Do hurricanes impact waterways more than other common storm events?

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Abstract

Hurricanes have historically caused widespread damage to developed and natural systems in the coastal areas in Florida, but hundreds of other precipitation events frequently occur in the same region. In the last five years, Hurricanes Matthew, Irma, and Dorian have impacted the coastal landscape of St. Augustine, FL. In order to assess the impact of these hurricanes in comparison to non-hurricane storm events, nutrient data collected by the Guana-Tolomato Matanzas National Estuarine Research Reserve (GTMNERR) and discharge data collected by United States Geological Survey (USGS) were used to calculate export of dissolved organic carbon (DOC), ammonia-N, nitrate, ortho-phosphate, and total kjeldahl nitrogen (TKN). Net ecosystem metabolism (NEM), community respiration (Rt) , and gross primary production (Pg) were also calculated using the "SWMPr" library. Monthly data was grouped based on precipitation. Low precipitation (group #1) was monthly precipitation < 50 mm, high precipitation was monthly precipitation > 150 mm (group #2), and hurricane months comprised the last group (group #3). A Kruskal-Wallis test determined that there were no significant differences in export between the three groups, but hurricanes did cause a mores significant decrease in NEM. This work suggests that the rapid input of organic matter inputs into aquatic systems during hurricanes greatly effects NEM characteristics even though the quantity of export is similar in longer (month) timescales.

Introduction

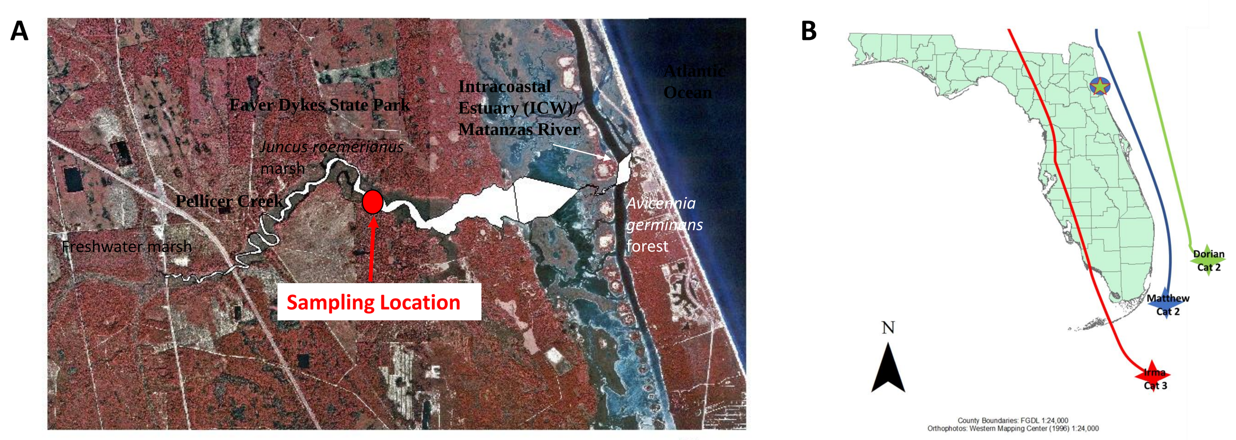


Figure 1: Study site is located in St. Augustine. FL in Pellicer Creek, a blackwater river, approximately 7 km inland in a tidally influenced brackish system that drains to the Intracoastal waterway.

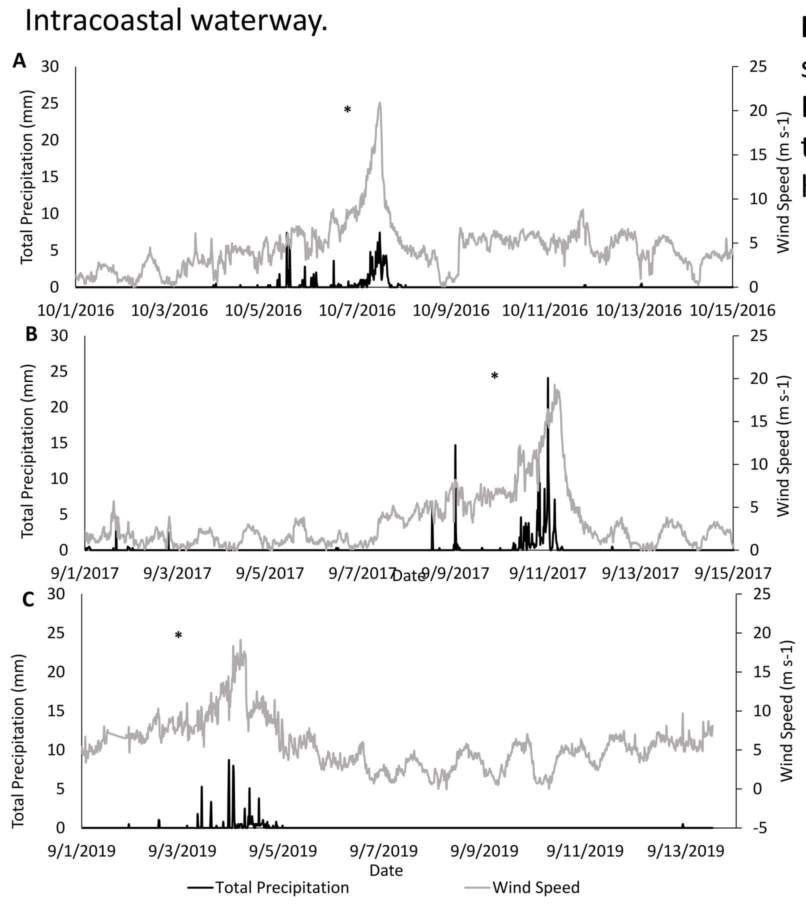


Figure 2: Precipitation and wind speed from hurricanes A) Matthew, B) Irma, and C) Dorian. * represents the passage of the eyewall of the hurricane in St. Augustine.

Florida averages 1362.71 mm of rainfall and 70-100 thunderstorms per year (depending on location within the state), the highest number in the United States (FSU climate center, NOAA). During the winter months when thunderstorms are less common, Florida's Atlantic coast additionally experiences the effects of nor'easters.

Question: Therefore, do hurricanes or other precipitation events have a greater impact on biogeochemical export and ecosystem metabolism?

Methods/ Results

DOM Export

Export of DOC, Ammonia-N, Nitrate-N, Nitrite-N, total kjeldahl nitrogen (TKN), and soluble reactive phosphorus (SRP) were calculated using monthly water sampling data collected by the Guana Tolomato National Estuarine Research Reserve (GTMNERR) and tidally filtered discharge data from the United States Geological Survey (USGS) stream gage. USGS's gage was out of commission between 2013 and April 2017, so discharge data was not collected during hurricane Matthew and is therefore estimated using figure 4 Below.

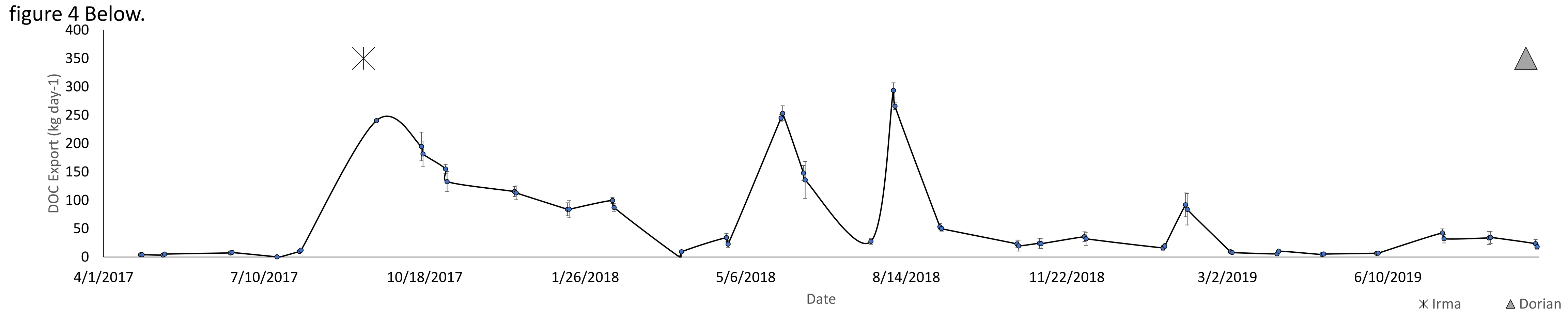


Figure 3: Export of DOC from the study site April 2017- September 2019. Symbols represent Hurricanes Irma and Dorian.

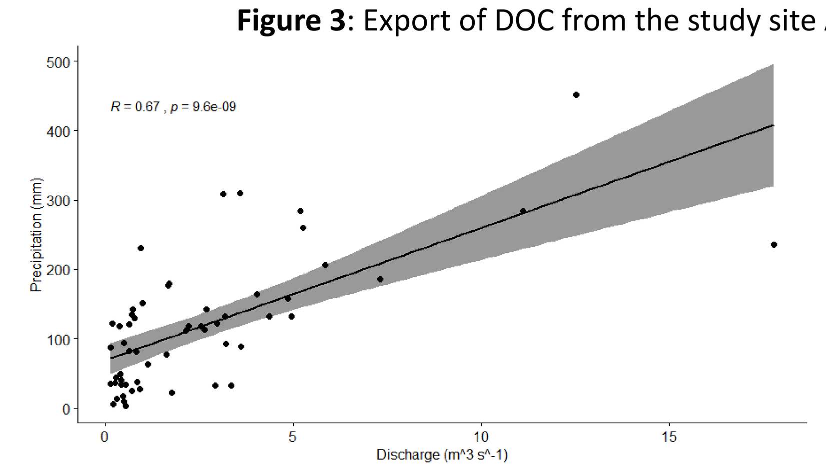


Figure 4: Pearson correlation between precipitation and discharge used to determine an estimate of discharge during Hurricane Matthew (precipitation = 142 mm). The two variables were moderately correlated ($R^2 = 0.67$), so estimates for discharge based on precipitation were also calculated for Hurricanes Irma and Dorian to validate the estimate through comparison to actual values.

Based on monthly precipitation:

Group 1: low precipitation months < 50 mm rainfall (~ 30% of data)
Group 2: high precipitation months > 150 mm (~ 30% of data)
Group 3: hurricane months (3 time points)

- Matthew (October 2016)
- Irma (September 2017)
- Dorian (September 2019)

Kruskal-Wallis Test Performed in R to examine significant differences.

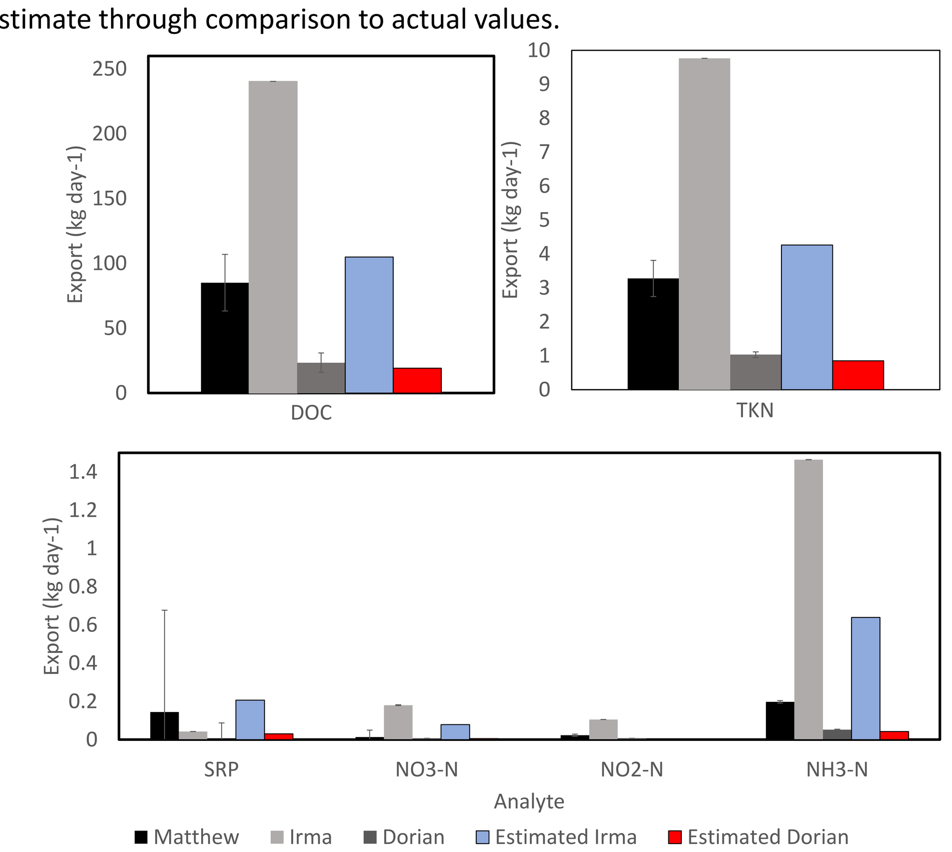


Figure 5: Comparison of average export of DOC, several nitrogen species, and SRP export. Actual values for Hurricanes Irma and Dorian and graphed next to estimates from figure 4. Estimates for Matthew might be 15- 20% off from actual values but are the best estimates available.

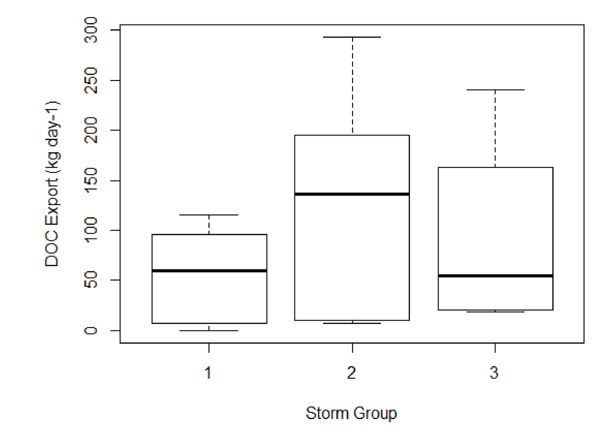


Figure 6: Box plots for DOC between the three precipitation groups. Average DOC export for group 2 is higher than for group 1 or the hurricane group, but no significant differences were found.

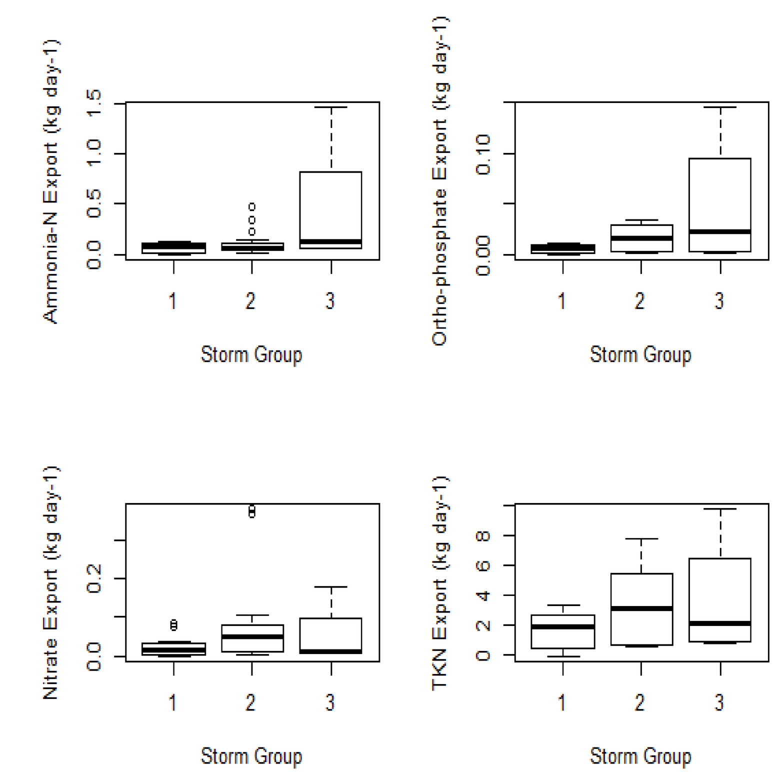


Figure 7: Box plots for ammonia-N, orthophosphate (SRP), nitrate-N, and TKN export. No significant differences were found between groups.

Net Ecosystem Metabolism

Net Ecosystem Metabolism (NEM) was calculated by data collected at the study site by a YSI 6600 data sonde. Dissolved oxygen (mm O_2 day^{-1}) data was used to calculate the net ecosystem metabolic characteristics using the SWMPr package in R.

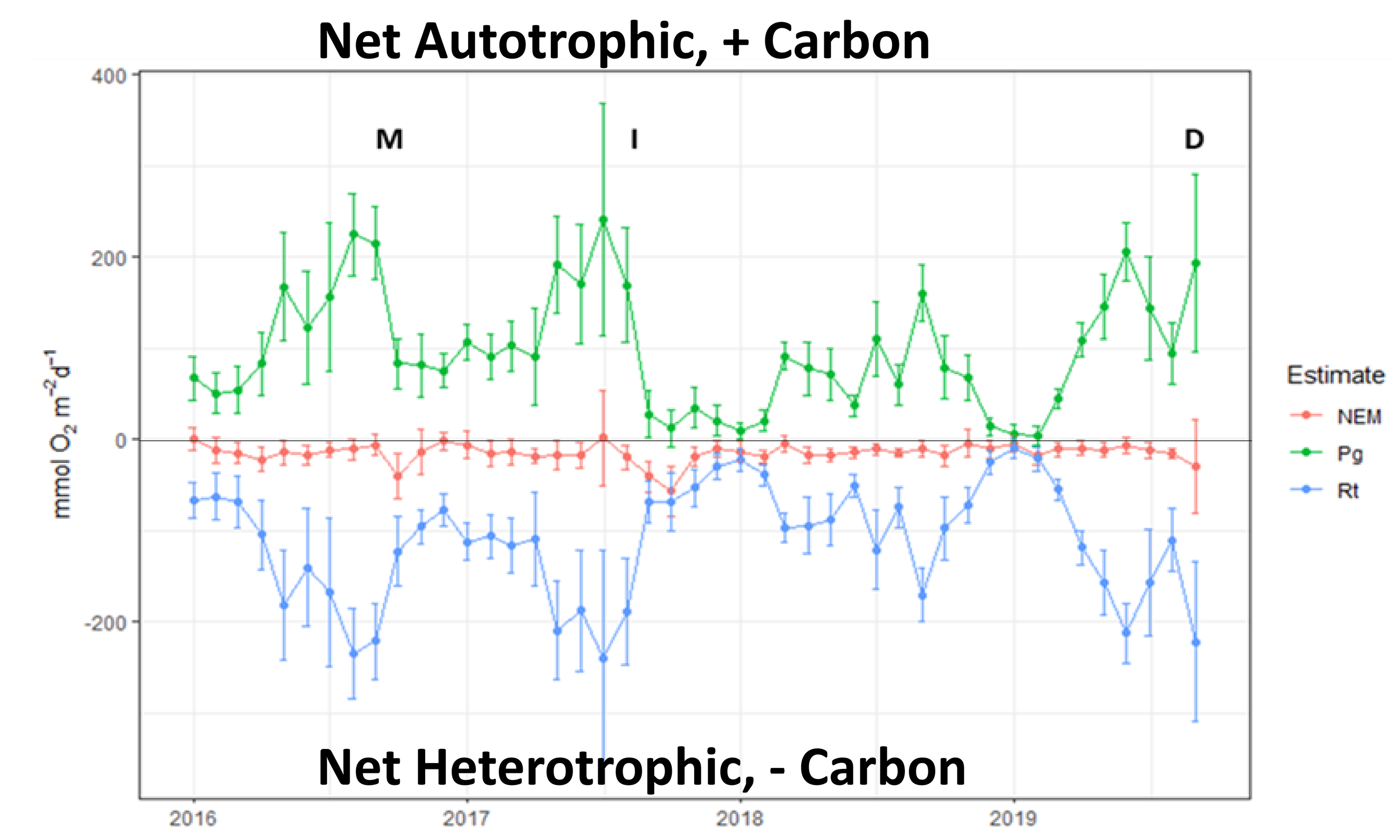


Figure 8: This graph shows the gross primary production (green line), community respiration (blue line), and NEM (pink line). If NEM is above 0, primary production is higher than heterotrophic cellular respiration and the system is dominated by autochthonous inputs from autotrophs. If NEM is below 0, allochthonous inputs and heterotrophic respiration is dominant. M, I, and D represent Hurricanes Matthew, Irma, and Dorian. This system is net heterotrophic since NEM is generally below the 0 line, NEM also decreases (increases in heterotrophy) after each hurricane event (Odum, 1956).

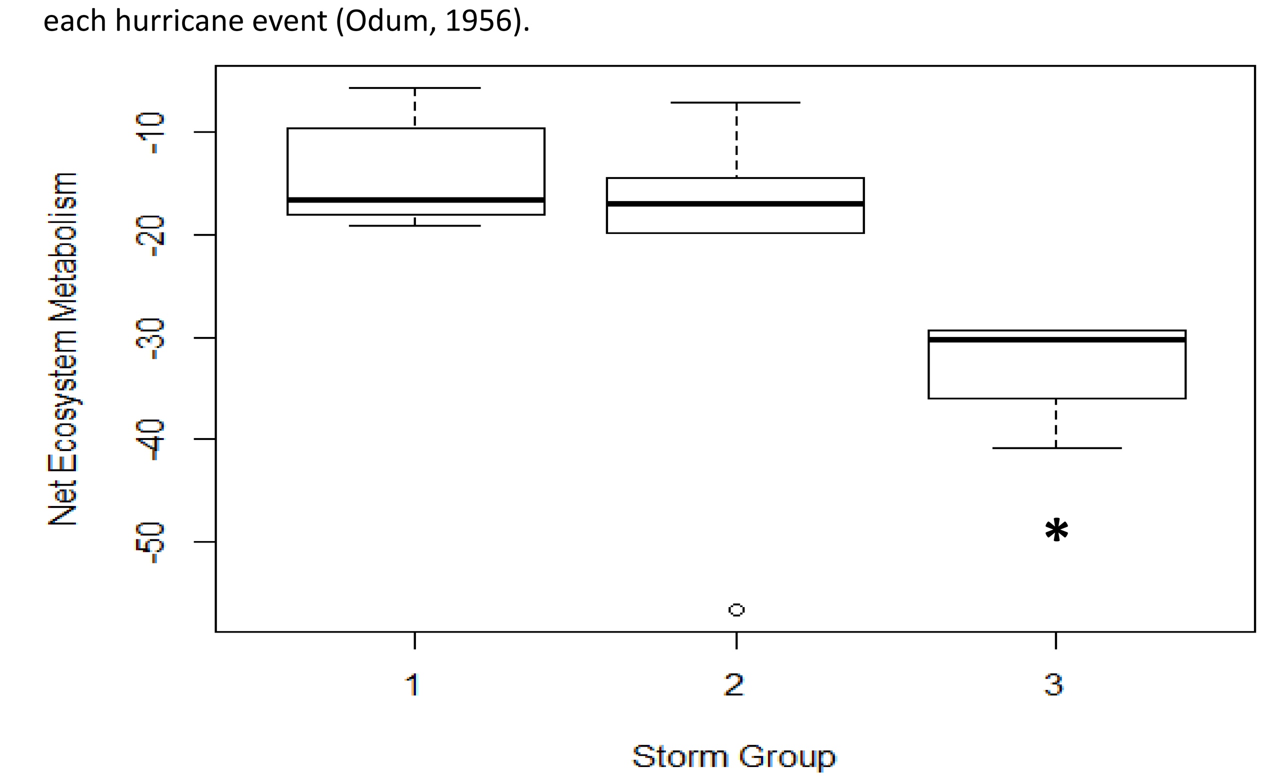
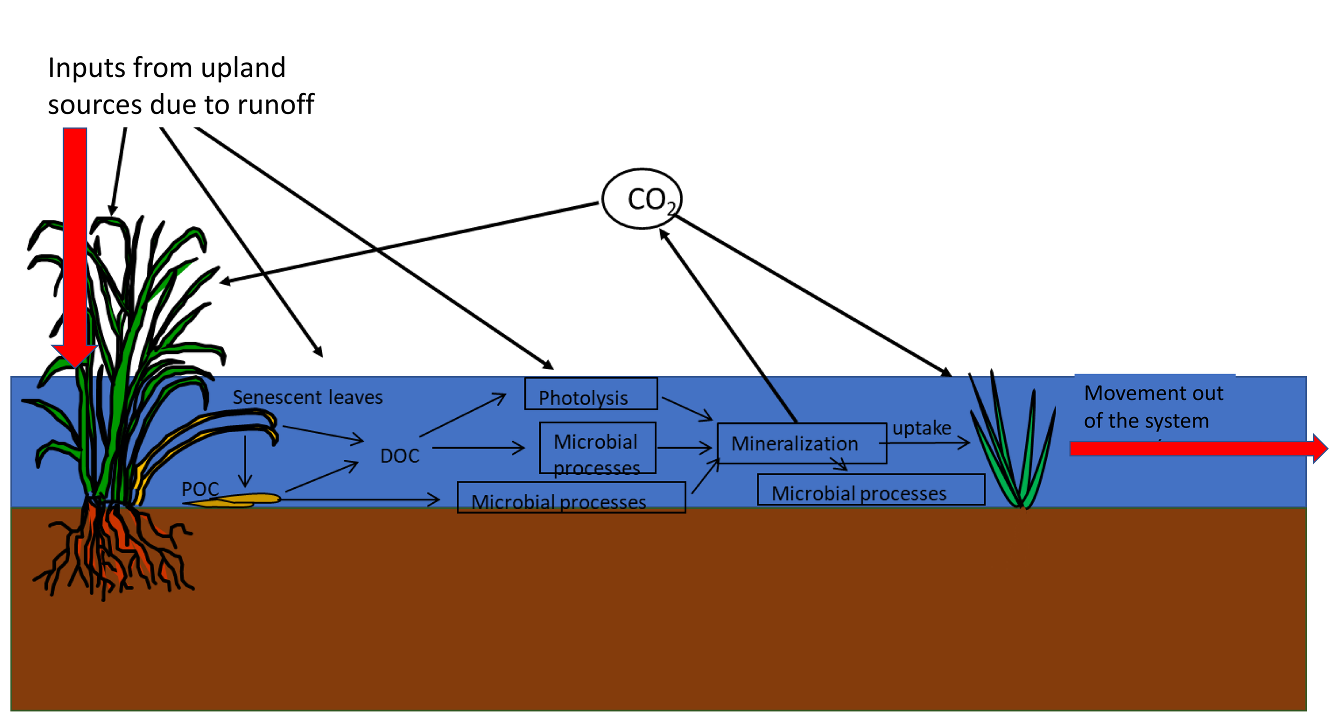


Figure 9: Groups were also plotted and compared by a Kruskal-Wallis test in R. The hurricane group was significantly more heterotrophic than the precipitation groups 1 and 2.

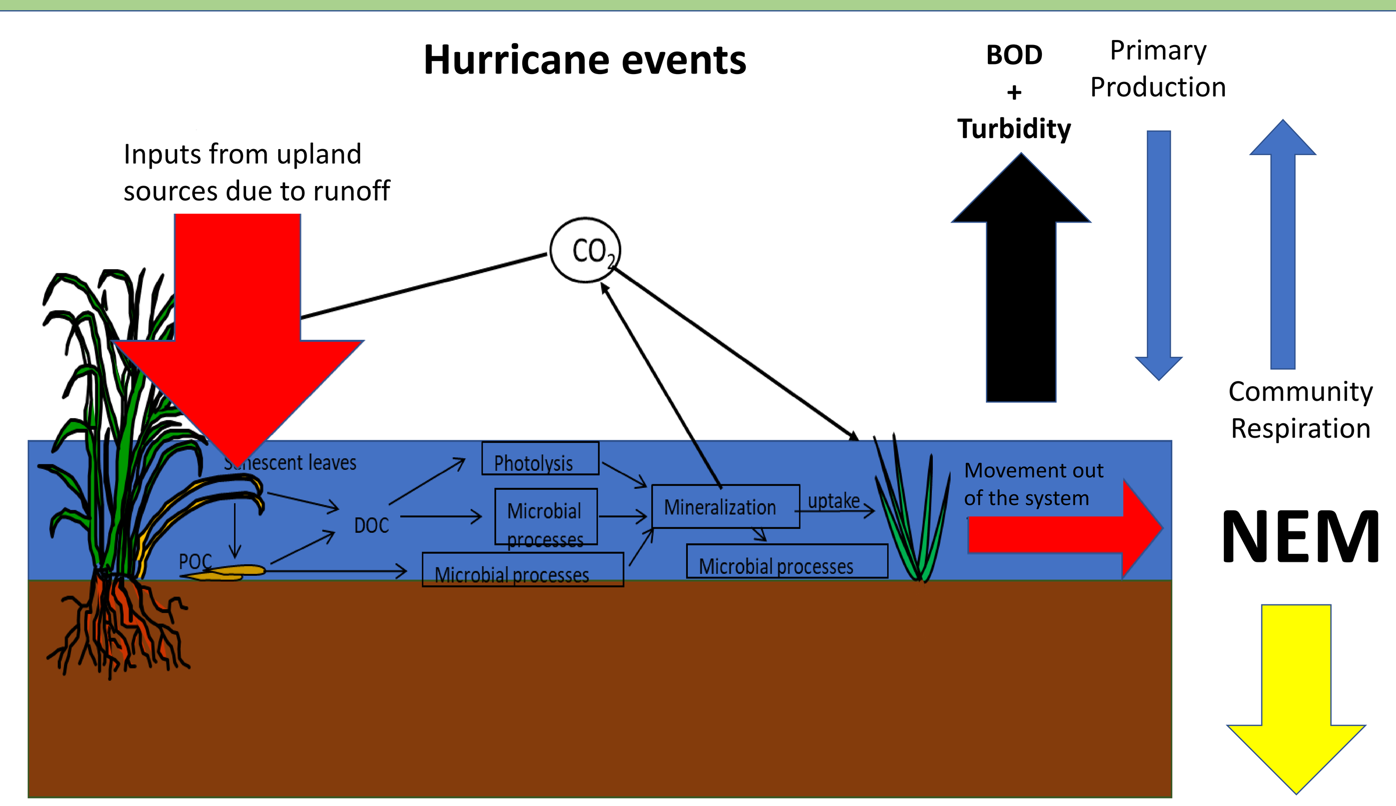
Conclusion

Nor'easters, thunderstorms, and other precipitation events



Nor'easters, thunderstorms, and other precipitation events slowly but frequently drive organic matter into waterways.

Hurricane events



Hurricanes drive large amounts (high percentage of yearly average) of organic matter into aquatic systems very rapidly.

Hurricanes quickly drive organic matter into waterways over a short interval . The increase in electron donors increases biological oxygen demand (BOD), and the rapid input of organic matter increases turbidity. Increased turbidity reduces light penetration necessary for primary production and increases respiration from heterotrophic micro-organisms , which drives down NEM. Other precipitation events do not have the same impact due to slower input of organic matter. Therefore, even though there were not any significant differences in export of organic matter between precipitation groups, the differences in input time create a significant difference in NEM characteristics across groups.

Acknowledgements

Thank you to the GTMNERR for access to Pellicer Creek and historical datasets from this location. Additionally, we would like to acknowledge USGS for making their stream gauge data public and restarting gauge maintenance 2017 to the present. Also, the entire Osborne lab has been compulsory in their help and support throughout this study.

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