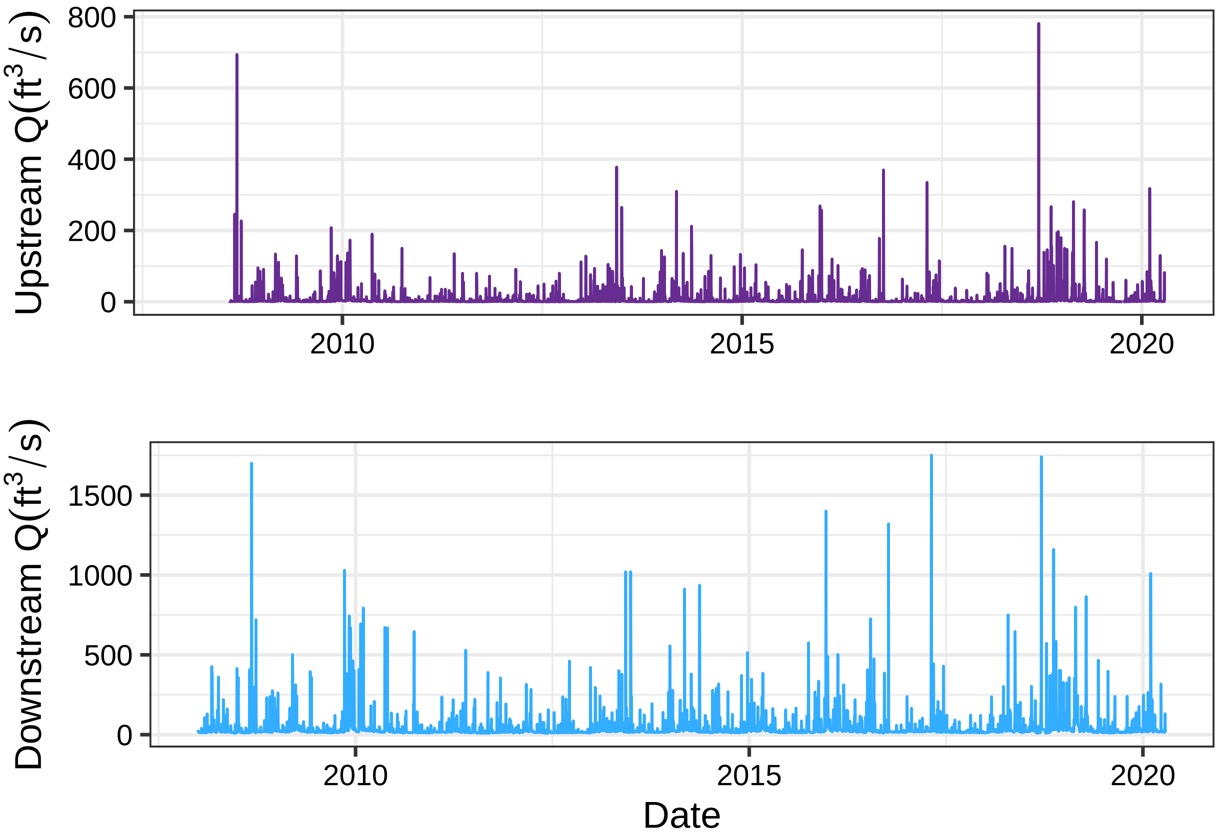

Figure 3: Daily discharge (Q) at along Ellerbe Creek from January 1, 2008 to April 17, 2020

The discharge over time at each location does not show any obvious seasonal or annual trends (Fig. 3).

3.4 Nutrient Data Exploration

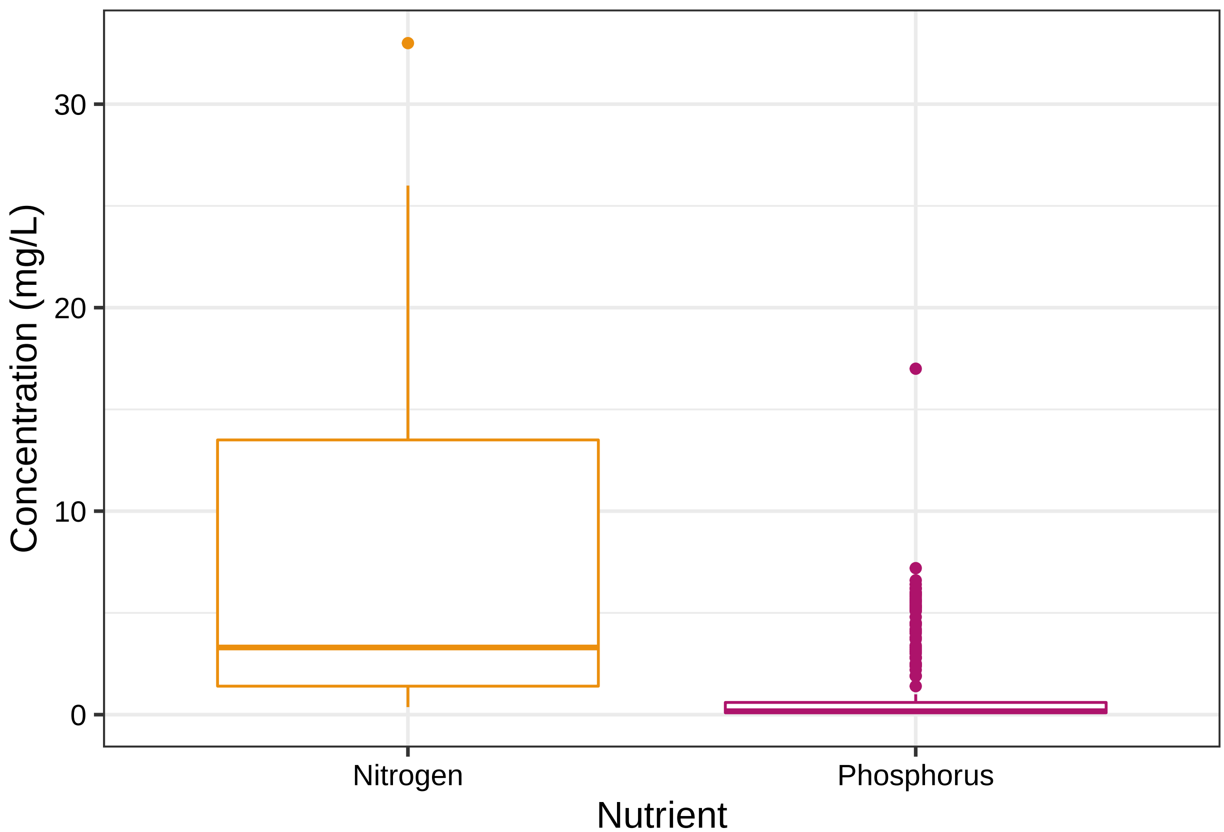

Figure 4: Distribution of Nitrogen and Phosphorus Concentrations in Ellerbe Creek from November 17, 1982 to December 17, 2018

4 Analysis

4.1 Question 1: Are Nitrogen and Phosphorus levels in Ellerbe Creek above recommended levels?

Maximun contaminent levels (MCL) for nitrate is 10 mg/L and for nitrite it is 1mg/L, but there is not recommended water quality standard for total nitrogen, which is analyzed in this report. The EPA states that an acceptable range for total nitrogen is 2mg/L to 6mg/L (EPA Nitrogen, 2013). There is no MCL for phosphorus, but the EPA says that 0.01 mg/L to 0.04 mg/L is an acceptable range (EPA Phosphorus, 2013). The mean concentration of each nutrient was compared with the higher end of the acceptable range to determine if nutrient levels in Ellerbe Creek are above recommended levels. In Table 1. you can see that the mean concentrations of N and P in the creek are botj above the recommended levels. Because the data are not normally distributed (Fig 6), a nonparametric stastical test was run. The results indicate that the average concentration of Nitrogen in Ellerbe Creek from 1984-2008 is not significantly greater than highest recommended value of 6mg/L (wilcoxon, p=0.3318). The average concentration of Phosphours in Ellerbe Creek from 1984-2008 is significantly higher

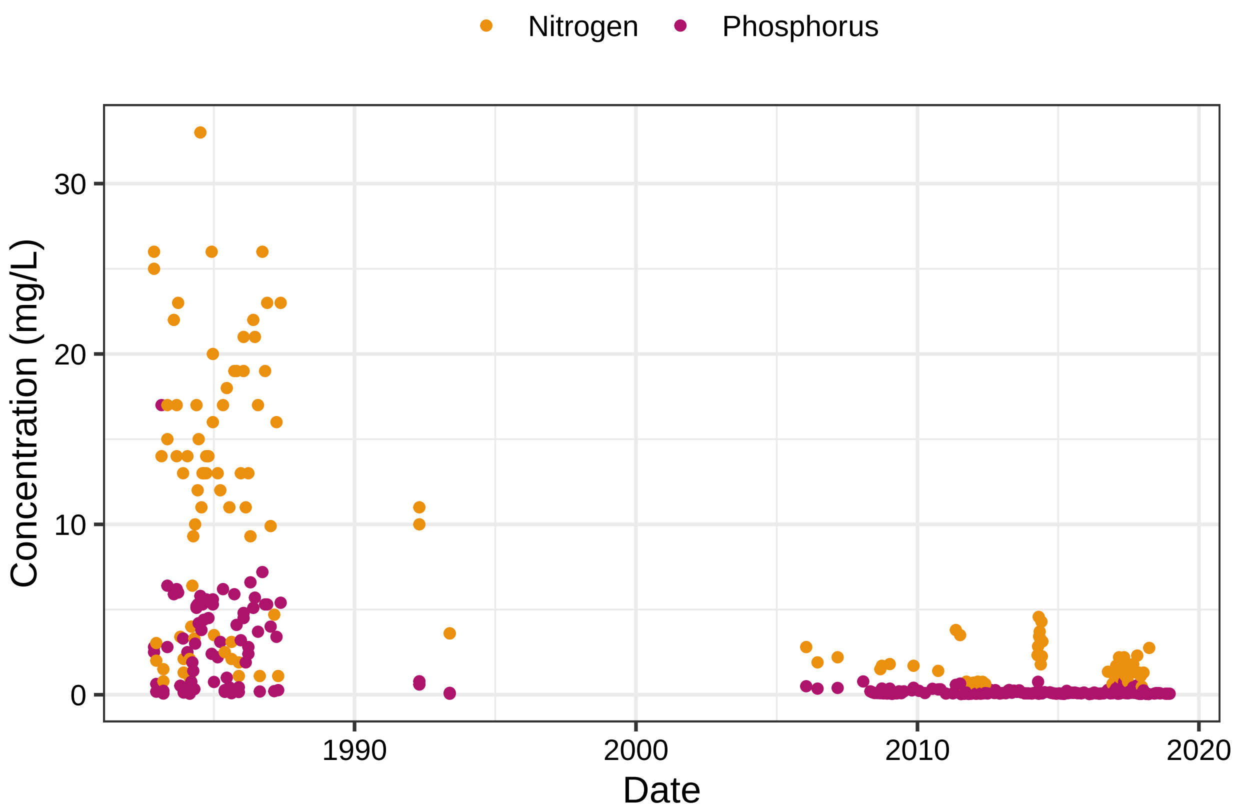

Figure 5: Concentrations of Nitrogen and Phosphorus over Time in Ellerbe Creek from November 17, 1982 to December 17, 2018

than the highest recommended value of 0.04 mg/L (wilcoxon, p=0.033). The density plot in figure 6 shows the distribution of the data with a veritcal line representing the maximun recommended level of each nutrient.

Table 3: Summary of Total Nitrogen and Phosphorus Conentrations

mean.N	min.N	max.N	Standard.dev.N	mean.P	min.P	max.P	Standard.dev.P
7.183095	0.37	33	7.773407	1.091398	0.039	17	2.082384

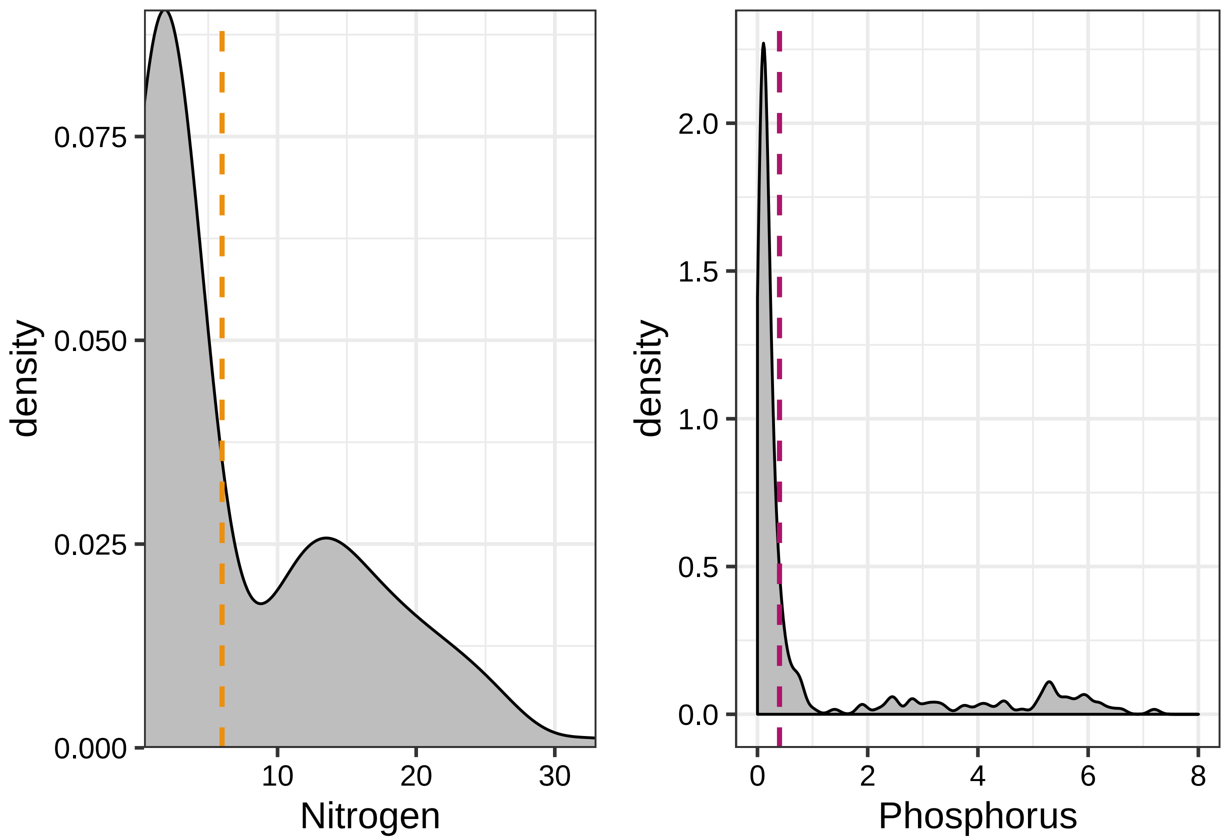

Figure 6: Density plots of Nitrogen and Phosphorus Concentrations

4.2 Question 2: Is there a relationship between flow and Nitrogen or Phosphorus levels?

A simple linear regression was run to compare nutrient concentrations with flow at the downstream gage location. There is no significant relationship between Nitrogen and discharge at a significance of 0.05, but there is nearly a significant relationship at the 0.1 signifance level (Simple Linear Regression, Adj R-squared = 0.018, df = 62, p = 0.1442). While we can't conclusively say there is a negative relationship between Nitrogen concetration and flow, you can see a downward trend in the results (Fig. 7). Flow is a significant predictor of Phosphorus levels and 33% of the variance in phosphorus concentration can be explained by flow in Ellerbe Creek (Simple Linear Regression, Adj R-squared = 0.3276, df = 162, $p < 0.0001$). As flow increases so does the concentration of Phosphorus (Fig. 8).

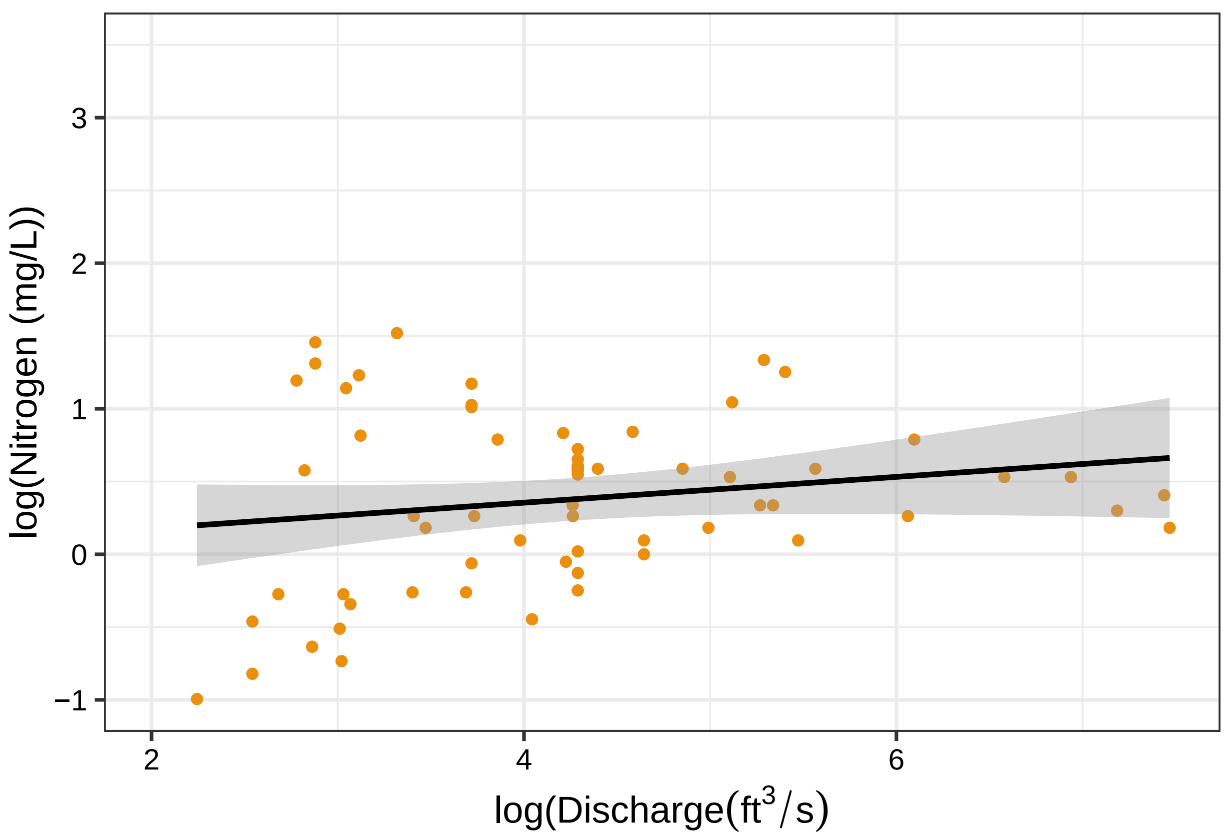

Figure 7: Linear regression of the log of Nitrogen Concentration vs. the log of Discharge

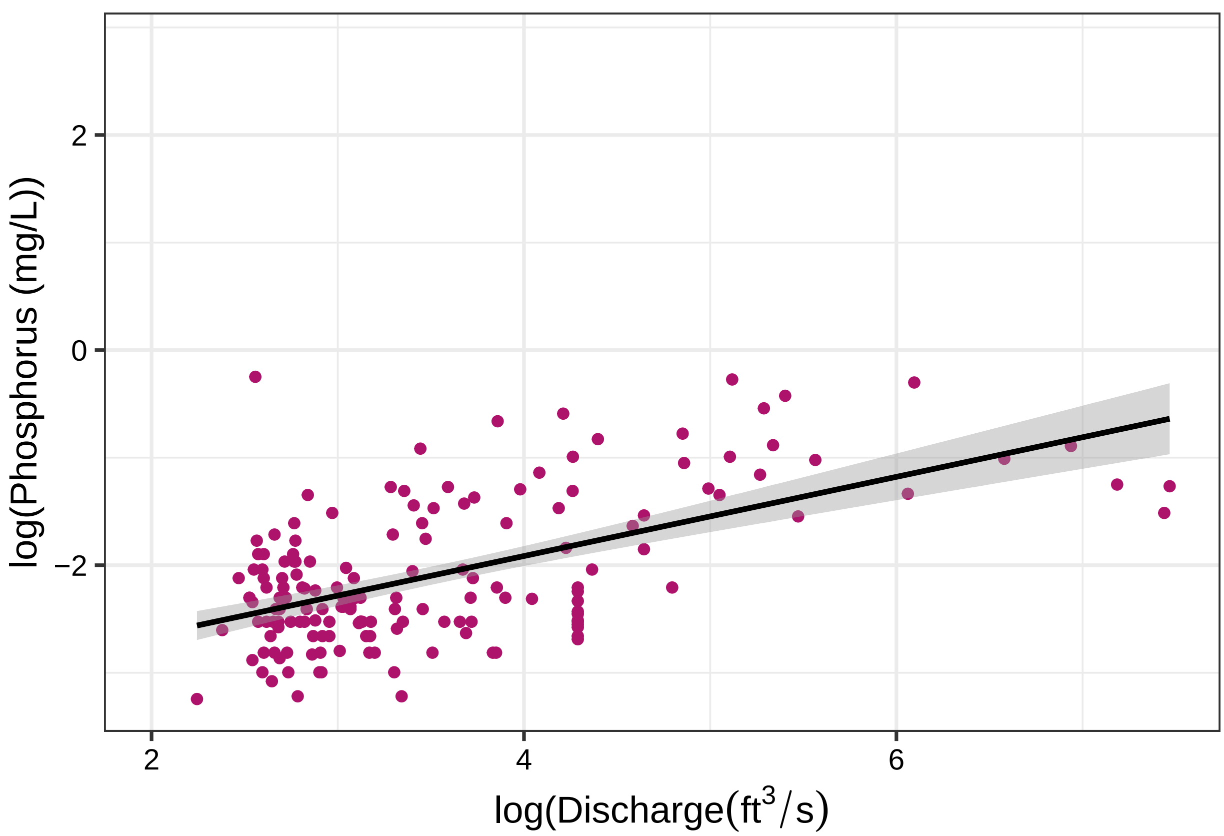

Figure 8: Linear regression of the log of Phosphorus Concentration vs. the log of Discharge

4.3 Question 3: How does location, upstream vs. downstream, impact nutrient levels?

The mean Nitrogen concentration from 1984-2018 is significantly higher downstream near where ELlerbe Creek enters Falls Lake than it is upstream near Club Blvd (Wilcoxon, $p < 0.0001$). There is no significant difference between the mean concentration of Phosphorus as the upstream and downstream monitoring sites (Wilcoxon, $p = 0.1651$) (Fig. 9; Table 4).

Table 4: Summary of Nitrogen and Phosphorus conentrations by Location

mean.N	min.N	max.N	Standard.dev.N	mean.P	min.P	max.P	Standard.dev.P
7.740577	0.37	33	7.952157	1.134506	0.039	17	2.116099

4.4 Question 4: Is there a significant difference between discharge at the upstream and downstream gages?

Average discharge from 2008-2020 is significantly higher downstream near where Ellerbe Creek enters Falls Lake than it is upstream (Wilcoxon, - < 0.0001).

Table 5: Summary of Discharge by Location

mean.Flow	min.Flow	max.Flow	Standard.dev.Flow
28.5721	0.02	1750	84.22213

4.5 Question 5: Is time of year, specifically month a predictor for flow or nutrient levels?

Because there is a significant relationship between flow and Phosphorus levels, it is interesting to examine if there are seasonal trends in that relationship. Month is a significant predictor of flow, which makes sense because precipitation and runoff change between seasons (Kruskal-Wallis, $df = 10$, p-value $= 0.04803$). Month is not a significant predictor of Phosphorus (Kruskal-Wallis, $df = 11$, p-value $= 0.4522$) or Nitrogen (Kruskal-Wallis, $df = 11$, p-value $= 0.935$) (Fig. 9).

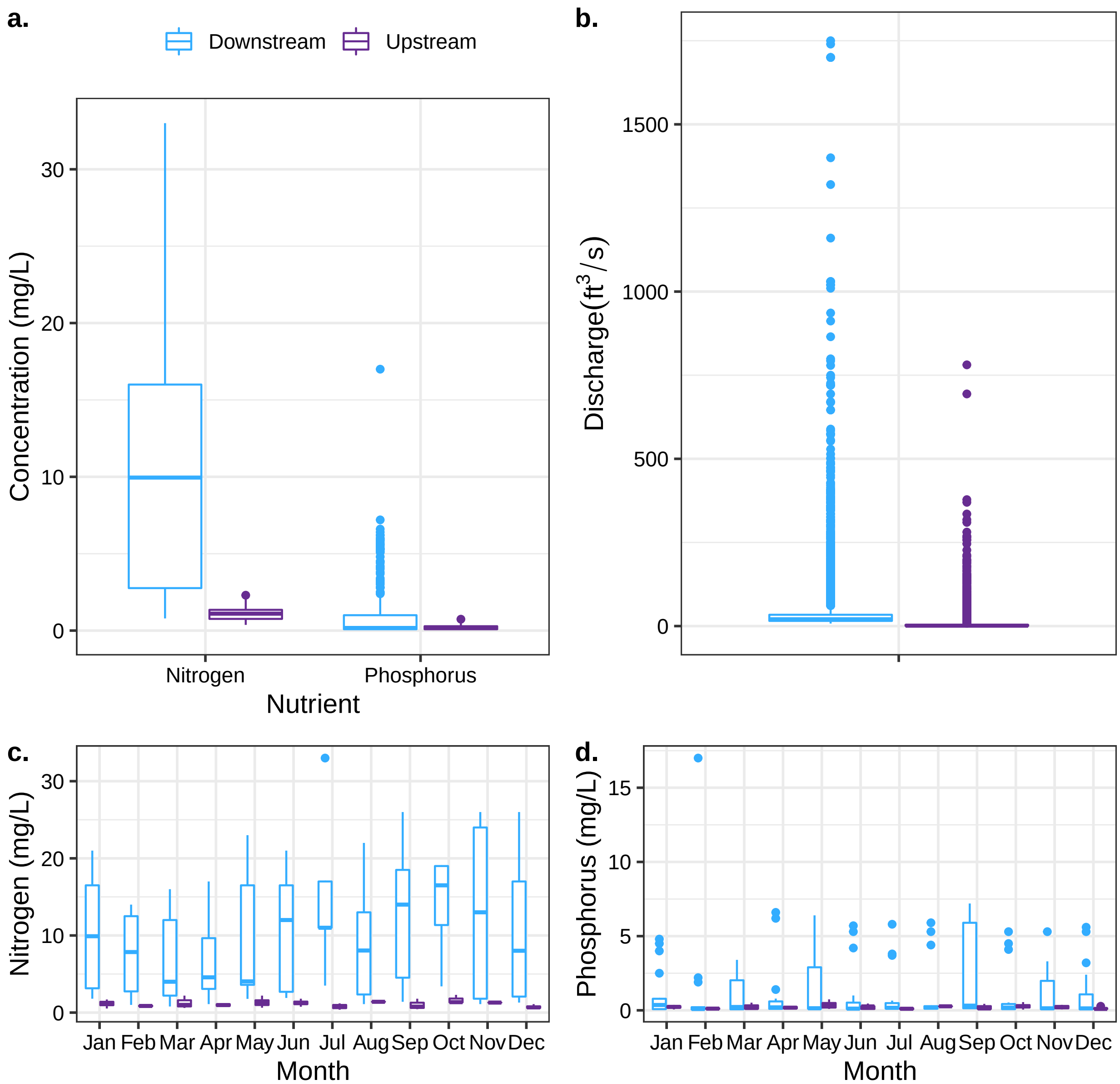

Figure 9: Distributions of nutrient concentrations and flow at upstream and downstream monitoring sites along Ellerbe Creek in North Carolina. a) Nitrogen and phosphorus concentrations at upstream and downstream monitoring sites. b) Flow at upstream and downstream monitoring sites. c) and d) Monthly distributions of nitrogen and phosphorus concentrations at upstream and downstream monitoring sites.

5 Summary and Conclusions

6 References

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