Impacts of Abiotic Factors on Seagrass Growth

Emma Beyer Nusrat Noor Desa Bolger

EDA Final Project - Fall 2023

Contents

0.1 R Markdown

This is an R Markdown document for the final project in EDA. This document explores the impacts of temperature and salinity on linear growth rates and production rates of the seagrass Thalassia testudinum.

0.2 Rationale

We chose a data set from the 2022 Johnson, Hanes, and Bolten publication titled "Seagrass growth rates and physical characteristics and measures of water temperature and salinity during a simulated green turtle grazing experiment in The Bahamas, 1999 – 2000." We chose to focus our research in the Bahamas because of the rich marine life in the area. This data set aims to understand how green turtle food consumption practices impact a specific species of seagrass (Thalassia testudinum). We appreciated how thorough this data set was, as it tracked blade width, number of blades per shoot, blade length, shoot density, and even had a leaf index in order to understand how the seagrasses were changing.

We focused on the non-green turtle simulation group of the seagrass. We wanted to see how abiotic factors (temperature and salinity) impacted marine species. This data set also included weekly temperature and salinity sampling, which allowed us to understand if abiotic factors were influencing seagrass growth.

Citation: Johnson, R.A., K.M. Hanes, A.B. Bolten, and K.A. Bjorndal. 2022. Seagrass growth rates and physical characteristics and measures of water temperature and salinity during a simulated green turtle grazing experiment in The Bahamas, 1999 – 2000. ver 1. Environmental Data Initiative. https://doi.org/10.6073/pasta/601ae427b99c240e6df52c0737efbab3 (Accessed 2023-11-25).

0.2.1 Research Questions

1. Does temperature impact mass growth rates of seagrass?
2. Does salinity impact mass growth rates of seagrass?
3. Does temperature impact linear growth rates of seagrass?
4. Does salinity impact linear growth rates of seagrass?

0.3 Dataset Information

We first imported the files for temperature/salinity (Temperature-Salinity.csv), mass growth rates (Seagrass-production-rates.csv), and linear growth rates (Seagrass-linear-growth-rates.csv). We used as.Date() to convert all dates if needed to the right format and filtered each of the files to only include reference data. Although the temperature and salinity data came from the same file, we separated the wrangling for each variable.

For the temperature data, we used mutate() to add a mean temperature created from the min_temp and max_temp columns, selected date, mean_temp, and exp_week for our final processed table, and omitted NAs. This was saved as a processed file.

For the salinity data, we selected out the date, exp_week, and salinity columns and omitted any NAs. For our linear growth data, we selected date, gr_length, and exp_week.

To wrangle our mass growth rate data, we selected the treatment, date, exp_week, and gr_mass columns and filtered by reference data. We grouped by date, summarized the mean growth, and mutated to include the reference treatment. This data was then saved as a processed file.

These files were joined using a full_join by the experimental week. For each dataframe, we selected out the columns needed to do our analysis and removed any NAs. To compare mean temperature and mass growth rates, we selected out date, mean_temp, exp_week, and mean_growth. To compare salinity and mass growth rates, we selected out date, salinity, exp_week, and meangrowth. To compare temperature and salinity with growtth length, For each of these joins, we selected the date, gr_length and either the mean temperature or salinity levels. The files were saved in the processed folder, plotted, and analyzed.

```
## -- Attaching core tidyverse packages ------------------------ tidyverse 2.0.0 --
## v dplyr     1.1.3     v readr     2.1.4
## v forcats   1.0.0     v stringr   1.5.0
## v ggplot2   3.4.3     v tibble    3.2.1
## v lubridate 1.9.3     v tidyr     1.3.0
## v purrr     1.0.2
## -- Conflicts ------------------------------------------ tidyverse_conflicts() --
## x dplyr::filter() masks stats::filter()
## x dplyr::lag()    masks stats::lag()
## i Use the conflicted package (<http://conflicted.r-lib.org/>) to force all conflicts to become errors
## here() starts at /home/guest/R/Final_Project/BeyerBolgerNoor_Env872_EDA_FinalProject
```

```
## [1] "/home/guest/R/Final_Project/BeyerBolgerNoor_Env872_EDA_FinalProject"
```

Table 1: Data Structure

Variable	Unit	Ranges	Notes
Date	Calendar Days	07/08/1999 - 12/13/2000	NAs removed
min_temp	Celsius	21.50- 31.00	
max_temp	Celsius	24.83 - 32.67	
mean_temp	Celsius	23.415- 31.750	(Min_Temp + Max_Temp)/2
gr_mass	g DM m^{-2} d^{-1}	0.224 - 1.872	Production growth rates
meangrowth	g DM m^{-2} d^{-1}	0.4716667 - 1.2384667	Mean mass growth rate
exp_week	Weeks	5 - 75	Experiment Week
salinity	g/kg	33.67 - 41.00	Salinity levels
gr_length	cm	0.955 - 4.856	Linear Growth

0.4 Exploratory Analysis

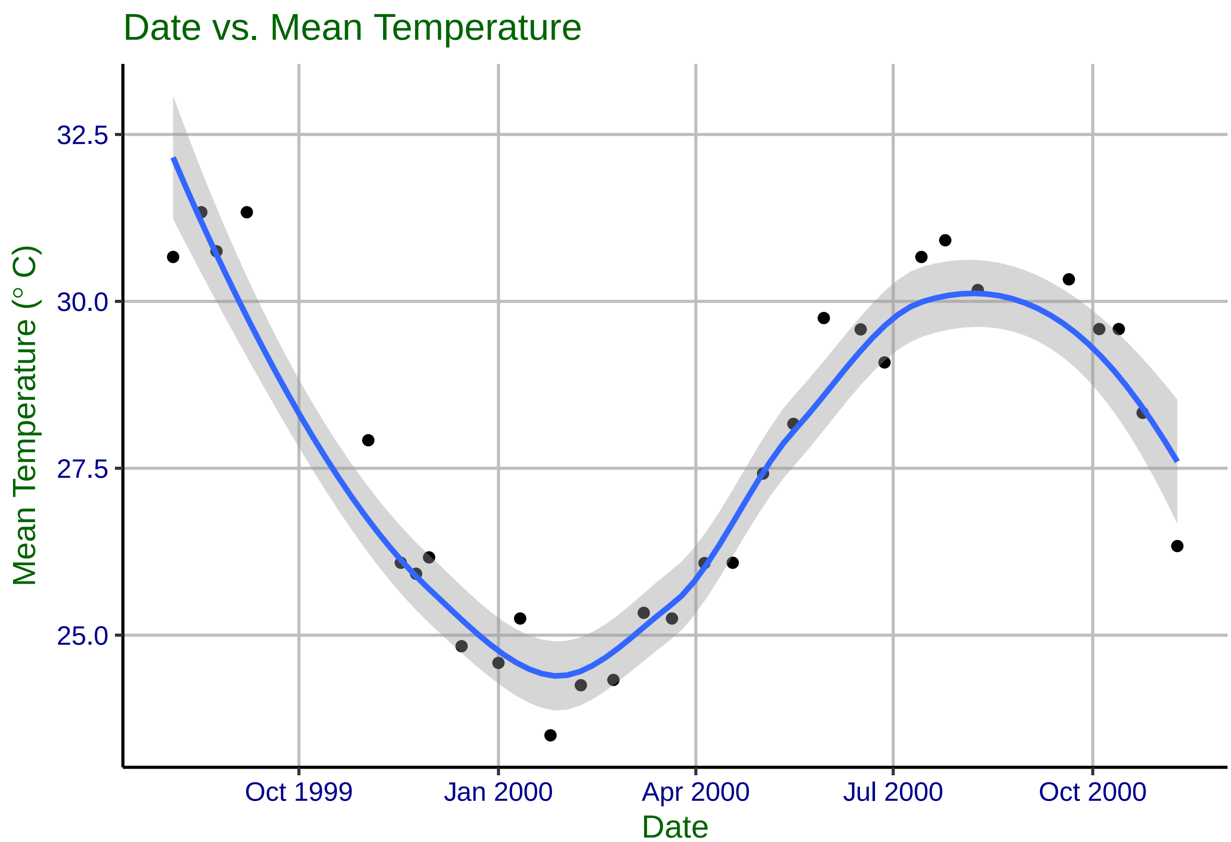

Figure 1: Relationship between date and mean temperature (° C) in the study site region in the Bahamas. Temperature was lowest in February 2000 (23.415 ° C) and highest in July 2000 (31.750 ° C).

Both Figures 1 and Figures 2 share a remarkably similar relationship and curvature. Given the location of the Bahamas, it makes sense that the weather is coldest in the winter (December to March) and warmest in the summer (June to August). The fact that these figures are so similar suggests that there may be a relationship between mean growth and temperature for the seagrass, but more analysis is needed.

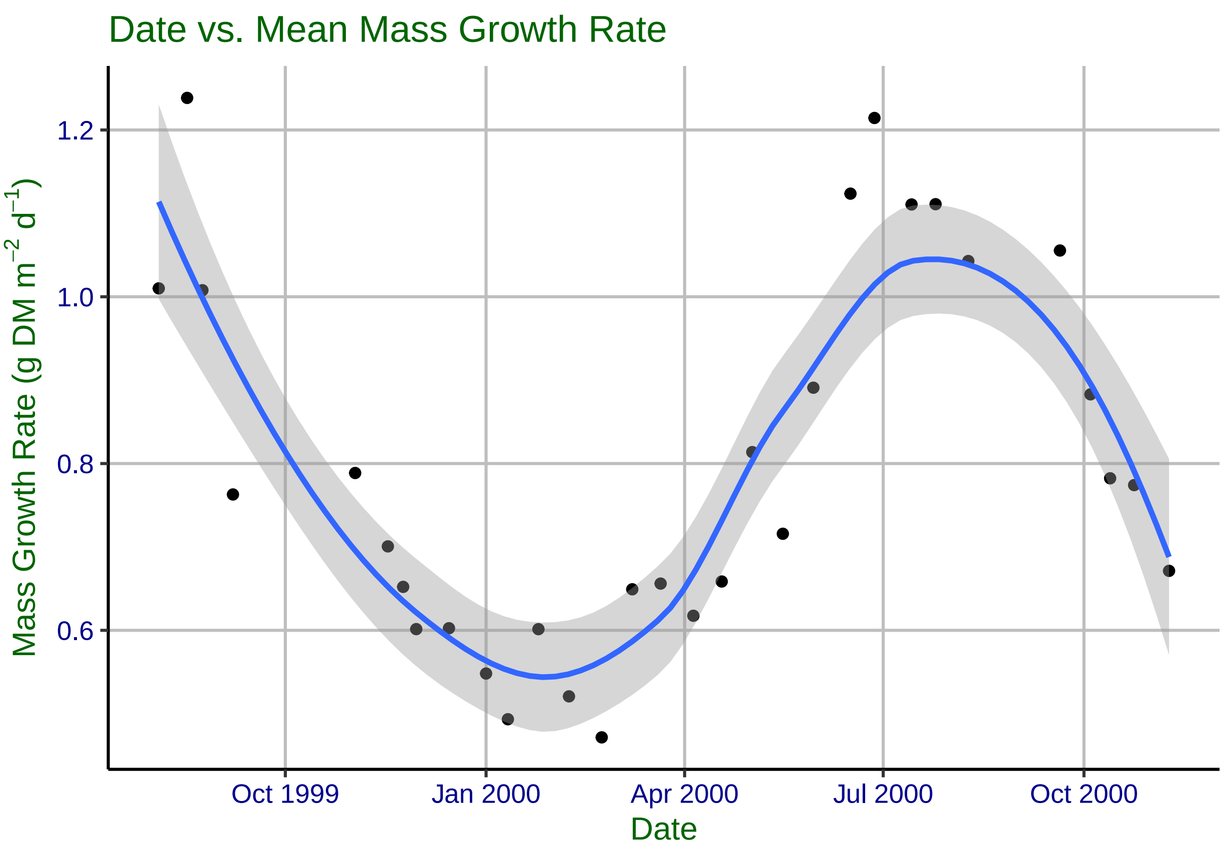

Figure 2: Relationship between date and mean growth rate of the seagrass (in g DM m^{-2} d^{-1}) in the study site region in the Bahamas. Mean growth is highest in August 1999 (1.2384667 g DM m^{-2} d^{-1}) and lowest in February 2000 (0.4716667 g DM m^{-2} d^{-1}).

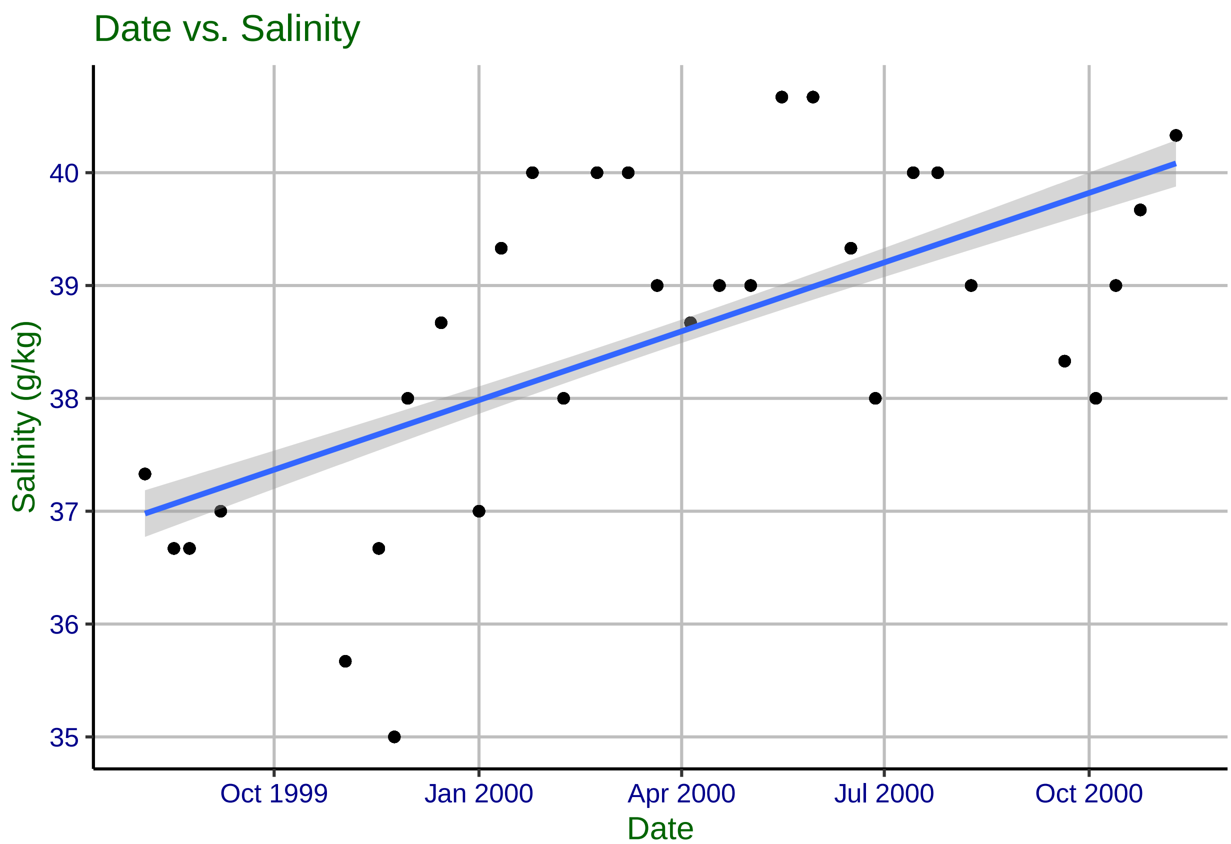

Figure 3: Relationship between date and salinity (g/kg). The lowest salinity was recorded in November 1999 (25.00 g/kg) and the highest was recorded in May 2000 (40.67 g/kg). This suggests a positive relationship where salinity is increasing over the study time.

```
##
## Call:
## lm(formula = salinity ~ date.x, data = salinity_lineargrowth_processed)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -2.7296 -0.9014  0.1979  0.7086  1.8548
##
## Coefficients:
##               Estimate Std. Error t value Pr(>|t|)
## (Intercept) -3.546e+01  4.318e+00  -8.213 2.17e-15 ***
## date.x       6.703e-03  3.911e-04  17.140  < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 1.137 on 463 degrees of freedom
## Multiple R-squared:  0.3882, Adjusted R-squared:  0.3869
## F-statistic: 293.8 on 1 and 463 DF,  p-value: < 2.2e-16
```

A linear regression was run to prove this relationship ($p < 2.2e^{-16}$, $R^2 = 0.3869$, $df = 463$). This confirms that there is a significant positive relationship between date and salinity. This means that salinity was increasing over time within the study site.

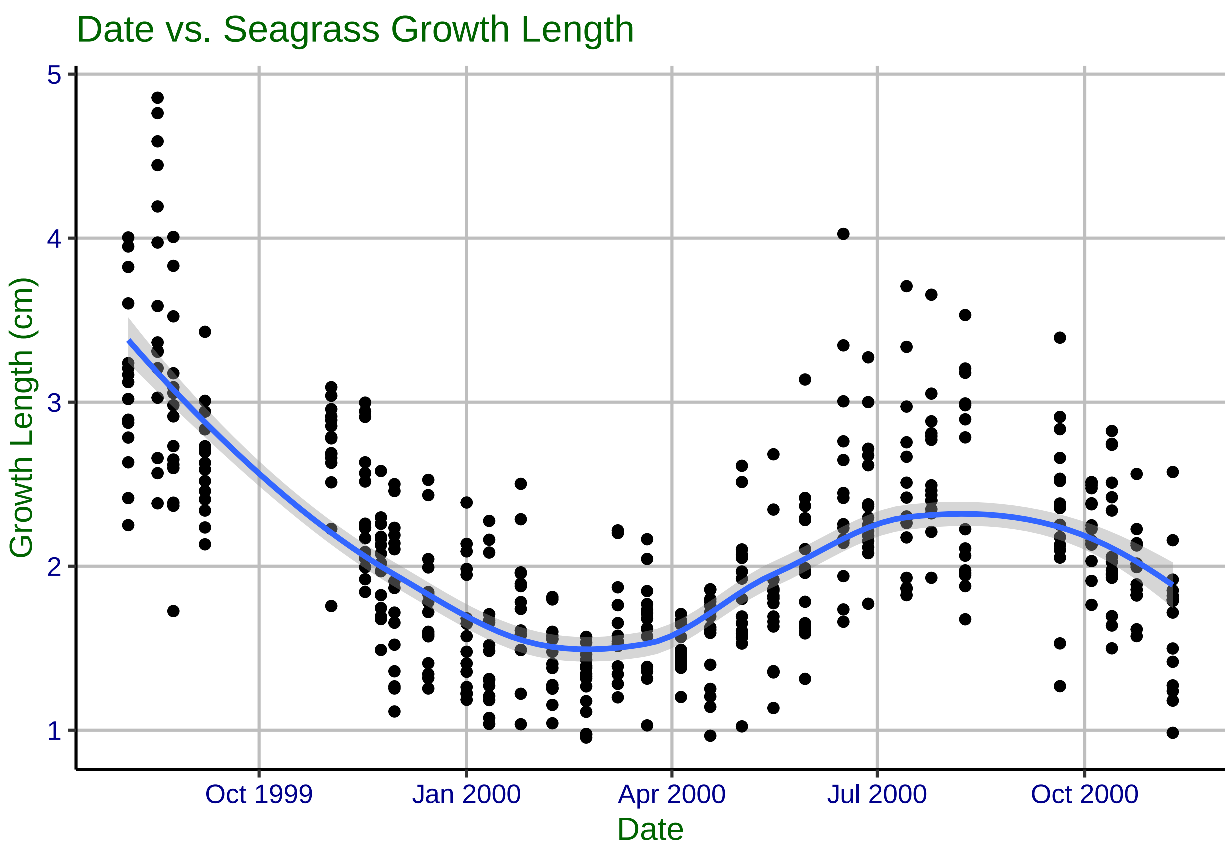

Figure 4: Relationship between date and seagrass growth length (cm) within the study site. The highest amount of growth was recorded in July 1999 (4.856 cm) and lowest amount of growth was recorded in February 2000 (0.955 cm).

0.5 Analysis

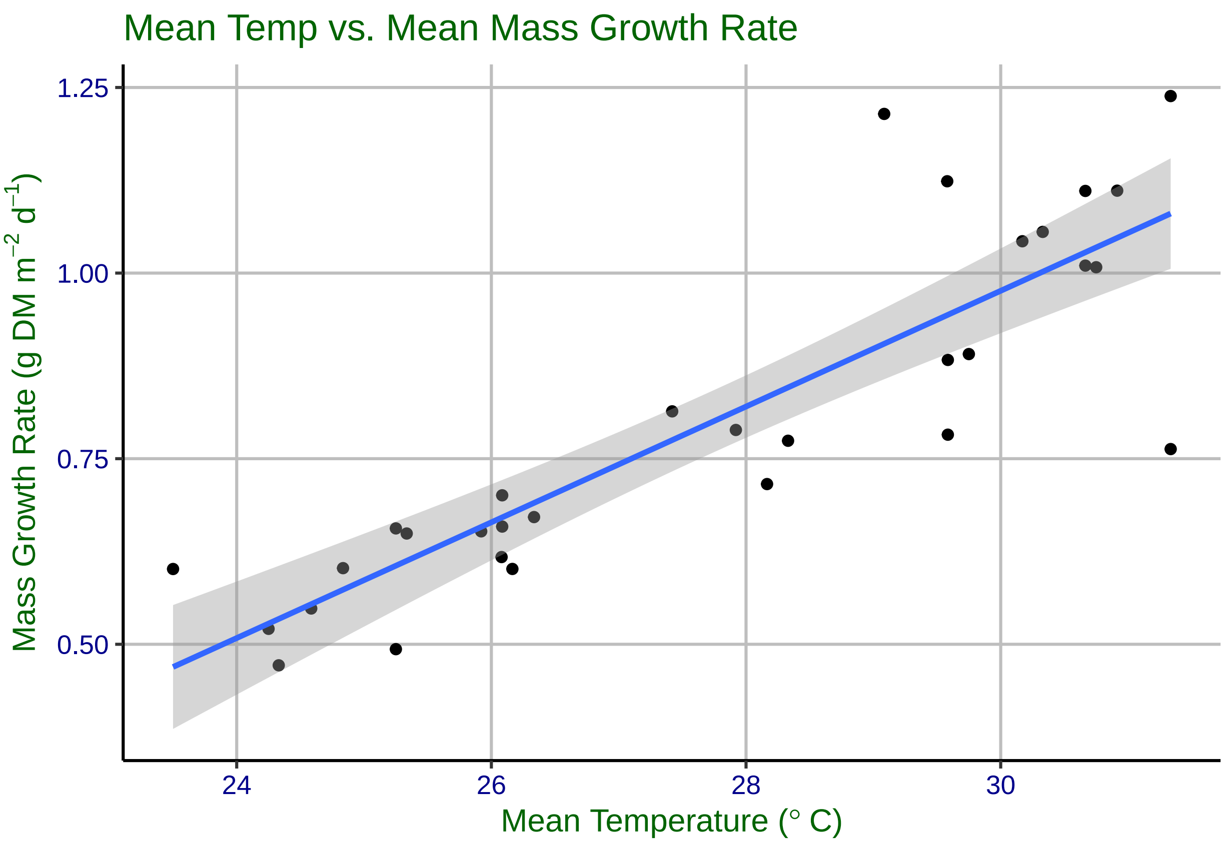

Figure 5: Relationship between mean temperature (° C) and seagrass mean growth (g DM m^{-2} d^{-1}).

```
##
## Call:
## lm(formula = mean_temp ~ meangrowth, data = temp_production_rate_processed)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -2.6417 -0.7128 -0.0632  0.6524  3.9540
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept)  20.0372     0.8545  23.448  < 2e-16 ***
## meangrowth    9.6257     1.0310   9.337 3.06e-10 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 1.265 on 29 degrees of freedom
## Multiple R-squared:  0.7504, Adjusted R-squared:  0.7418
## F-statistic: 87.17 on 1 and 29 DF,  p-value: 3.06e-10
```

A linear regression was run on the relationship between mean temperature and seagrass mean growth. As is visible in Figure 5, ProductionRate = 9.6257(temp) + 20.0372. According to this test, temperature significantly positively impacts seagrass production rate ($p < 3.06$ e^{-10}, $R^2 = 0.7504$). This makes sense given our exploratory graphs, where the figures tracking date versus mean temperature and mean growth had incredibly similar shapes. This supports our hypothesis that temperature impacts the linear growth rates of seagrass, given our p-value of less than 0.05.

```
##
```

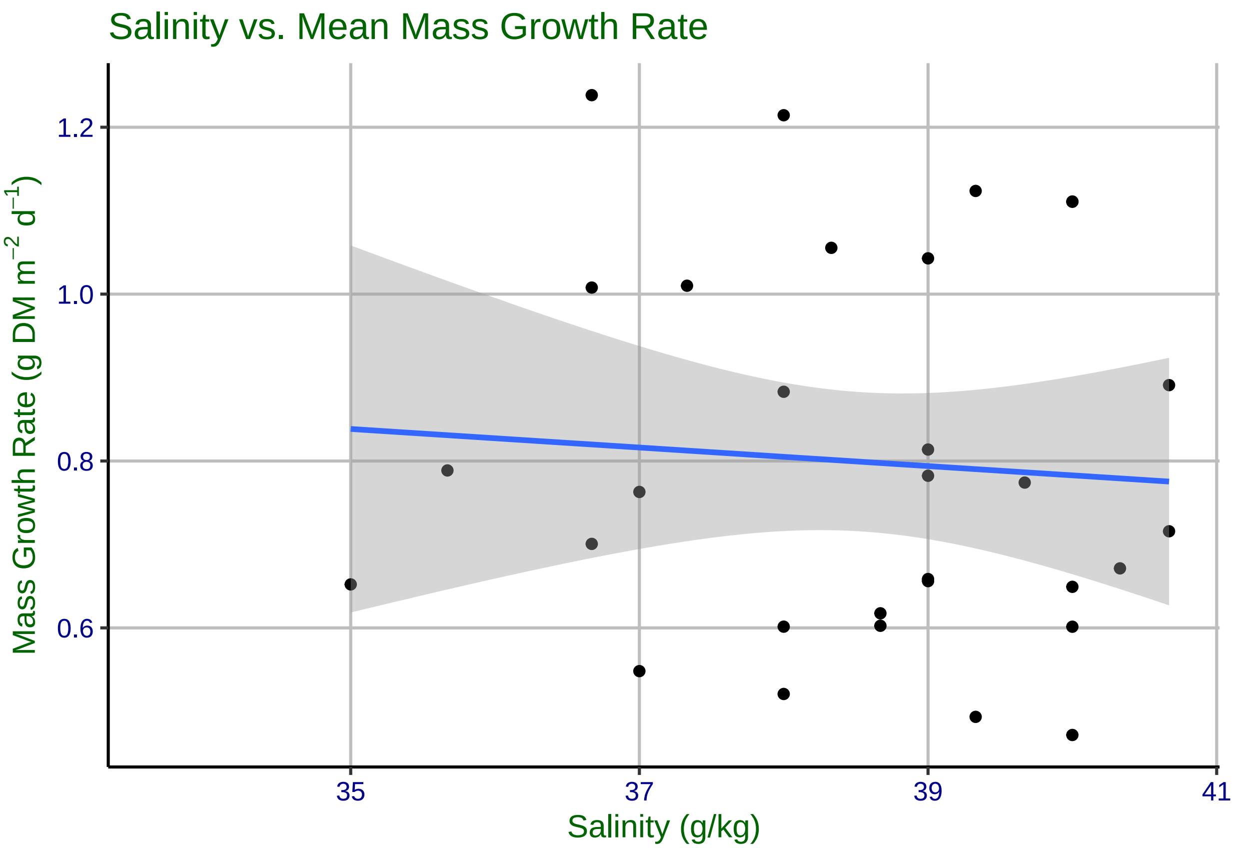

Figure 6: Relationship between salinity (g/kg) and seagrass production rates (g DM m^{-2} d^{-1}). The graph shows that there does not seem to be any relationship between the two variables.

```
## Call:
## lm(formula = salinity ~ meangrowth, data = salinity_prod_rates)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -3.6089 -0.8893  0.3930  1.2121  2.1762
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept)  38.9231     1.0108  38.509   <2e-16 ***
## meangrowth   -0.4818     1.2194  -0.395    0.696
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 1.496 on 29 degrees of freedom
##   (38 observations deleted due to missingness)
## Multiple R-squared:  0.005355,   Adjusted R-squared:  -0.02894
## F-statistic: 0.1561 on 1 and 29 DF,  p-value: 0.6956
```

A linear regression was run and showed there was not a significant relationship. The p-value is 0.6956 and r^2 is -0.02894.

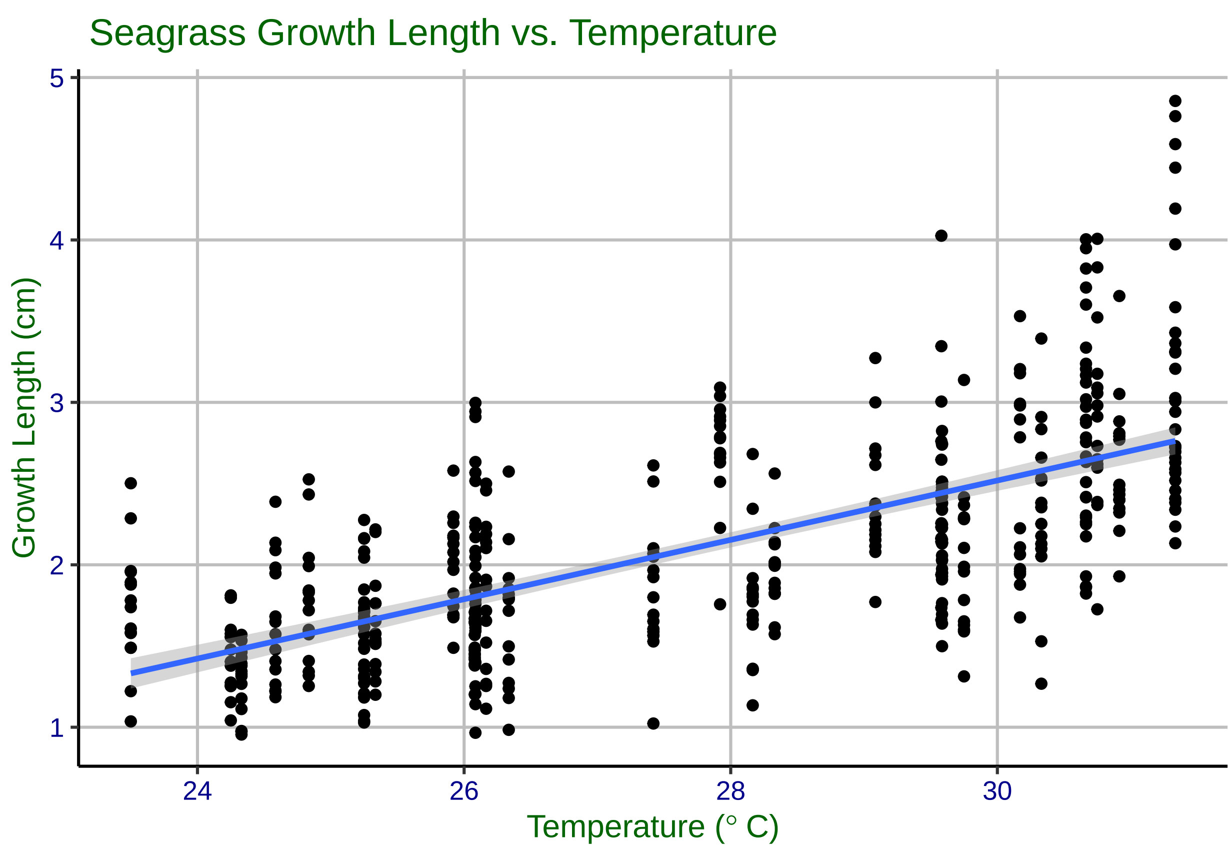

Figure 7: Relationship between seagrass growth length (cm) and water temperature (° C). This suggests a positive relationship where as temperature increases, growth length also increases.

```
##
## Call:
## lm(formula = mean_temp ~ gr_length, data = temp_lineargrowth_processed)
##
```

```
## Residuals:
##     Min      1Q  Median      3Q     Max
## -5.1758 -1.4607 -0.1001  1.4551  4.5908
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept)  22.7217     0.2788   81.50   <2e-16 ***
## gr_length     2.3797     0.1261   18.87   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 1.844 on 463 degrees of freedom
## Multiple R-squared:  0.4347, Adjusted R-squared:  0.4335
## F-statistic: 356.1 on 1 and 463 DF,  p-value: < 2.2e-16
```

A linear regression was run to prove this relationship ($p < 2.2e^{-16}$, $R^2 = 0.4335$, df = 463). This confirms that there is a significant positive relationship between temperature and seagrass linear growth. This means that seagrass linear growth increases as the temperature increases within the study site.

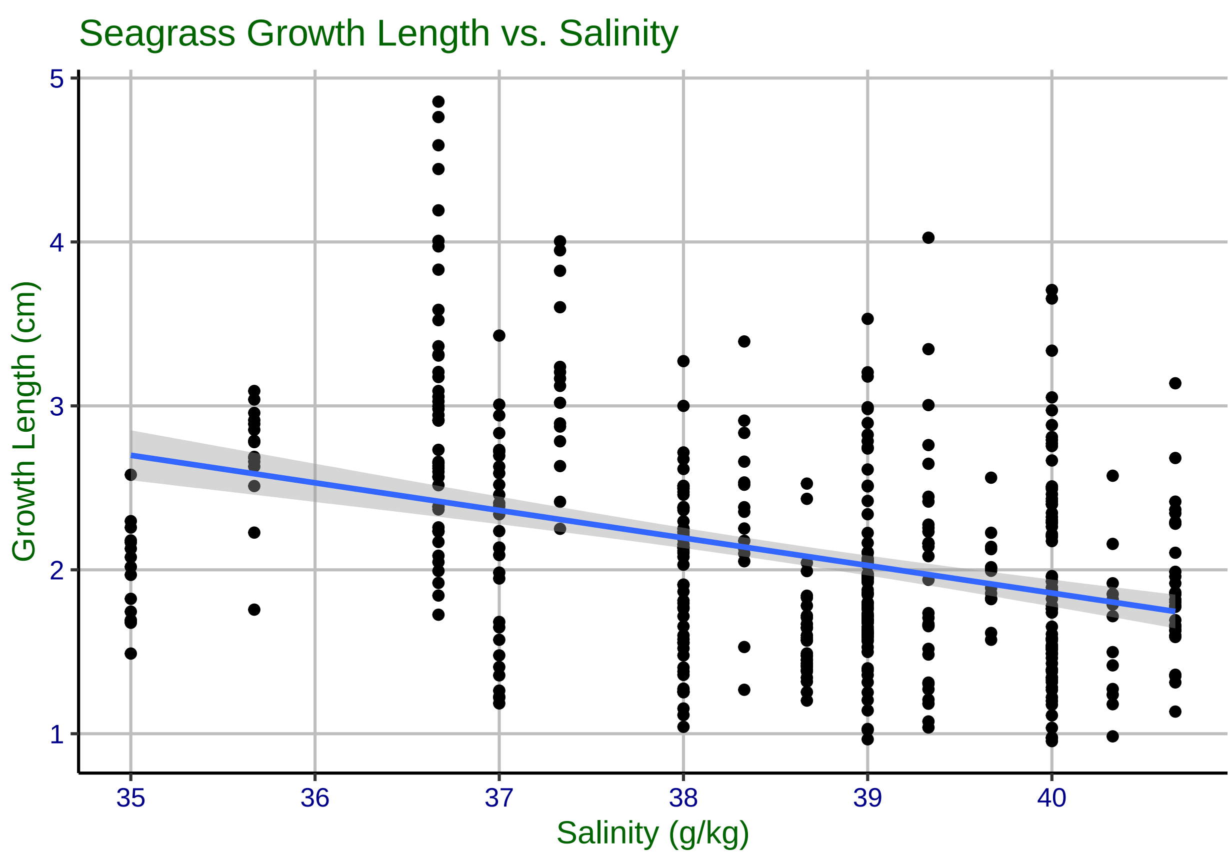

Figure 8: Relationship between seagrass growth length (cm) and salinity (g/kg). This suggests a negative relationship where as salinity increases, growth length decreases.

```
##
## Call:
## lm(formula = salinity ~ gr_length, data = salinity_lineargrowth_processed)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -4.0108 -0.8356  0.0906  1.0184  2.9268
```

```
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept) 40.15543    0.20503 195.848  < 2e-16 ***
## gr_length   -0.76870    0.09275  -8.288 1.26e-15 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 1.357 on 463 degrees of freedom
## Multiple R-squared:  0.1292, Adjusted R-squared:  0.1273
## F-statistic: 68.69 on 1 and 463 DF,  p-value: 1.256e-15
```

A linear regression was run to prove this relationship ($p = 1.256e^{-15}$, $R^2 = 0.1273$, df = 463). This confirms that there is a significant negative relationship between seagrass linear growth and salinity. This means that seagrass linear growth decreases as the salinity increases within the study site.

0.6 Summary and Conclusions

Through our analysis, we were able to answer all of our research questions. We found that there is a positive relationship between temperature and seagrass production rates/mean growth (Figure 5). Our linear regression produced a p-value of $< 3.06\ e^{-10}$, making the relationship significant. With an R^2 of 0.7504, we can conclude that 75% of the variance in production rates is explained by temperature.

On the other hand, we found that salinity does not have a relationship with seagrass production rates (Figure 6). This was corroborated by our linear regression test which gave us a p-value of 0.6956 and an R^2 is -0.02894. Even within the plot, while there was a slight negative trend where production rates decreased as salinity decreased, the data was fairly random and widely dispersed.

Temperature and salinity both had significant relationships with the linear growth rates of the seagrass Thalassia testudinum. Our results showed that as temperature increased, so did the growth length with a significant p-value of $< 2.2e^{-16}$. The R^2 came out to be 0.4335, meaning that 43% of the variance in linear growth lengths is explained by the temperature (Figure 7). Salinity and linear growth have an inverse relationship with a significant p-value of $1.256e^{-15}$. As salinity increased, linear growth rates decreased. However, with an R^2 of 0.1273, only about 13% of the variance in linear growth rates was explained by salinity changes (Figure 8).

Ultimately, our analysis was able to show us if and how abiotic factors impacted the growth of the seagrass Thalassia testudinum in the Bahamas.