A Tale of Two Creeks: Cedar Run and Mill Creek at Barnegat Bay, NJ

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The effects of development and population growth on the condition of local mainland marsh creek habitats is an ongoing concern for coastal communities. Alterations to a marsh creek's natural structure can give rise to unintended consequences, commonly in the form of algae blooms, stagnant waters, and high nitrogen levels. Lack of fresh water flow is especially debilitating in altered creek habitats, as it enables algae blooms and abnormal bacterial growth, potentially resulting in the water becoming a health hazard for the surrounding community. Altered creek habitats may also be unappealing or inaccessible to native species, limiting their areas for potential habituation and forcing them to shift their populations elsewhere. Comparing the biochemical constituents of highly developed and less developed areas can provide insight as to which components are most unstable following infrastructure development. The most revealing variables to compare between systems include chlorophyll levels, nutrient levels, dissolved oxygen, and water velocity (flow), as these factors are reliable indicators of the general condition of a water system. Distinguishing the biochemical components that differ most drastically between altered and unaltered areas gives a focal point to the direction of watershed protection and restoration efforts, as well as provides valuable information to guide wiser development and planning of any future marsh creek communities.

STATEMENT OF PURPOSE

Research Question: **What are the biochemical differences between a highly developed and less developed mainland marsh creek habitat within the same Barnegat Bay sub-watershed?**

Objective: **Determine how various biochemical factors (nitrate-nitrogen levels, dissolved oxygen, water flow, chlorophyll levels) differ between an altered and unaltered mainland marsh creek habitat.**

Hypotheses:

<u>Null:</u> There are no differences in water flow, nitrate-nitrogen levels, chlorophyll levels, turbidity, pH, or dissolved oxygen between an altered mainland marsh creek habitat (Beach Haven West) and an unaltered marsh creek habitat (Cedar Run Dock Road).

<u>Alt:</u> Dead-end lagoons and stagnant waters in Beach Haven West (BHW) contribute to high chlorophyll and nitrogen levels, and low dissolved oxygen content, compared to the relatively undeveloped Cedar Run Dock Road (CRDR) area.

INTRODUCTION

Beach Haven West, a community built on former marshlands, is one of the largest lagoon developments in New Jersey ("History of Stafford Township" n.d.). The lagoons of BHW are entirely manmade, and the landscape of the area has hardly retained its natural structure, resembling more of a maze than a marsh. In recent years, BHW and other similar lagoon communities in New Jersey have become areas of water quality concern (Saphr 2010). The construction of such housing developments results in dead-end lagoons that do not conduct adequate water flow to and from a larger outlet, like Barnegat Bay. Stagnant waters can promote algae blooms, high nitrogen levels, and abnormal bacteria growth, all of which make an ecosystem an unfit place for native wildlife habituation and human recreation (Lopez 2008). In 2012, the Save Barnegat Bay Water Quality Team detected high ammonia levels upstream in Mill Creek, near the Garden State Parkway interchange at route 72. Mill Creek runs through the BHW development, and the 2012 Water Quality Team also found increased nitrate levels on the western boundary of Beach Haven West, thus it is imperative that the nutrient levels along Mill Creek be further inspected (Save Barnegat Bay Report, 2012). In addition to these past findings, Stafford Township ordered residents of BHW to stay out of the water and report any dead fish or bird encounters during a 10-day contamination scare this past summer, after a number of dead ducks were found in the lagoons (Zimmer 2017). Even after the ducks' cause of death had been attributed to botulism, which is not contagious, Stafford Township officials still do not recommend that BHW residents use the lagoons for recreational swimming, and do not approve of any lagoon being used as a harvest area for crabs or fish (Miller 2017).

To the south of Beach Haven West is Cedar Run Dock Road, which runs through a relatively unaltered marshland. There are some homes lining CRDR, but it hardly compares to the level of development that has occurred in BHW. Beach Haven West and Cedar Run Dock Road were probably very similar areas at one time, but while CRDR has remained relatively unchanged, BHW has changed drastically. These two areas make strong candidates for a comparison of the biochemical differences between an altered and unaltered mainland marsh creek habitat.

METHODOLOGY

Study Site: Data will be collected at Cedar Run Dock Road and Beach Haven West in Ocean County, New Jersey. Cedar Run Creek runs along Cedar Run Dock Road, and is representative of a less developed mainland marsh creek habitat, as there is some development along the road but the natural landscape is relatively unchanged. Mill Creek at The Beach Haven West site will represent an altered marsh creek habitat, as it is runs through a highly developed and increasingly populated area. Mill Creek and Cedar Run flow parallel to one another into the Barnegat Bay, and they are considered parts of the same sub-watershed. There were four sampling locations along each creek. These locations were determined by accessibility (Fig. 1).

FIG 1: Cedar Run (lower) runs parallel to Mill Creek (upper). Mill Creek runs through Beach Haven West and Cedar Run flows through the southern area pictured. Both open into the Barnegat Bay. Water sampling sites and data logger locations are indicated by the red circles along each creek.

Sampling Time-frame: Data was collected 2-3 days a week from 6/4/18-7/25/18. Data collection was coordinated with different tidal stages according to NOAA's tide prediction site (https://tidesandcurrents.noaa.gov/noaatidepredictions.html?id=8533941).

Data Collection Procedures

- Water Collection: At each site, a water sample was collected using a sampling pole and a 250 mL bottle. Samples were stored in a dark cooler. Water temperature (℃), dissolved oxygen (mg/L), and flow (cm/s) data was collected on site. Water temperature was continuously monitored throughout the sampling period at Cedar Run and Mill Creek using four HOBO pendant 8k temperature data loggers (+/- 0.5 C), which were set 1m in depth at each of the four sampling spots along Mill Creek and Cedar Run **(Fig. 2)**. Dissolved oxygen (DO) was measured with a YSI-85 meter, calibrated every ten days using NJ Department of Environmental Protection Protocols. The DO meter was verified against a Winkler titration procedure. The accuracy required between the reading from the DO meter and the results of the Winkler test had to be within +/- 0.3 mg/L of each other. A flowmeter (model 2030 R6) was used to collect rotor revolution counts, which were further used to calculate water velocity (flow) at each site **(Fig. 3)**. Flow rates were assessed over five minute intervals in 1 meter depths at each sampling location along Cedar Run and Mill Creek. Once a rotor revolution count was determined, it was used to calculate water velocity in this equation: $Speed\ in\ cm/sec = \frac{\left|\frac{\text{difference in counts x 26,873}}{999999}\right| x\ 100}{120}$.

- *Laboratory Tests:* Chlorophyll (ug/L), turbidity (NTU), nitrate-nitrogen (ppm), and pH data was collected at the MATES laboratory. Chlorophyll and turbidity were determined using a fluorometer. Nitrate-nitrogen levels were determined using a LaMotte SMART 2 Colorimeter, and readings were divided by 4.4 to calculate solely for nitrogen values. pH values were determined using an Ohaus portable pH meter that was calibrated daily using a three-point calibration with buffer standards including 10.00, 7.00 and 4.01. The unit had to be within 0.1 units of the buffer standards after a buffer check and no more than 0.3 units after three hours of calibration. □□
- *Statistical Analysis:* Student's T-test was performed for comparisons between quantitative variables at each site (ex: flow at CRDR vs. BHW) to determine if there are significant differences between variables in the altered and unaltered conditions.

FIG 2: HOBO pendant 8k temperature data logger.

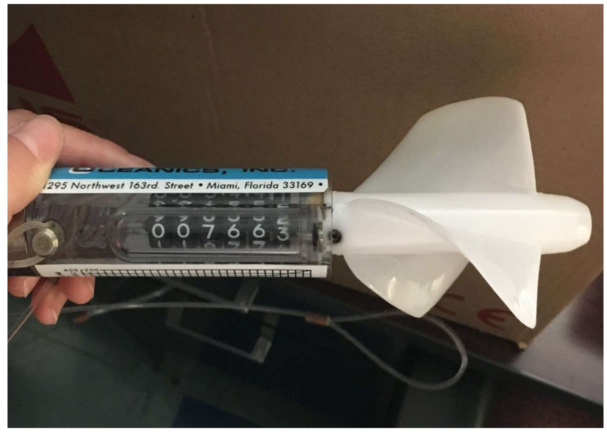


FIG 3: A flowmeter, used to calculate water velocity (flow) at each site.

RESULTS

Dissolved Oxygen:

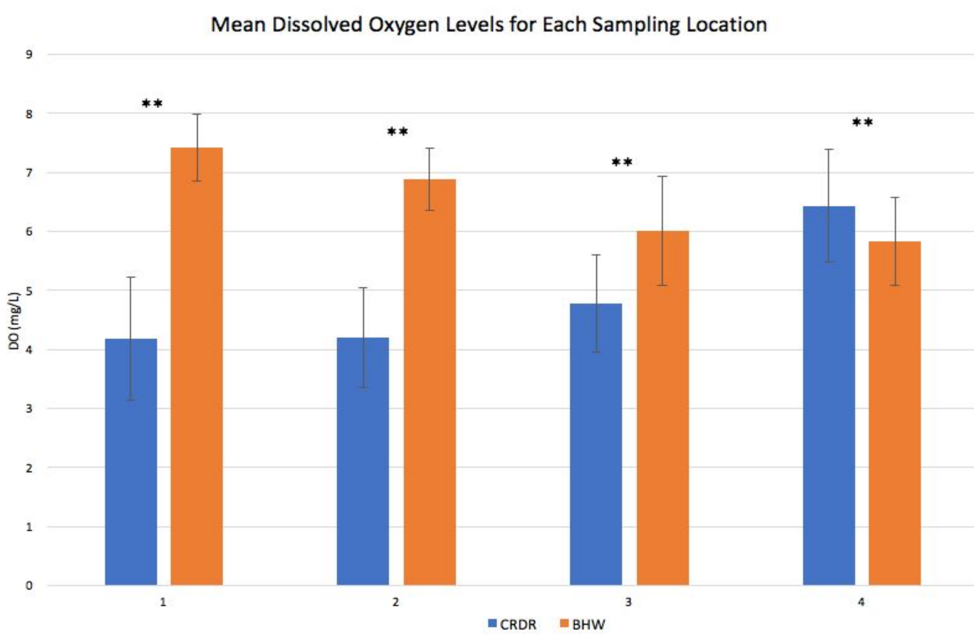


FIG 4: BHW sampling locations 1, 2, and 3 had higher mean DO levels than their CRDR counterparts.

CRDR 4 had a higher mean DO than BHW 4.

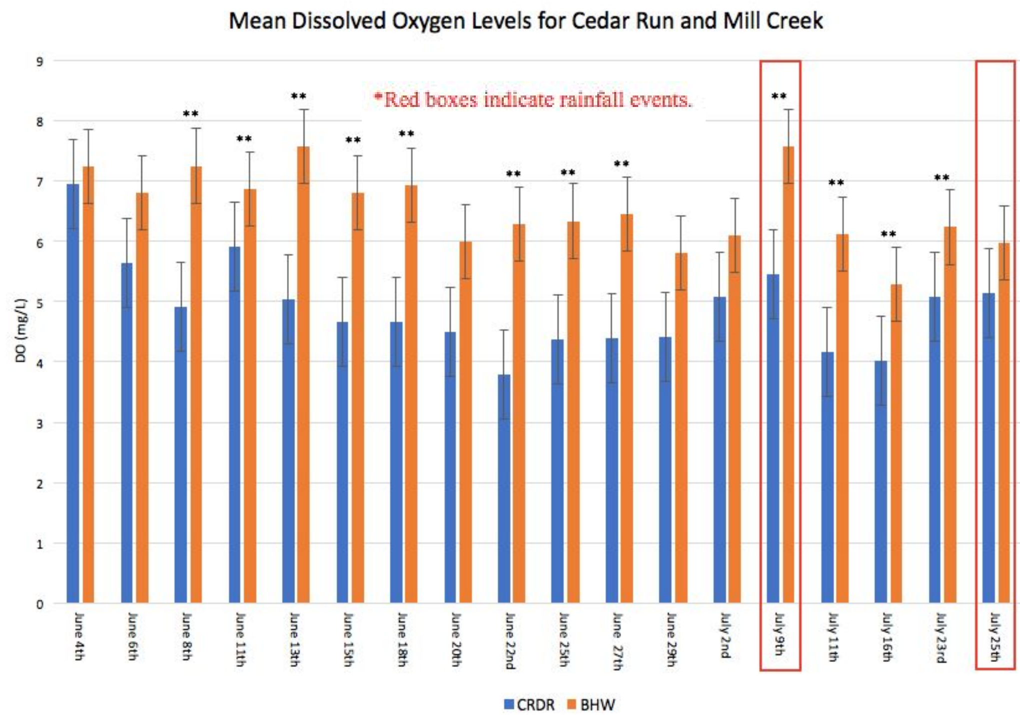


FIG 5: BHW had significantly higher average DO values than CRDR on almost every sampling date.

Nitrogen:

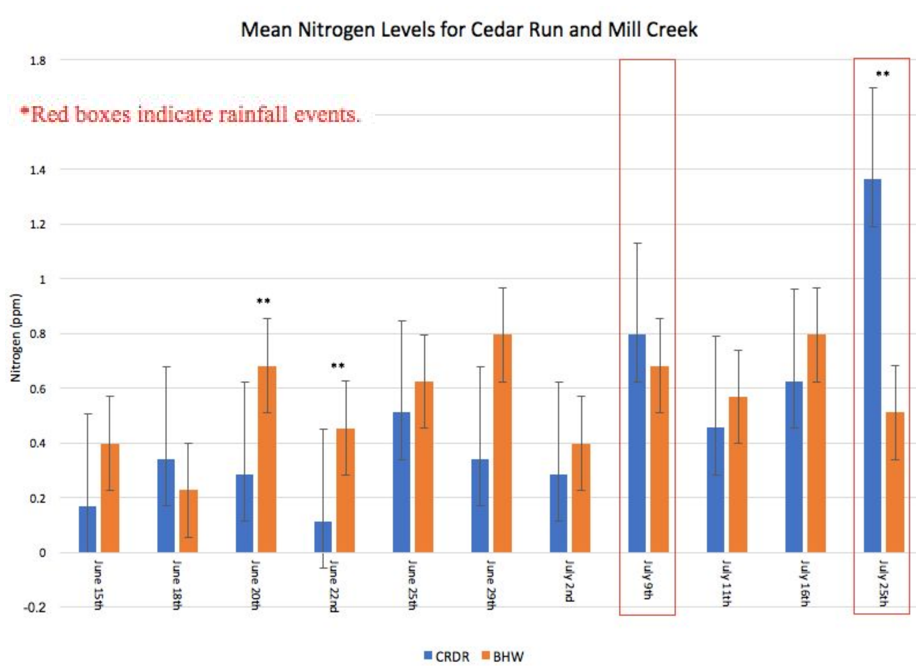


FIG 6: BHW has higher mean nitrogen levels on 6/20 and 6/22. CRDR has higher mean nitrogen on 7/25.

Chlorophyll:

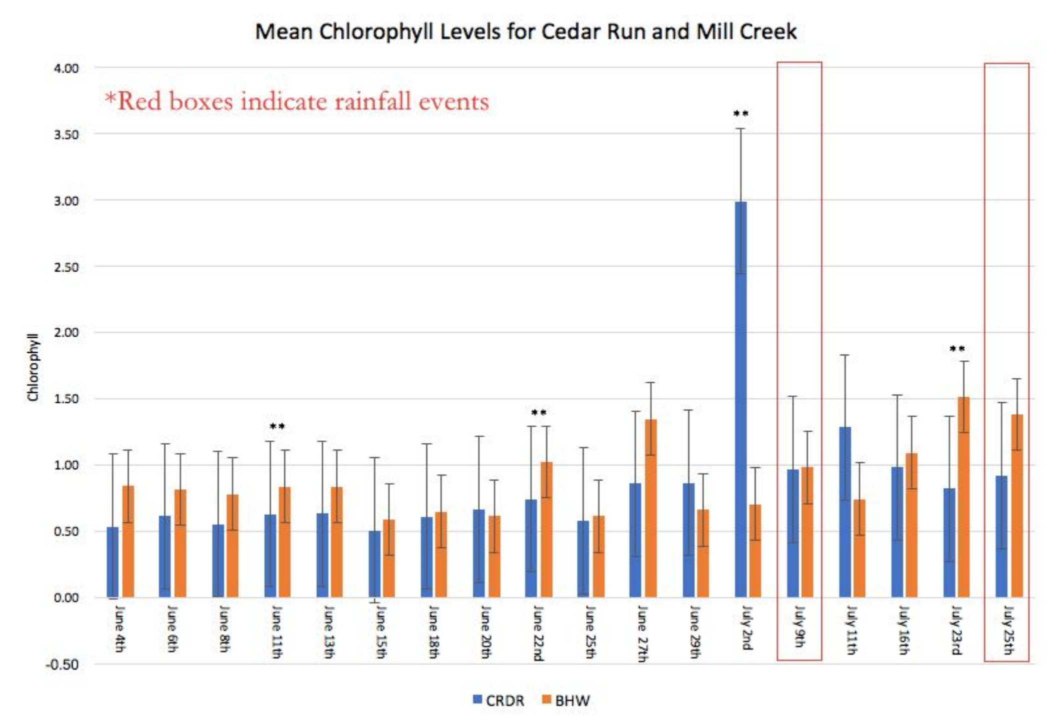


FIG 7 : BHW has higher mean chlorophyll levels on 6/11, 6/22, 7/23. CRDR has higher chlorophyll on 7/2.

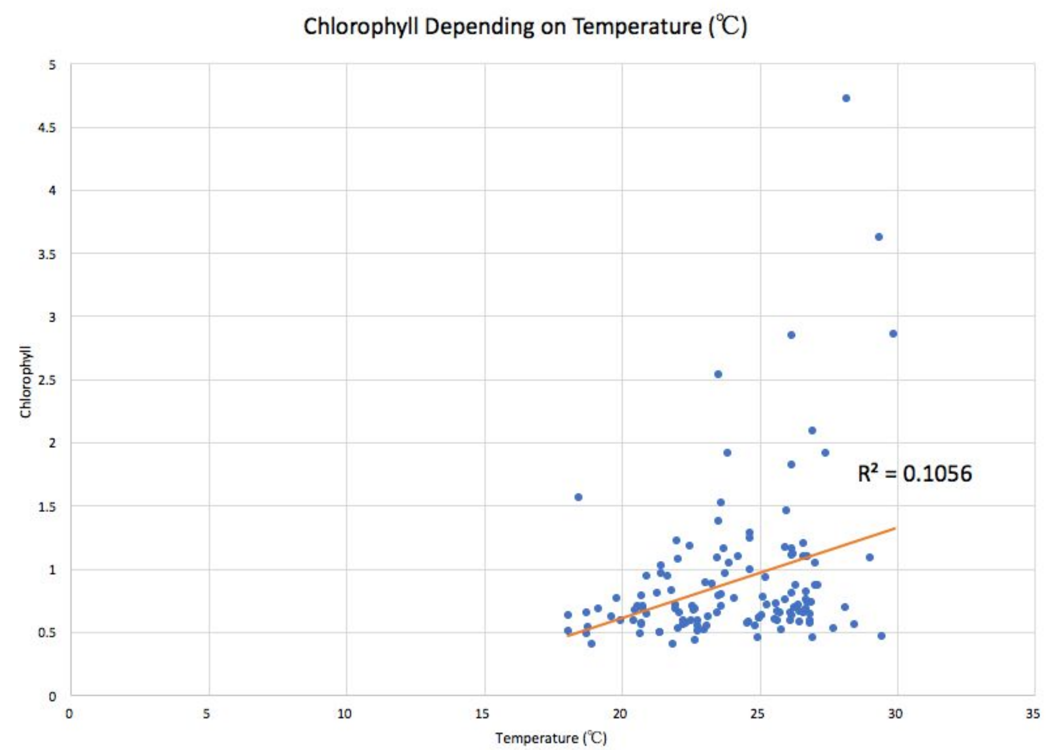


FIG 8: A regression line formed by the relation of chlorophyll and temperature has an R-squared value of 0.1056.

pH:

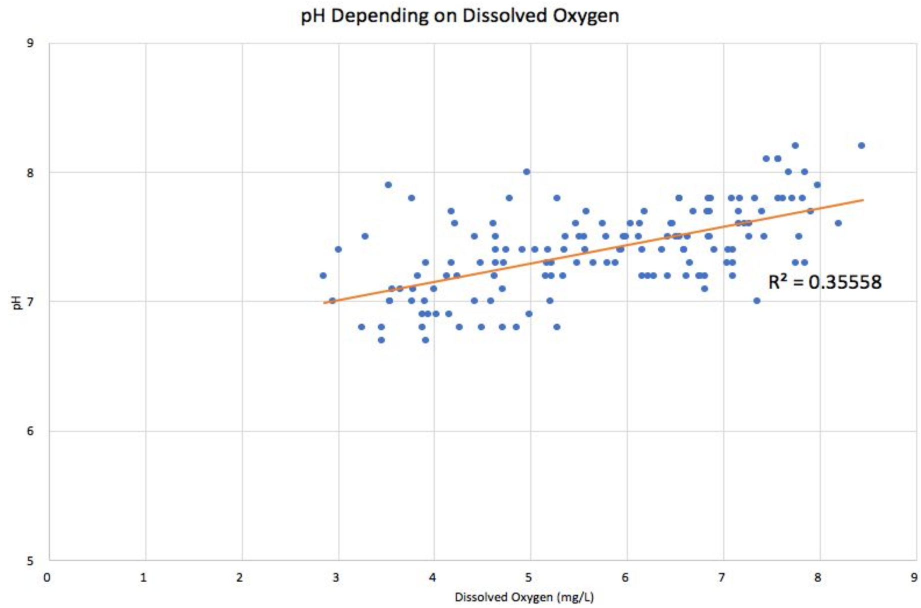


FIG 9: A regression line formed by the relation of pH and dissolved oxygen has an R-squared value of .35558.

Turbidity:

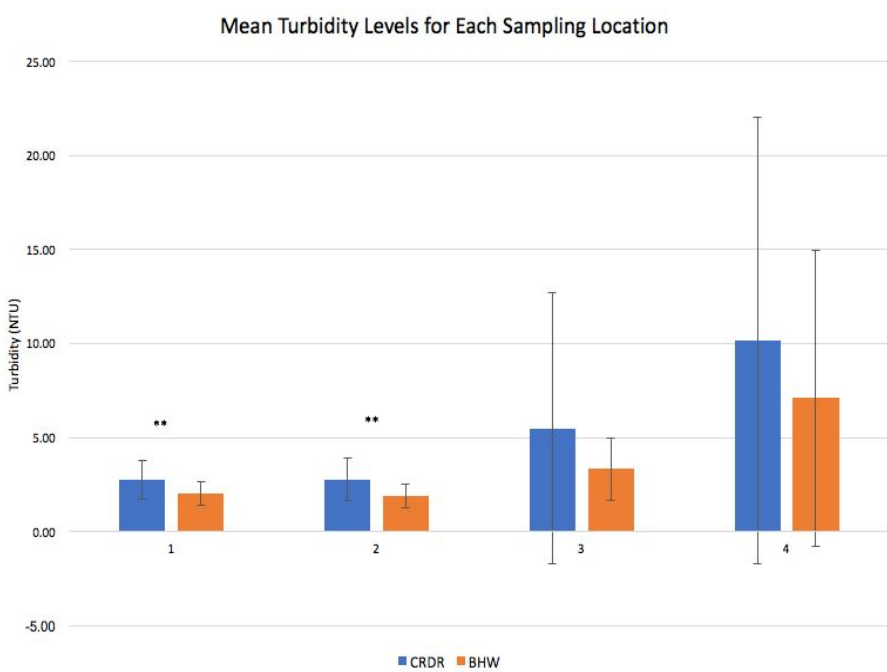
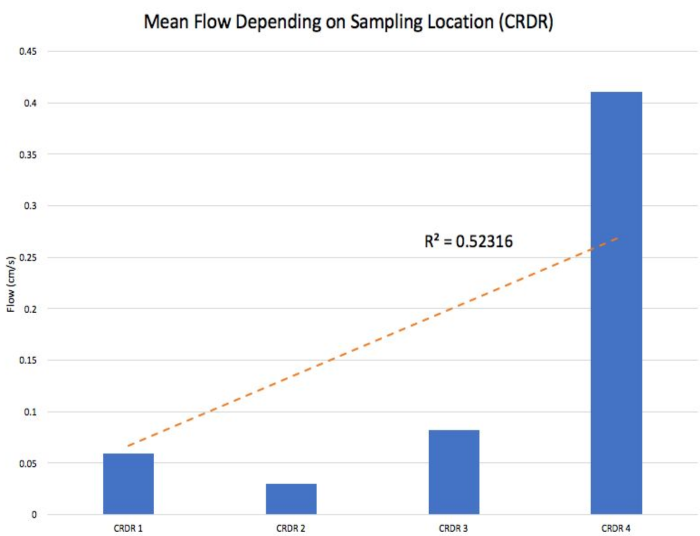


FIG 10: CRDR sampling locations 1 and 2 had higher mean turbidity levels than their BHW counterparts.

Flow:



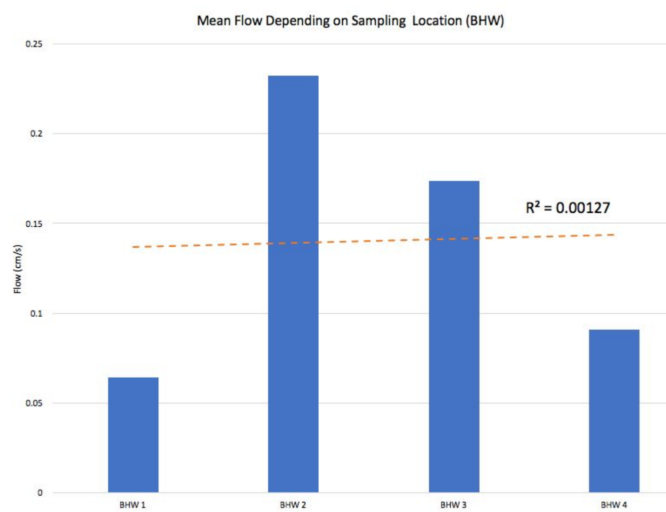


FIG 11 & 12: The relation between flow and sampling location in CRDR has an R-squared value of .52316. The same relation at BHW has an R-squared of 0.00127.

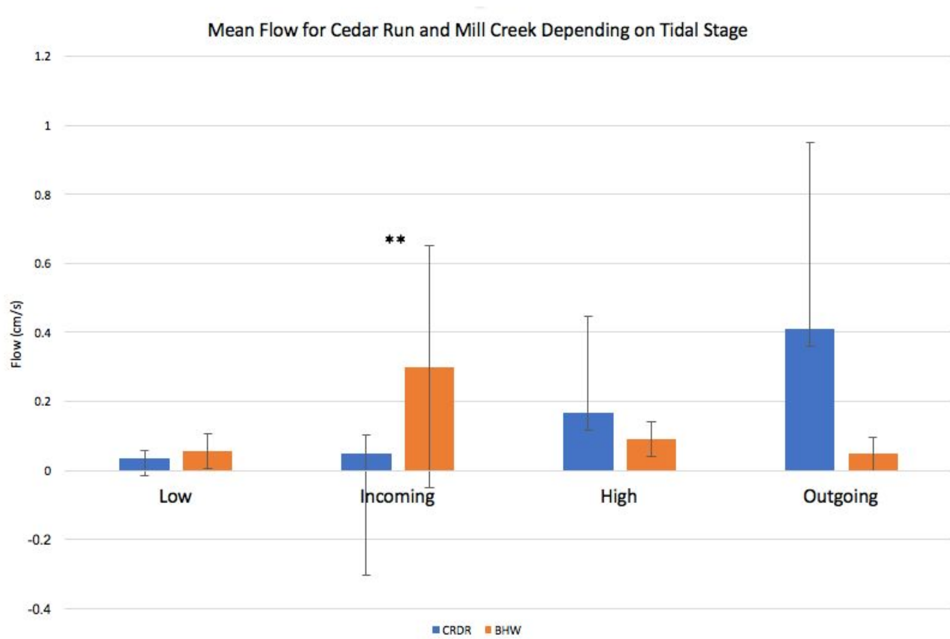


FIG 13: Flow at BHW is faster than flow at CRDR during incoming tides.

DISCUSSION

- *Dissolved Oxygen (DO):* Overall, Mill Creek had a significantly higher average DO level than Cedar Run (p= 1.509E-14) throughout the course of the study **(Fig. 5)**. DO levels at CRDR 1, 2, and 3 were significantly lower than their BHW counterparts. However, CRDR 4 had a higher overall DO average than BHW 4 (p=.023) **(Fig. 4)**. This may be due to the fact that CRDR 1, 2, and 3 are in very narrow parts of Cedar Run, and CRDR 4 was at the mouth of the creek, where it meets Barnegat Bay. Flow in Cedar Run was typically slower at locations further upstream in the creek, and became faster towards the mouth of the creek, so this may account for the low DO values found at CRDR 1, 2, and 3, but the relatively higher DO values at CRDR 4 **(Fig. 11)**. Mill Creek appears to be uniform in width throughout, and flow does not seem to vary between locations, which may explain why DO values don't vary much by location upstream in Mill Creek **(Fig. 12)**. However, the data does not support a strong overall correlation between DO and flow (R^2= .0088). Increased DO may also be the result of generally higher chlorophyll levels in Mill Creek **(Fig. 7)**, as an increase in chlorophyll would result in an increase in dissolved oxygen as a product of photosynthesis, but the data does not support a strong correlation between chlorophyll and dissolved oxygen values (R^2= .0052).
- *Nitrogen:* The general trend in the data shows higher daily nitrogen levels in Mill Creek, but only significantly higher on two sampling dates. Cedar Run had a spike in nitrogen levels on July 25th, during a major rainfall event **(Fig. 6)**. It isn't abnormal to see heightened nitrogen levels during or after major rainfall events due to runoff. However, this nitrogen spike is rather high and might be due to something more serious- the drainage system at Cedar Run may warrant further inspection. Overall, nitrogen levels were not significantly different between Mill Creek and Cedar Run (p= .187). Nitrogen levels did not significantly differ between each Cedar Run sampling location and its Mill Creek counterpart. Nitrogen levels were not significantly different between each creek at

any tidal stage, however, nitrogen levels overall (with a culmination of data from both creeks) were significantly higher during incoming tides than low tides (p= .0498).

- *Chlorophyll:* Mill Creek generally had higher chlorophyll levels, but only significantly higher on three sampling dates. Cedar Run had a spike in chlorophyll on July 2nd, which was the warmest day of sampling **(Fig. 7)**. A linear regression model of water temperature and chlorophyll values results in an R^2 value of .106, indicating a slight positive relationship between the two variables, which could explain the spike on July 2nd **(Fig. 8)**. Chlorophyll levels did not significantly differ between each Cedar Run sampling location and its Mill Creek counterpart.
- *pH:* Average pH was significantly higher at Mill Creek than at Cedar Run (p= 8.385E-07), however, all pH values for both creeks throughout the study were normal (lower: 6.7; upper: 8.1) (Oram n.d.). A linear regression model of pH and dissolved oxygen values results in an R^2 value of .356, indicating a somewhat strong, positive relationship between the two variables **(Fig. 9)**. This correlation may explain why Cedar Run had an overall lower pH than Mill Creek. Higher pH indicates a more basic solution, or, a solution containing more hydroxide (OH-) ions, and therefore it makes sense to expect a solution with higher a dissolved oxygen content (Mill Creek had significantly higher DO levels) to also have a higher pH.
- *Turbidity:* The average turbidity level was significantly higher at Cedar Run than Mill Creek (p=.0484). Daily sampling data did not show much of a difference between the average turbidity values at each creek- there was only one sampling date where turbidity was significantly higher at Cedar Run than at Mill Creek (June 13th, p=.047). When turbidity levels at each Cedar Run sampling location were compared to their Mill Creek counterparts, CRDR 1 and 2 had significantly higher turbidity levels than BHW 1 and 2 **(Fig. 10)**. Again, this is likely due to the narrow width of Cedar Run at these upstream locations, relative to the width of Mill Creek.
- *Flow:* Overall, flow was not significantly different between the two creeks (p=.449). However,

flow was significantly faster at Mill Creek than at Cedar Run during incoming tides ($p = .04982$) **(Fig. 13)**. A linear regression model of sampling location and flow at Cedar Run results in an R^2 value of .523, indicating that there is a strong relationship between flow and distance inland at Cedar Run **(Fig. 11)**. The same comparison at Mill Creek did not reproduce the same result ($R^2 = .0013$), likely due to the fact that Mill Creek is relatively the same width throughout, while Cedar Run becomes drastically wider as it gets closer to its outlet **(Fig. 12)**.

CONCLUSION & FUTURE CONSIDERATIONS

Mill Creek and Cedar Run differ most in their dissolved oxygen levels. This difference could be due to the narrow upstream structure of Cedar Run, or the generally higher chlorophyll levels at Mill Creek. Overall, pH is significantly higher at Mill Creek, but both creeks have an average pH within normal limits. The higher pH at Mill Creek can be reasonably explained by the relationship between DO and pH. Nitrogen and chlorophyll are typically higher at Mill Creek, but usually not significantly higher. Mill Creek does not appear to be dramatically different from Cedar Run in flow, chlorophyll, nitrogen, or turbidity. It is possible that the creek itself is in decent condition, and the dead-end lagoons branching off from Mill Creek are the larger areas of concern.

The lagoons of Beach Haven West should be a focal point of water quality concern in the future. Assessments for nutrient levels (nitrogen, sulfates, phosphates), salinity, chlorophyll, bacterial presence and quantity, water velocity, and biodiversity could be carried out with samples from the lagoons of Beach Haven West, possibly with a specific concentration on the lagoons involved in last summer's contamination scare. The drainage system and runoff sources at Cedar Run may also warrant future examination, since there was an alarming nitrogen spike in Cedar Run during a rainfall event.

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