Trends in Giant Kelp Nitrogen Concentration and Surge Uptake

Erin Ansbro, Cara Kuuskvere, Tani Valdez Rivas

December 2023

Contents

List of Tables

List of Figures

Rationale and Research Questions

Kelp forests along the United States West Coast are impacted by increasing temperatures as a result of climate change. Since the late 19th century, Santa Barbara County in Southern California has had an increase in average temperature by 4.1 degrees Fahrenheit (Wilson, 2019). Kelp not only provides a healthy ecosystem for other flora and fauna but also provides ecosystem services to humans as well. Kelp assists with human-related environmental issues in two ways. First, kelp can sequester a large amount of carbon, aiding in climate change mitigation (Hurlimann, 2019). Secondly, they absorb excess nitrogen, which can lessen the impacts of agricultural runoff (Conroy, 2023).

A recent study has shown that increased nitrogen uptake by kelp can limit the effect that heat has on them. This is an interesting development because nitrogen and eutrophication are generally seen as negative consequences of human interference. However, in this case, it could assist kelp and help them survive increased climate-change-related temperature increases (Fernández, 2020). Interested in this recent research, data about nitrogen concentration amount and uptake were located in the Long-Term Ecological Research database titled "SBC LTER: Reef: Surge uptake capability in Macrocystis pyrifera in response to pulses of three different forms of nitrogen" (Cedeno, 2021) and " SBC LTER: Reef: Macrocystis pyrifera CHN content (carbon, hydrogen, nitrogen), ongoing since 2002" (Santa Barbara, 2021). This data looked simple enough to clean and manipulate, while also providing enough information for a research project.

We are interested in trends in giant kelp nitrogen concentration amount and nitrogen surge uptake. Specific questions include: 1. Has nitrogen concentration in kelp changed over the years (2002-2021)? 2. Does giant kelp nitrogen concentration amount vary by season? 3. Does nitrogen surge uptake vary between the spring and summer seasons? 4. Does giant kelp nitrogen surge uptake vary based on the amount of exposure? 5. Does uptake vary by type of nitrogen (ammonium, nitrate, and urea)?

Github Information: https://github.com/Tani-ValdezRivas/ValdezKuuskvereAnsbro

Dataset Information

Data sets were found on the Environmental Data Initiative. All sets were from the Santa Barbara Coastal Long Term Ecological Research Site (SBC LTER) which is based within the University of California, Santa Barbara (UCSB) Marine Science Institute, and is part of the National Science Foundation's LTER Network.

The first data set focuses on one experiment done that examines nitrogen and biomass uptake by kelp during timed nitrogen blasting. The first data set was used to determine if nitrogen uptake varies by time (minutes), season, or nitrogen type. The second data set has dates and percent nitrogen of kelp over almost a twenty year period. This second data set was used to gain a general sense of nitrogen found in kelp in Santa Barbara, CA and to see if that has changed over time.

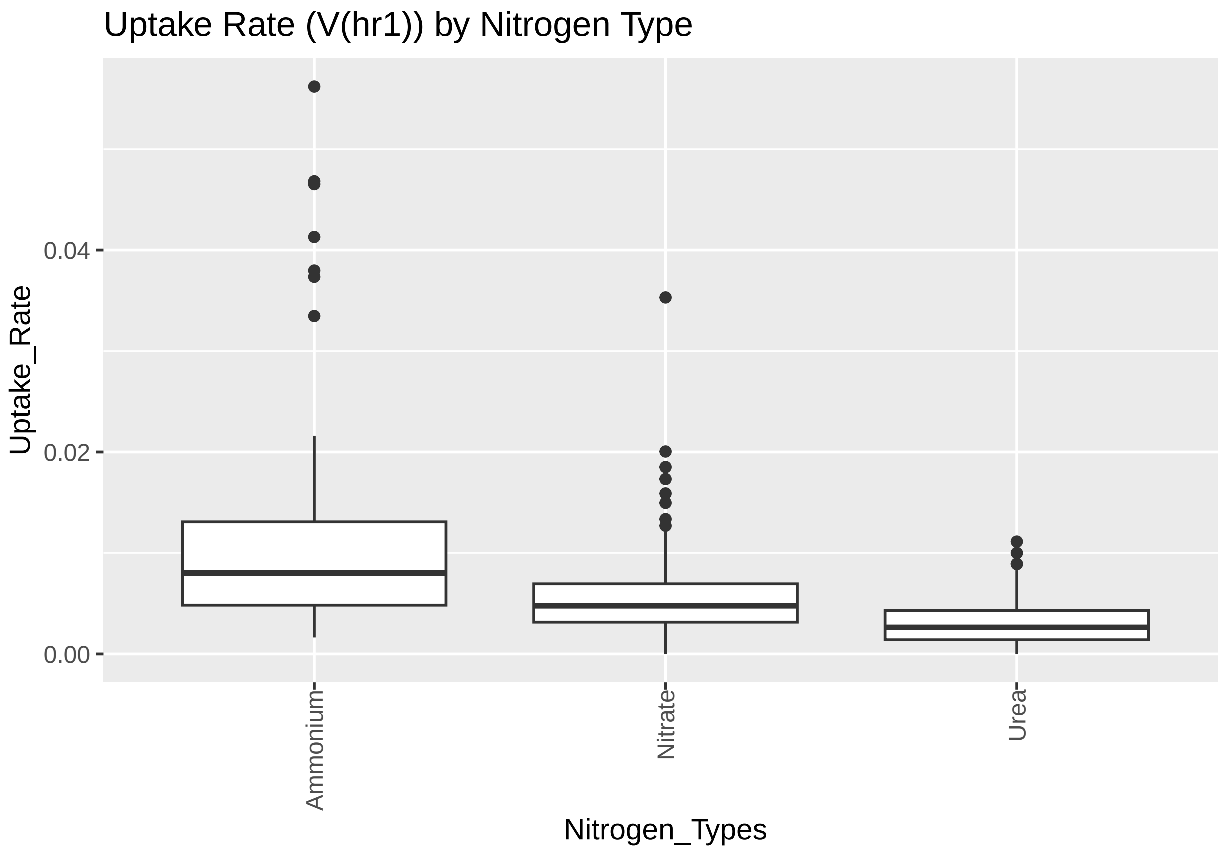
Table 1:Data Set Information

Detail	Data Set 1	Data Set 2
Source	Santa Barbara Coastal Long Term Ecological Research (LTER)	Santa Barbara Coastal Long Term Ecological Research (LTER)
Retrieved from	https://portal.edirepository.org/nis/mapbrowse?packageid=edi.1022.2	https://sbclter.msi.ucsb.edu/data/catalog/package/?package=knb-lter-sbc.24
Variables Used	Nitrogen Types, Season, Day Replicate, Time, Blade Replicate, Uptake Rate, Biomass Uptake Rate	Year, Month, Date, Nitrogen Percent
Date	2021	2002-2021

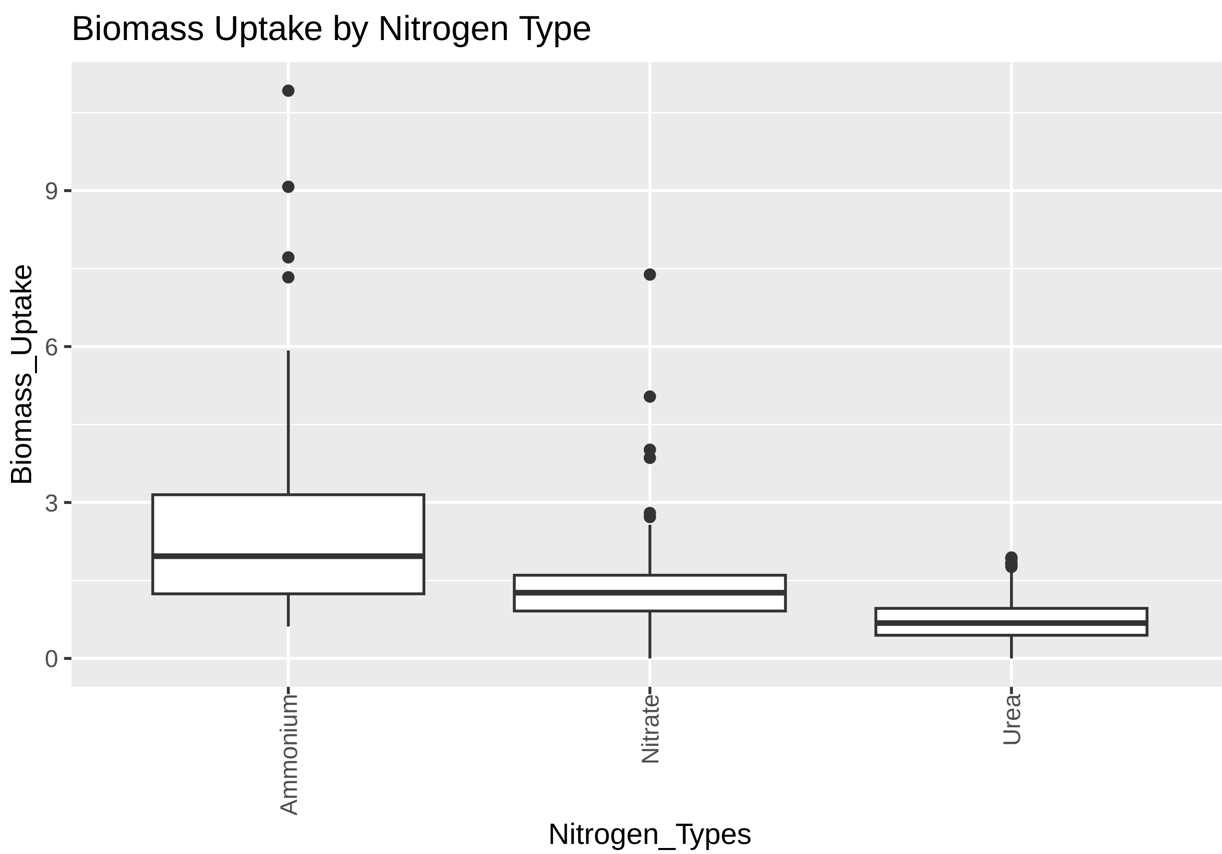
The data for nitrogen uptake was cleaned by renaming the column names to be better understood by the public. Multiple columns including columns for Blade Replicate, Day Replicate, Time, Season, and Nitrogen Type were changed to factors. Season and Nitrogen Type also had labels added to capitalize the names of seasons and nitrogen types.Data cleaning for the second data set entailed renaming column names as well. Date was changed from a factor to a date data type. Sites with missing values were also removed.

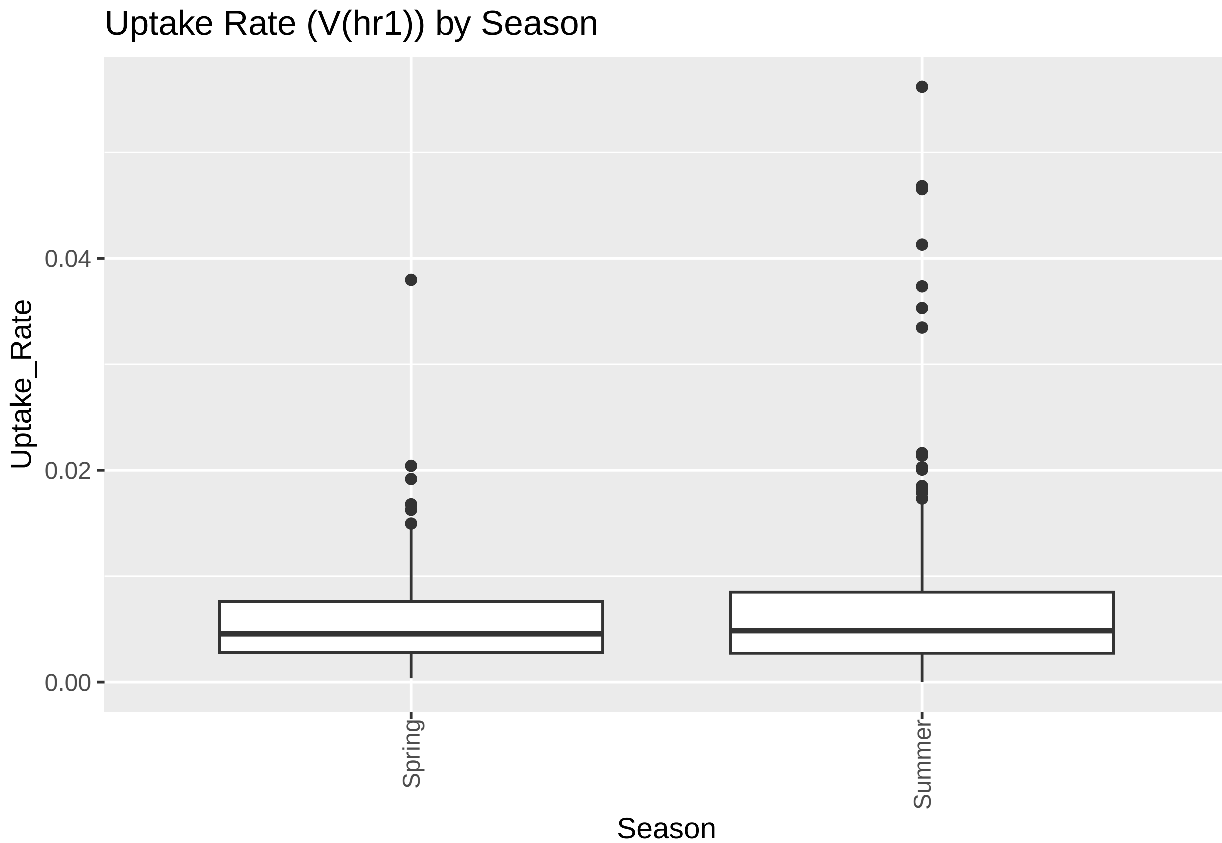
Exploratory Analysis

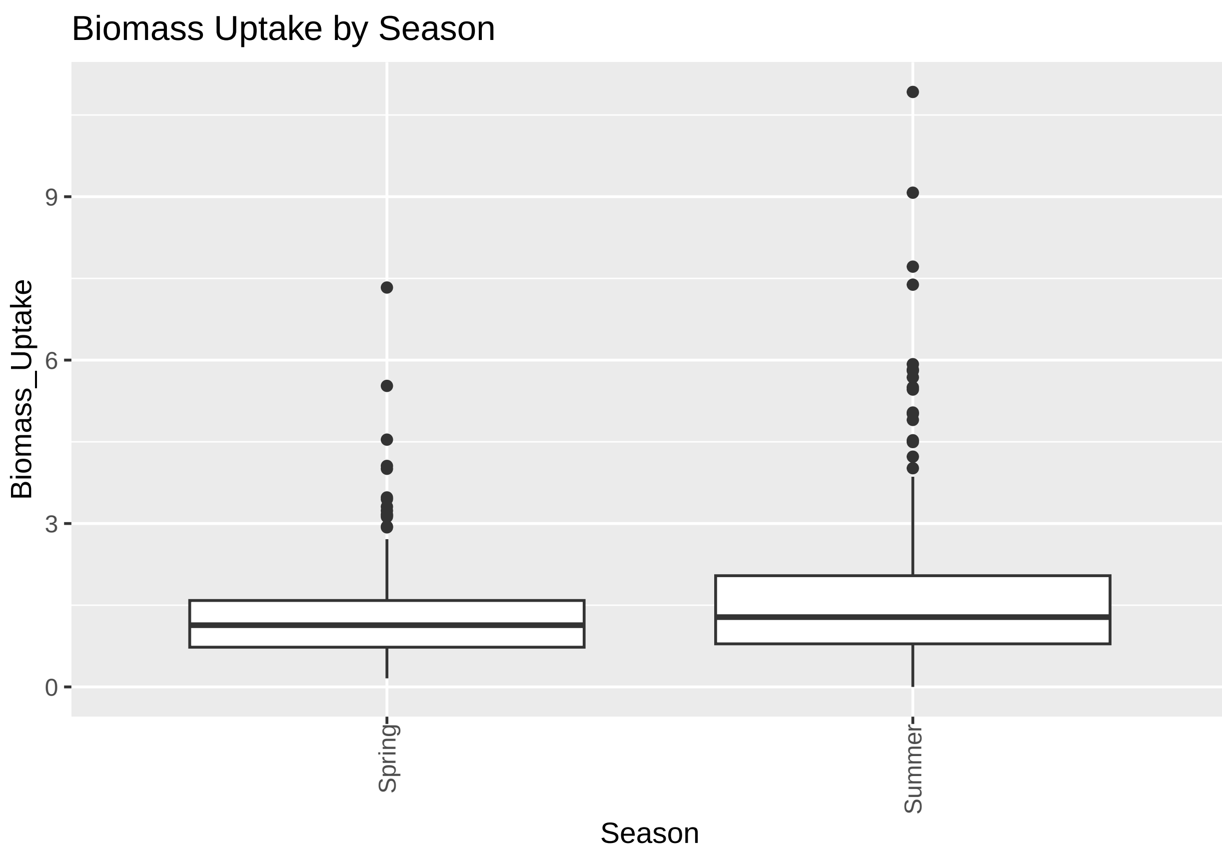
A map was created to gain a sense of location. The Map shows the sampling sites of nitrogen uptake along the coast of California.

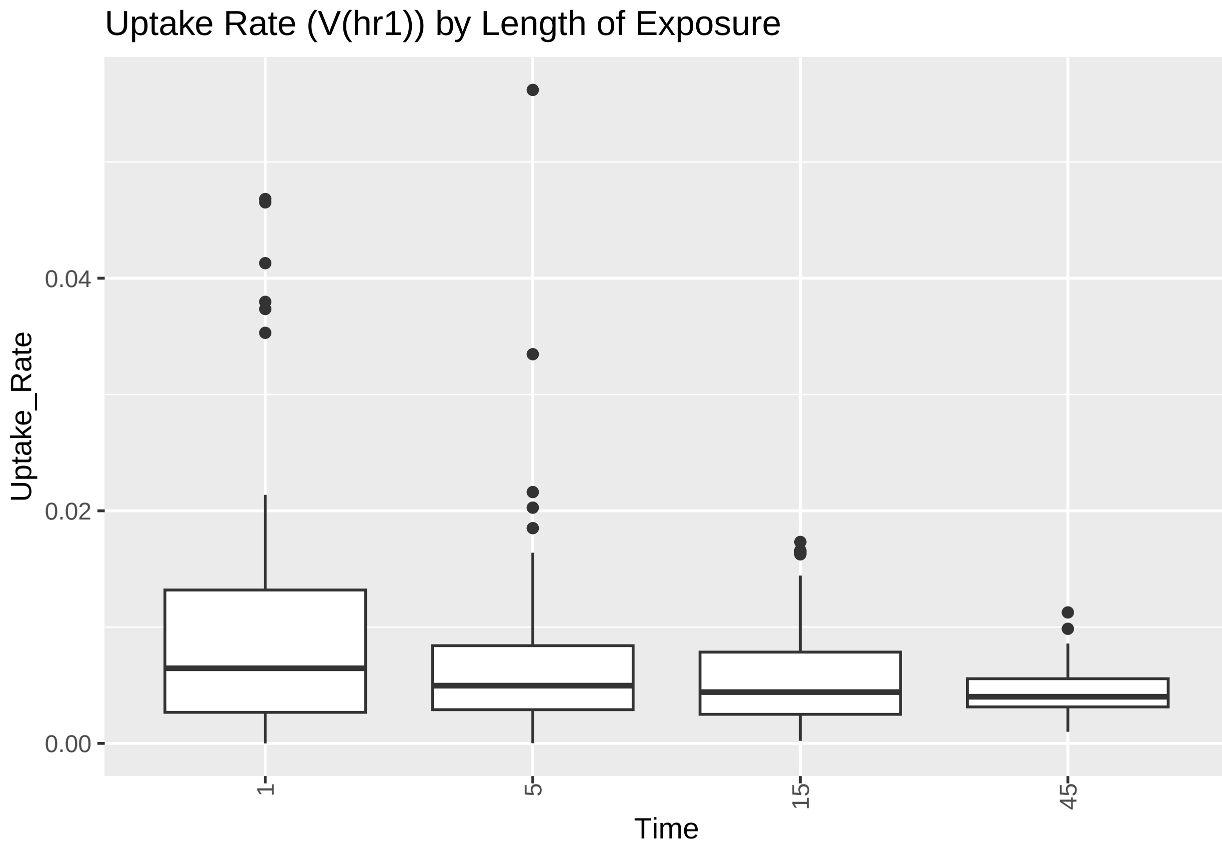


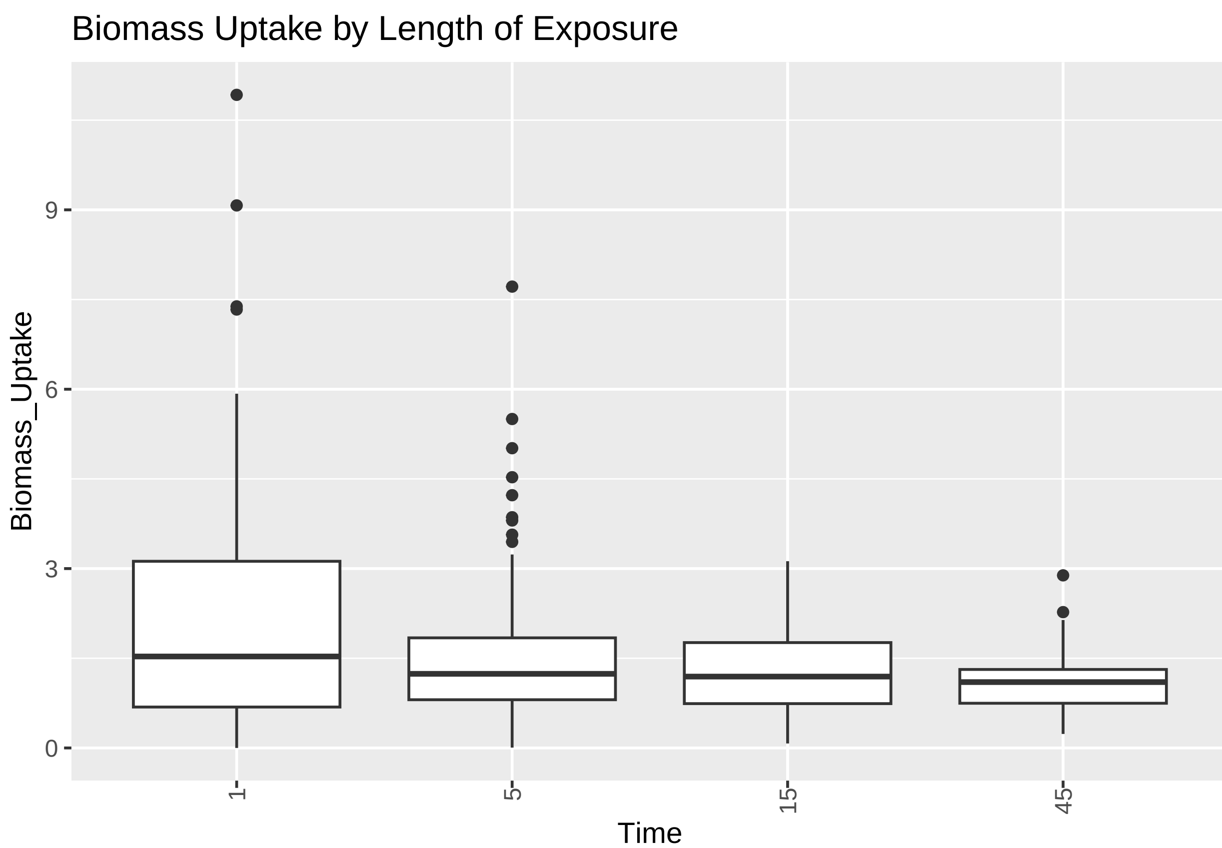
Boxplot text

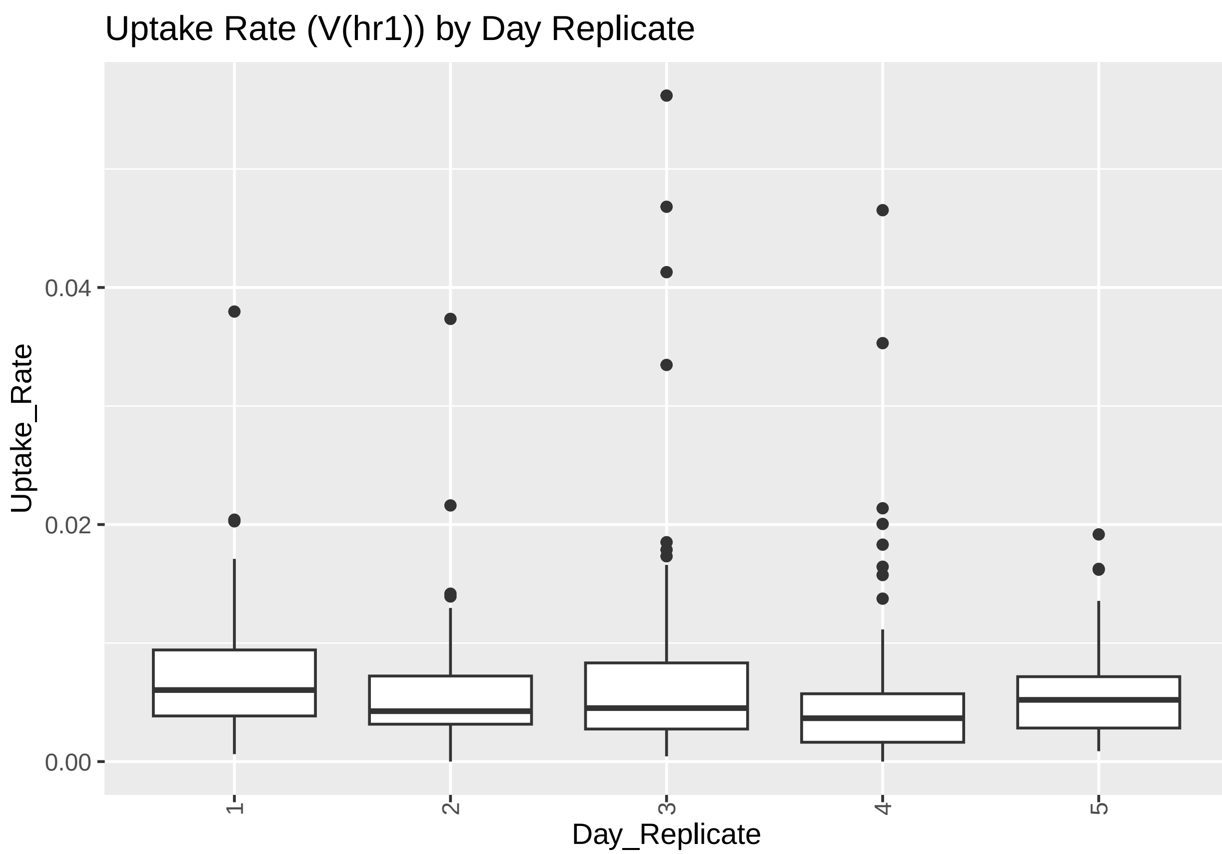

Biomass Uptake by Nitrogen Type
Biomass_Uptake
9
6
3
0
Ammonium
Nitrate
Urea
Nitrogen_Types

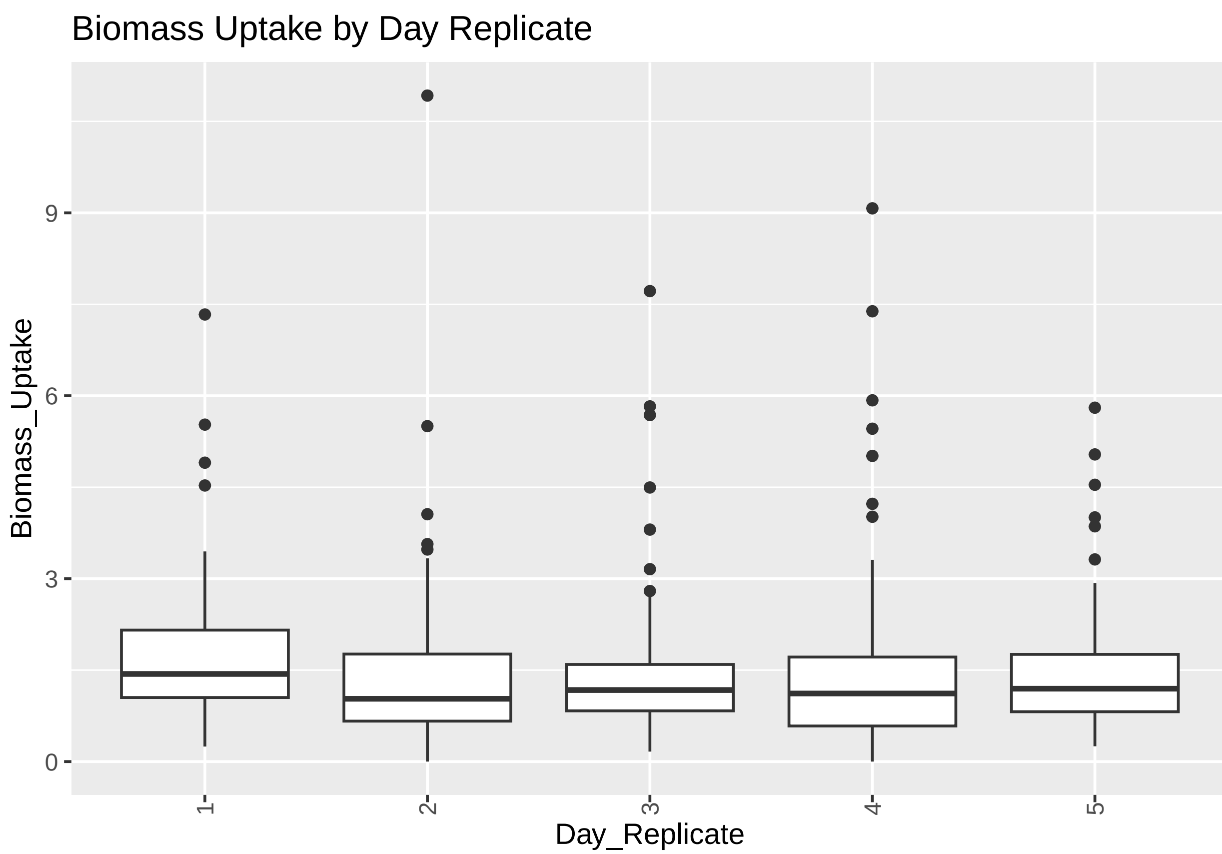

Uptake Rate (V(hr1)) by Season
Uptake_Rate
0.04
0.02
0.00
Spring
Summer
Season

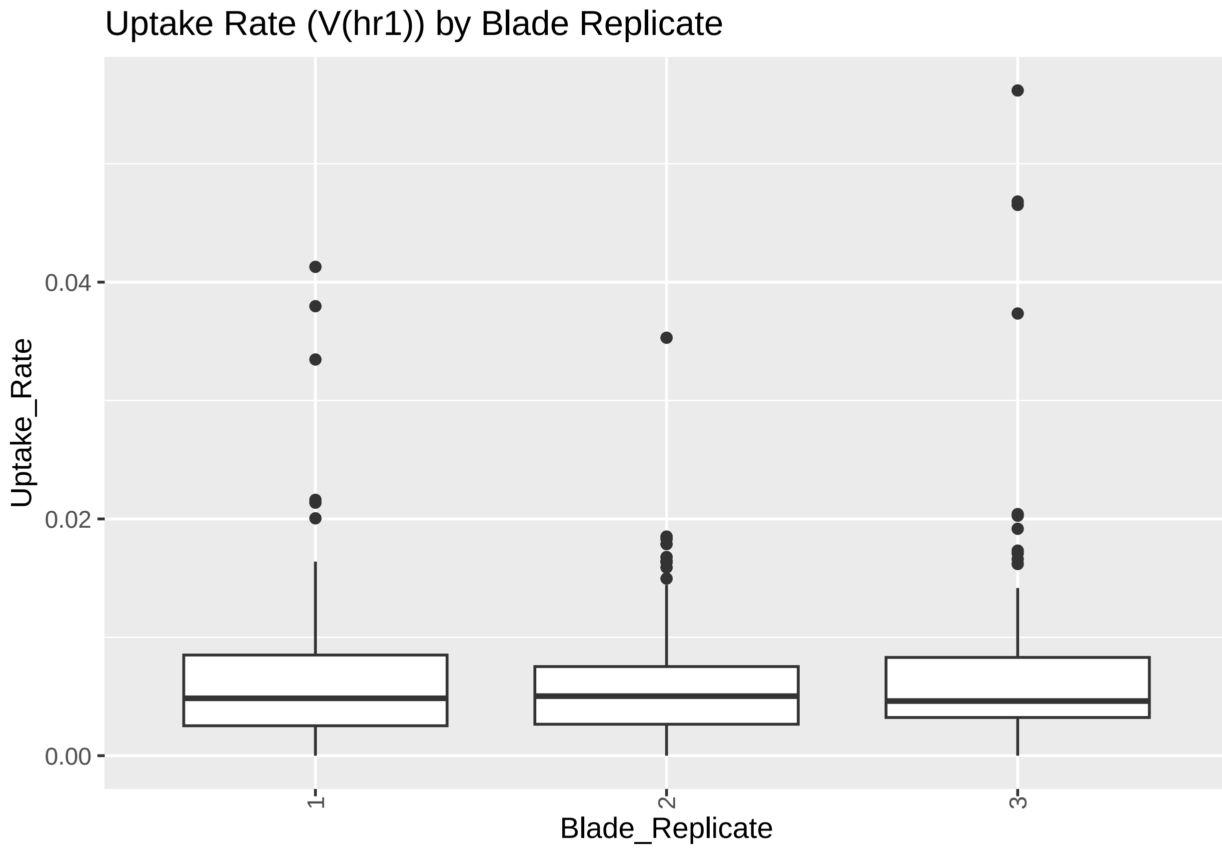

Biomass Uptake by Season
Biomass_Uptake
9
6
3
0
Spring
Summer
Season


Uptake Rate (V(hr1)) by Length of Exposure
Uptake_Rate
0.04
0.02
0.00
1
5
15
45
Time

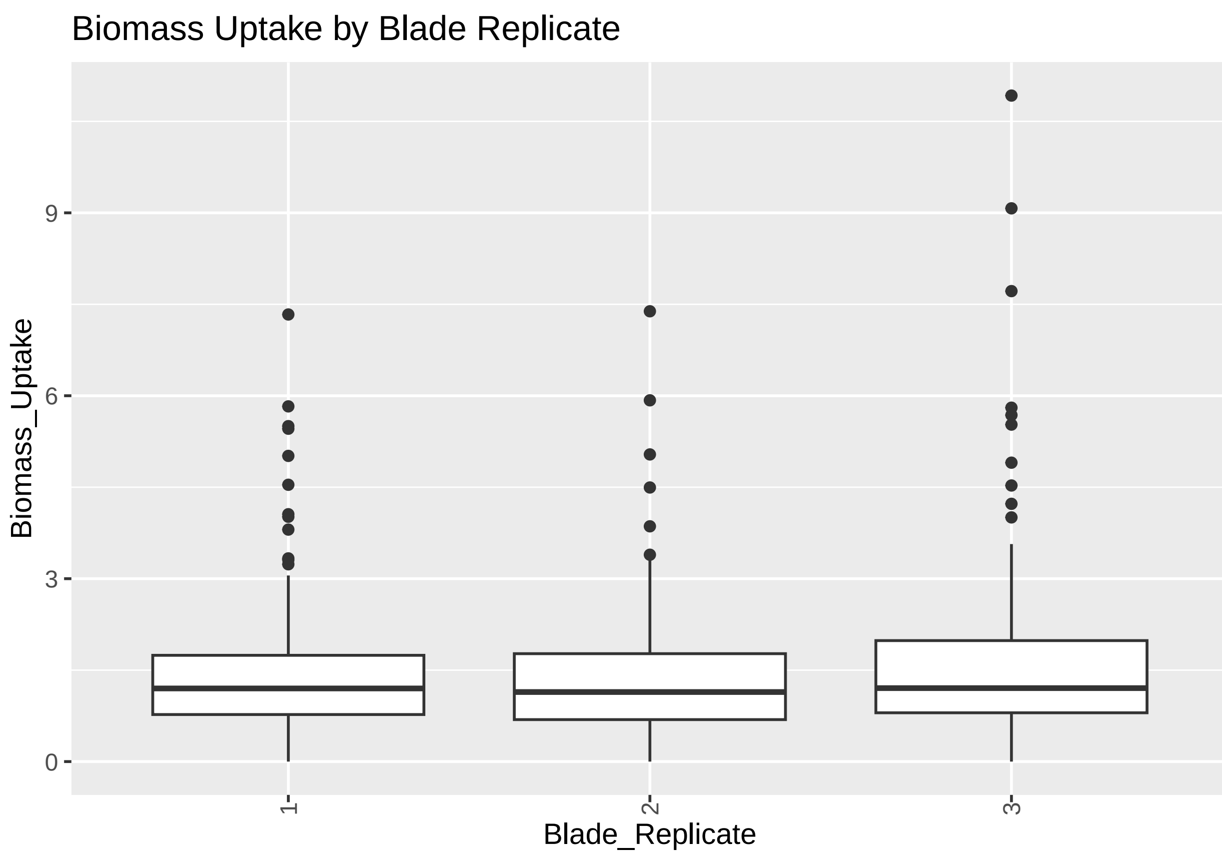

Biomass Uptake by Length of Exposure
Biomass_Uptake
9
6
3
0
1
5
15
45
Time

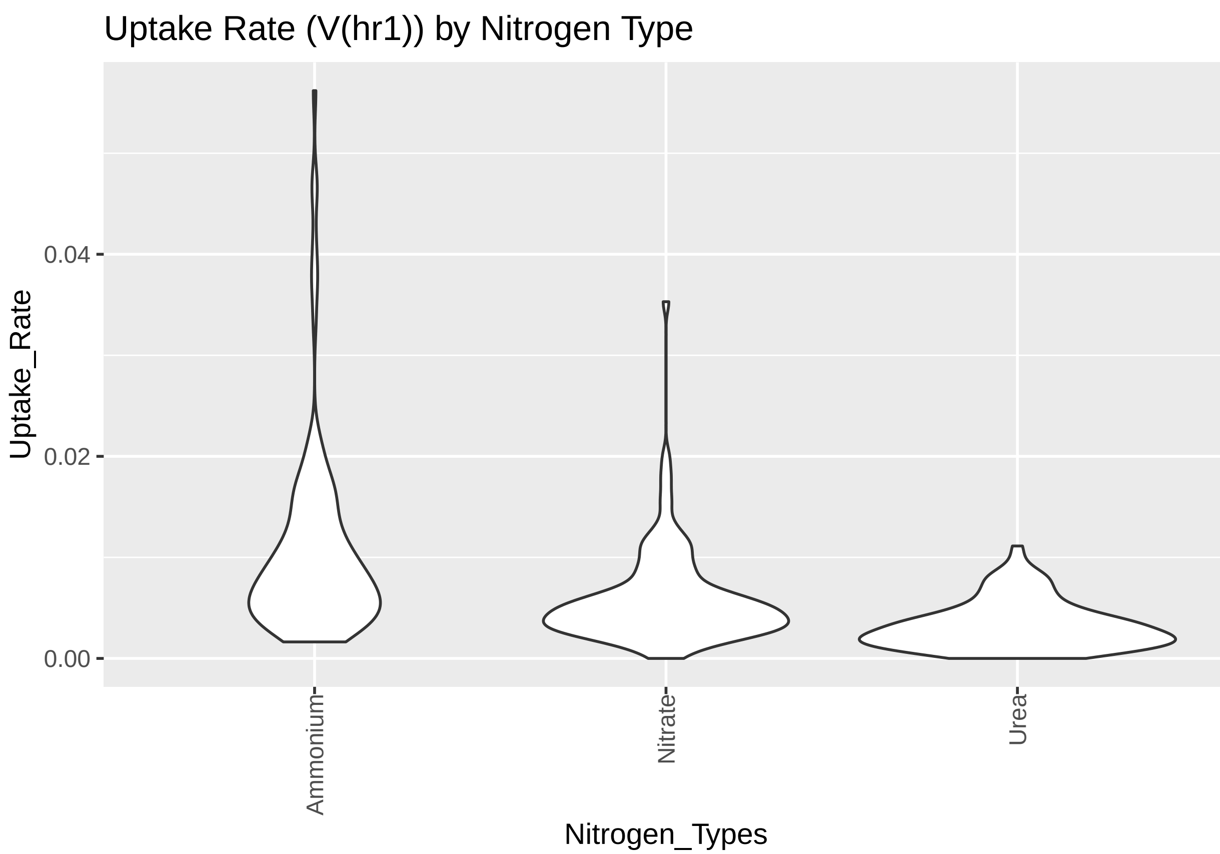

Uptake Rate (V(hr1)) by Day Replicate
Uptake_Rate
0.04
0.02
0.00
1
2
3
4
5
Day_Replicate


Biomass Uptake by Day Replicate
Biomass_Uptake
9
6
3
0
1
2
3
4
5
Day_Replicate

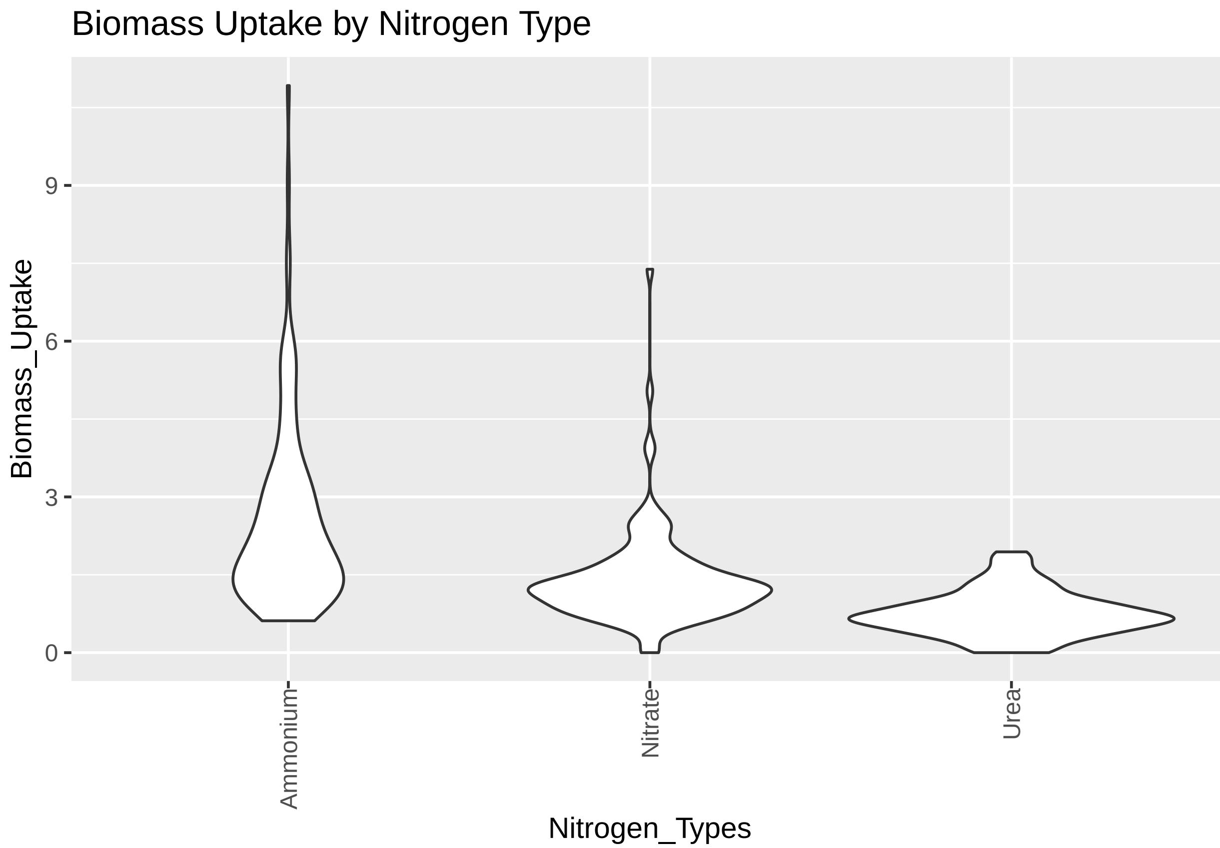


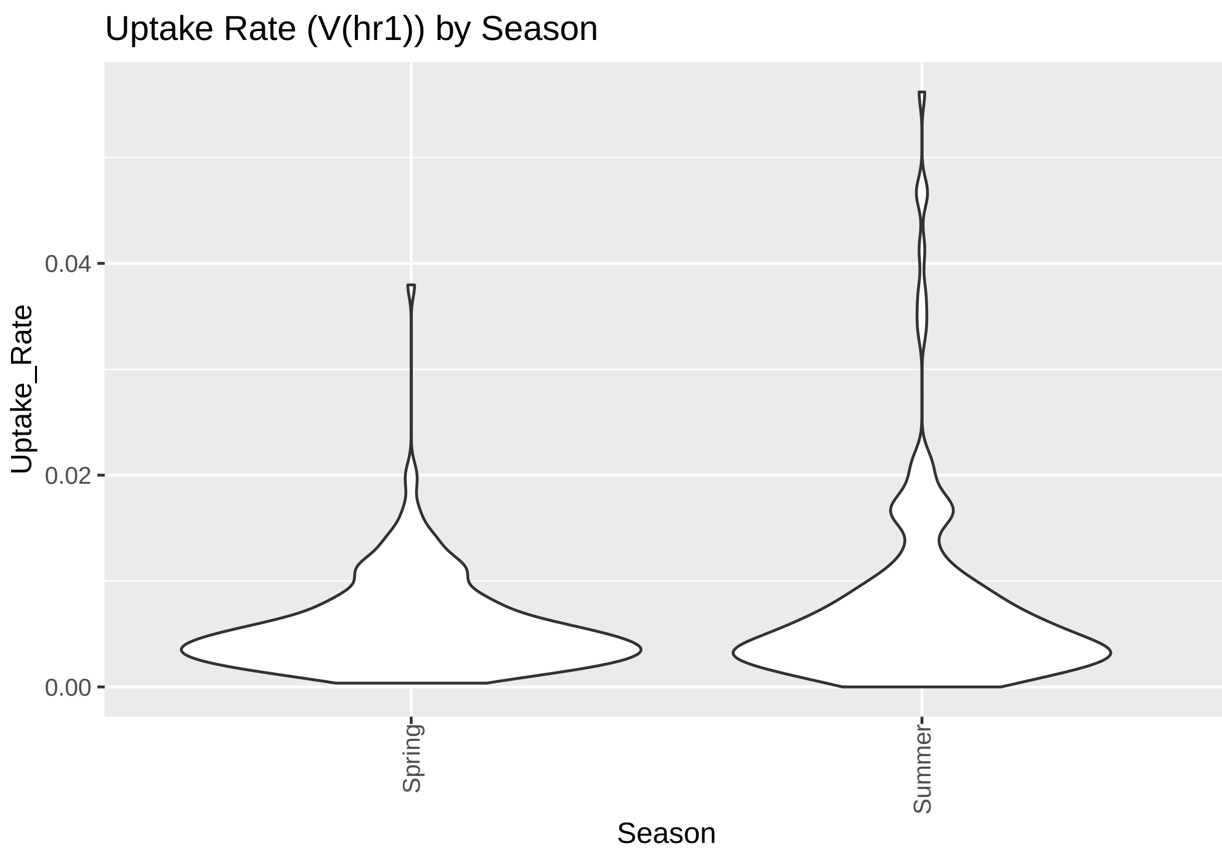
Uptake Rate (V(hr1)) by Blade Replicate
Uptake_Rate
0.00
0.02
0.04
1
2
3
Blade_Replicate

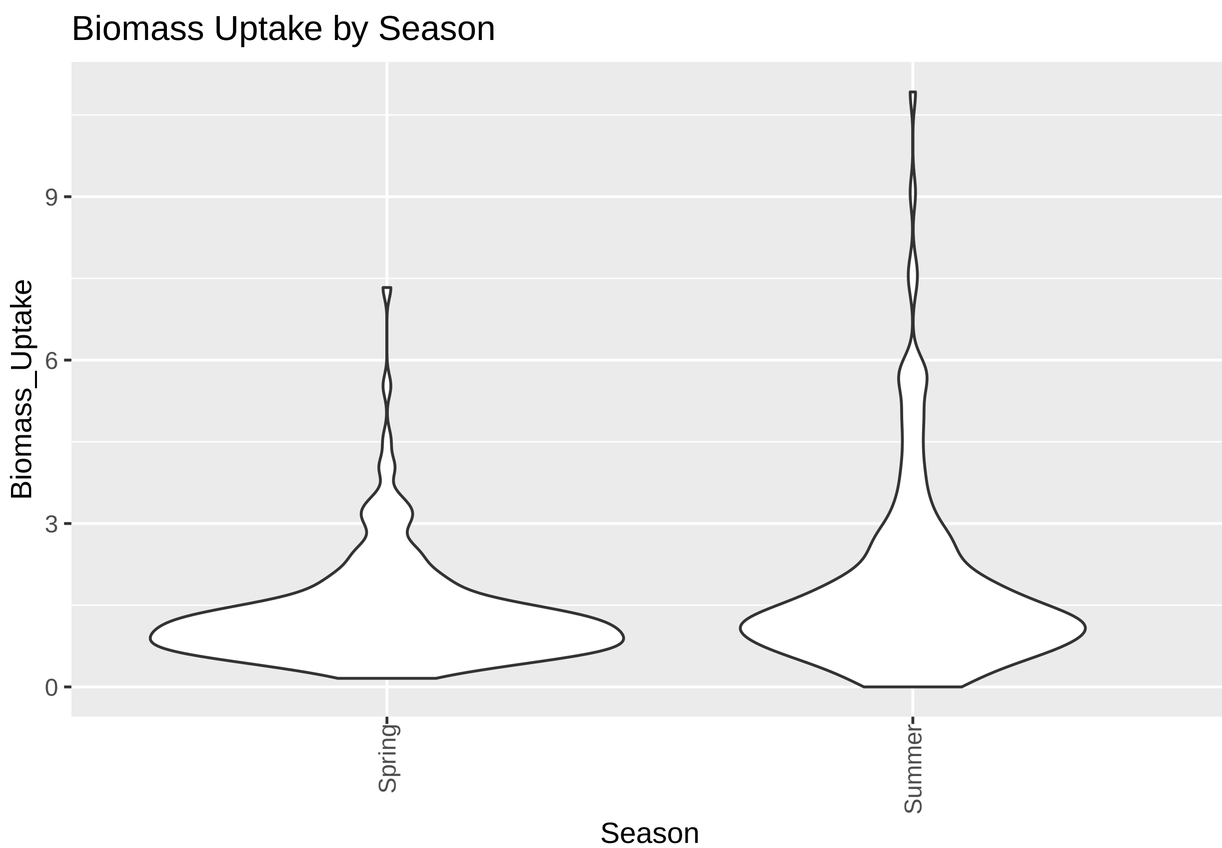

Biomass Uptake by Blade Replicate
Biomass_Uptake
9
6
3
0
1
2
3
Blade_Replicate

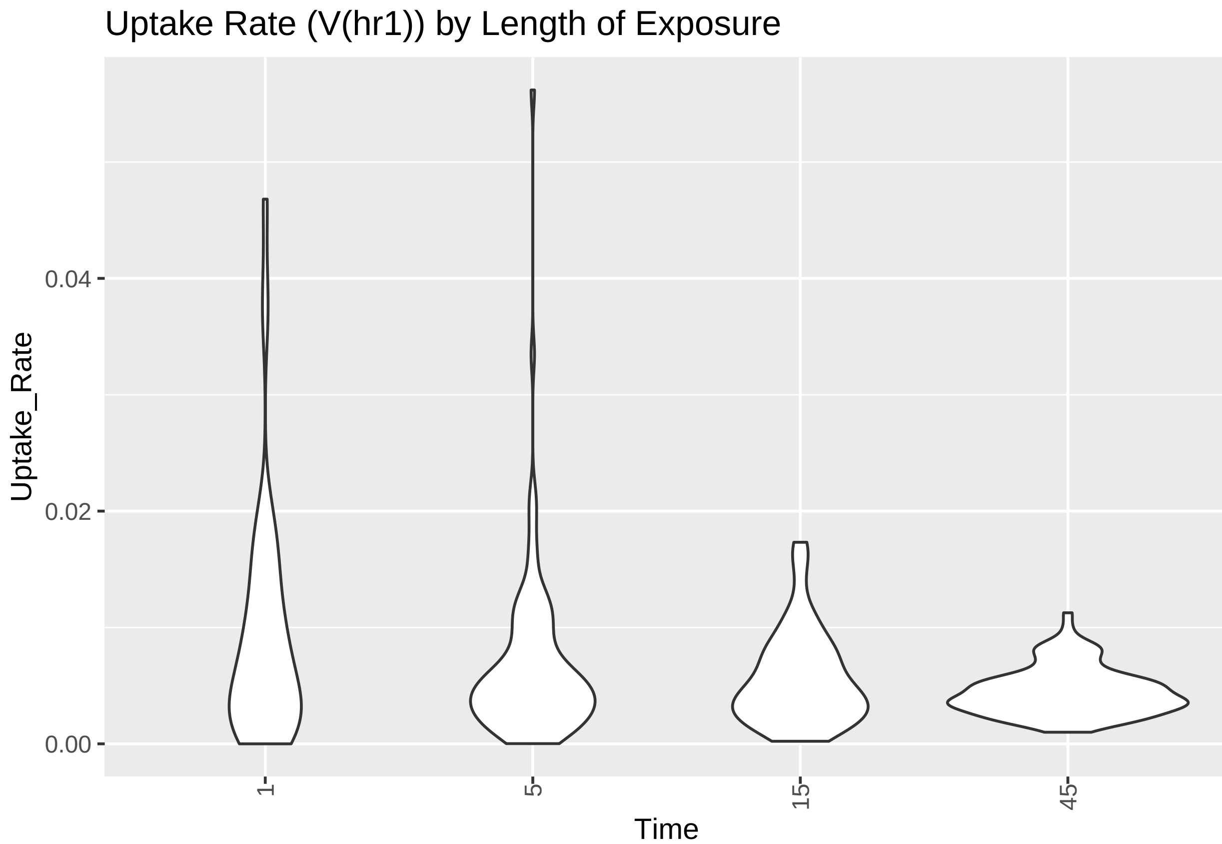

Uptake Rate (V(hr1)) by Nitrogen Type
Uptake_Rate
0.04
0.02
0.00
Ammonium
Nitrate
Urea
Nitrogen_Types

Violin text

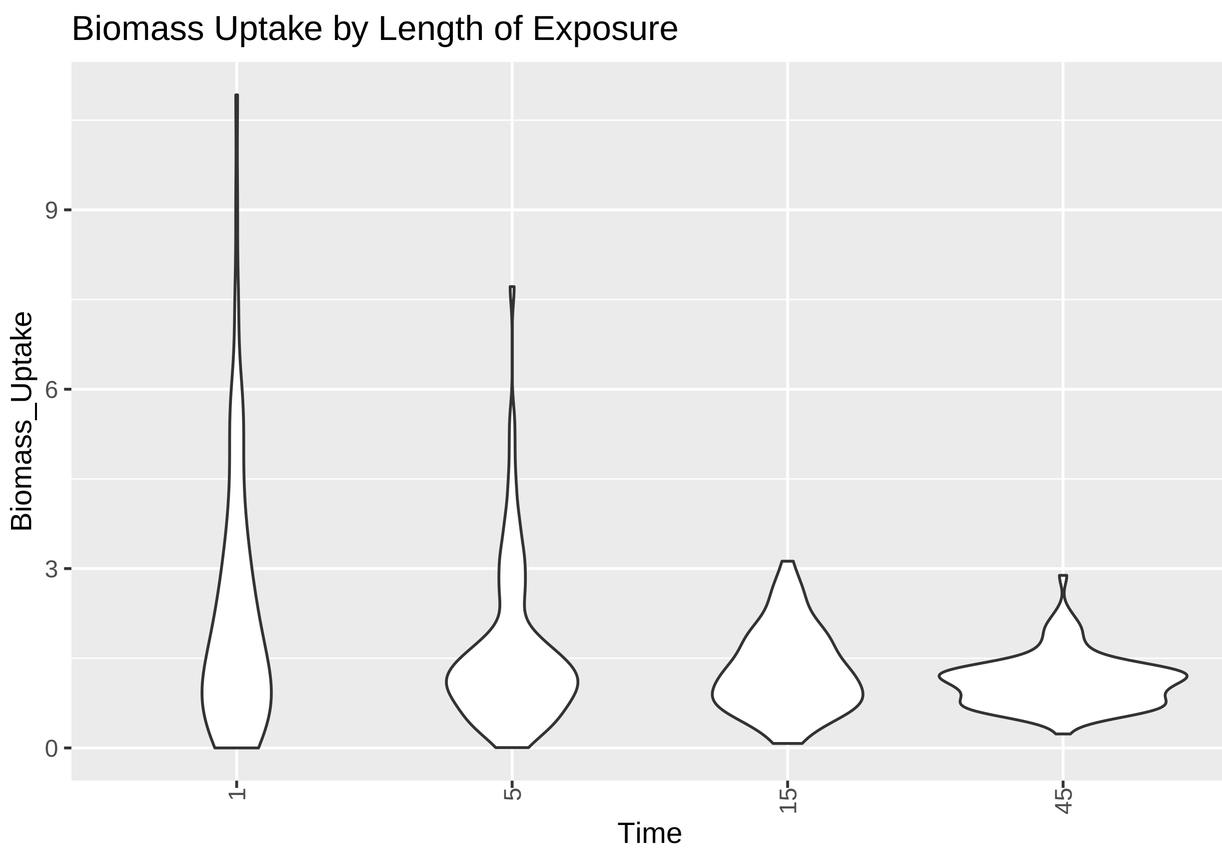

Biomass Uptake by Nitrogen Type
Biomass_Uptake
9
6
3
0
Ammonium
Nitrate
Urea
Nitrogen_Types


Uptake Rate (V(hr1)) by Season
Uptake_Rate
0.04
0.02
0.00
Spring
Summer
Season

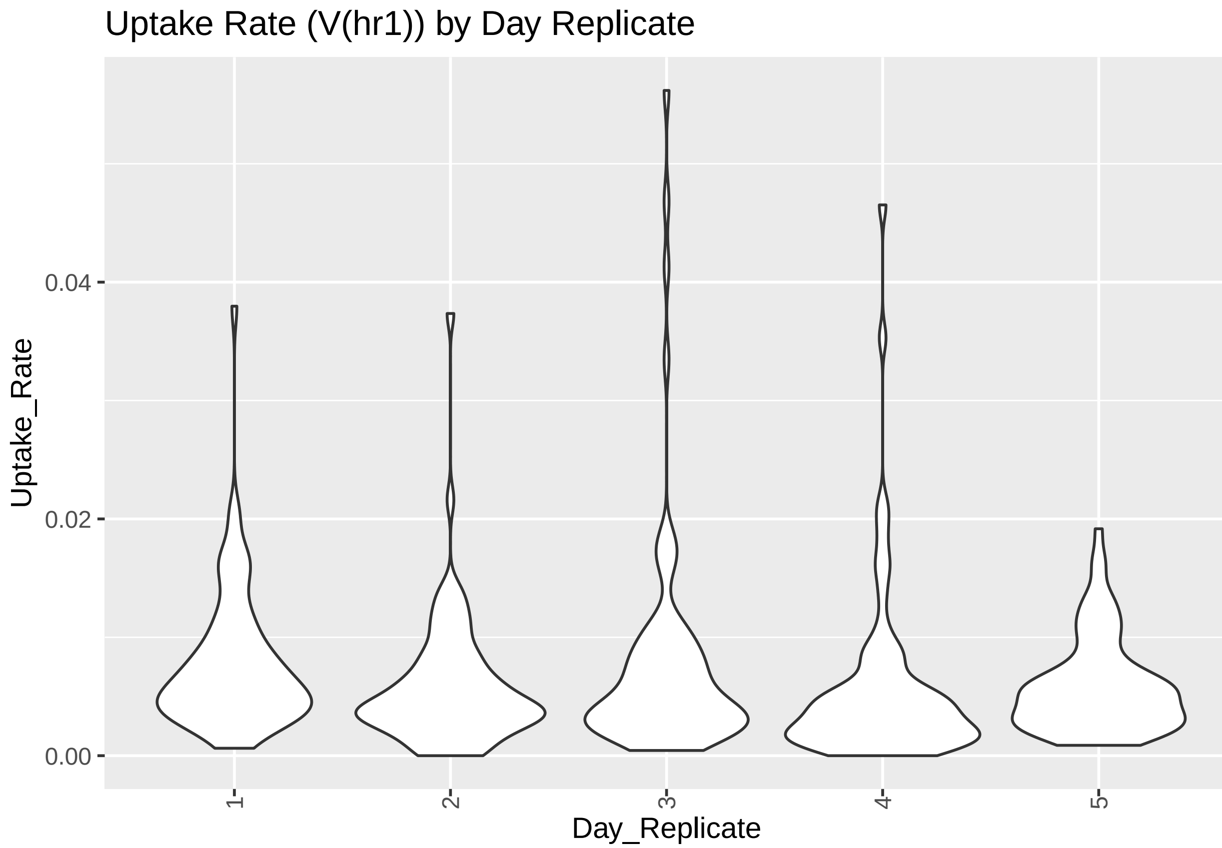

Biomass Uptake by Season
Biomass_Uptake
9
6
3
0
Spring
Summer
Season



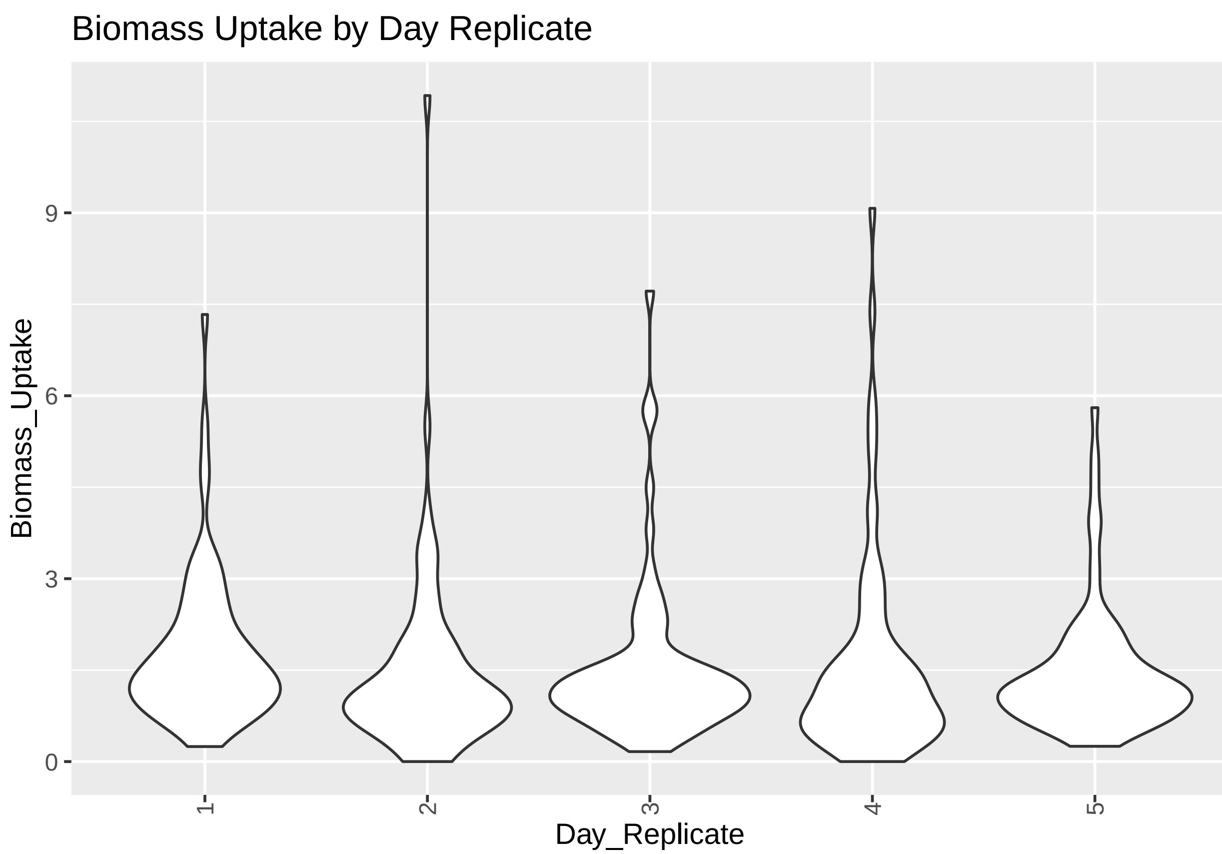
Uptake Rate (V(hr1)) by Length of Exposure
Uptake_Rate
0.04
0.02
0.00
1
5
15
45
Time

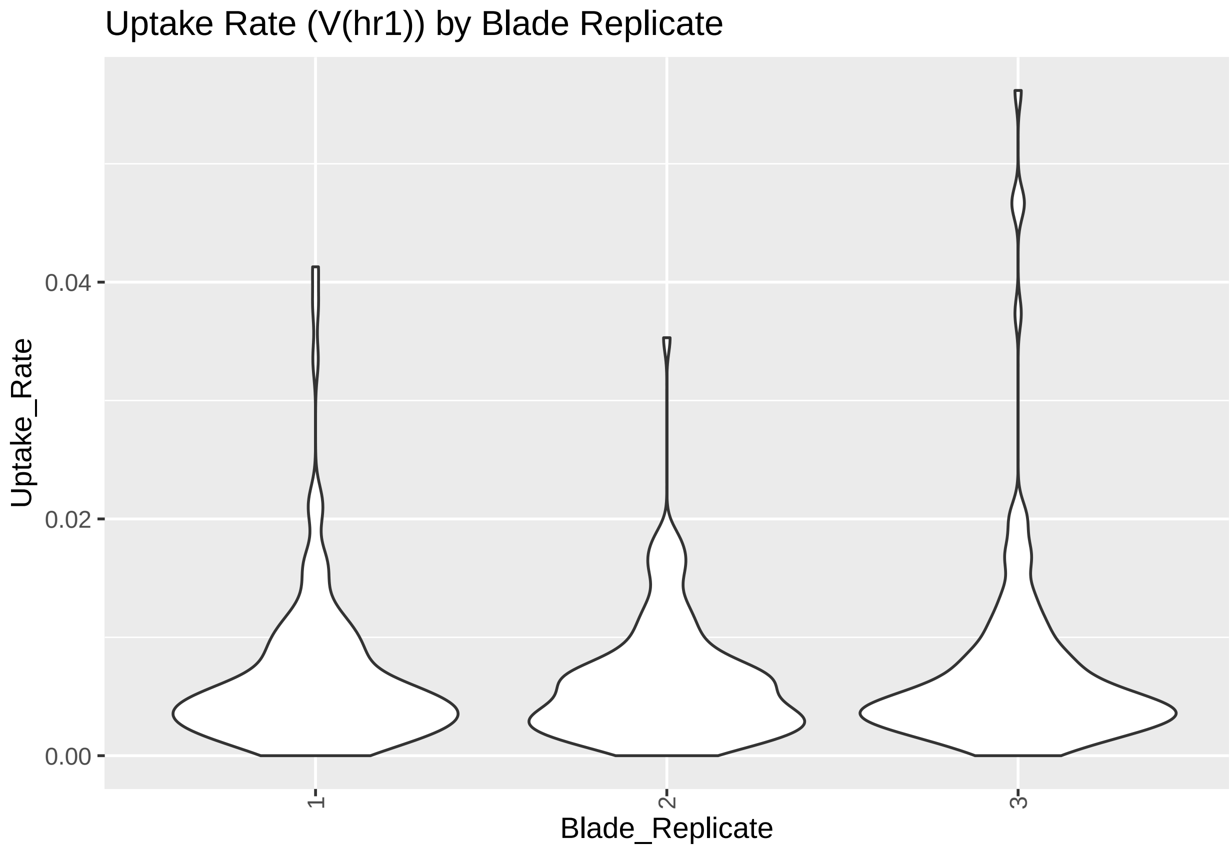


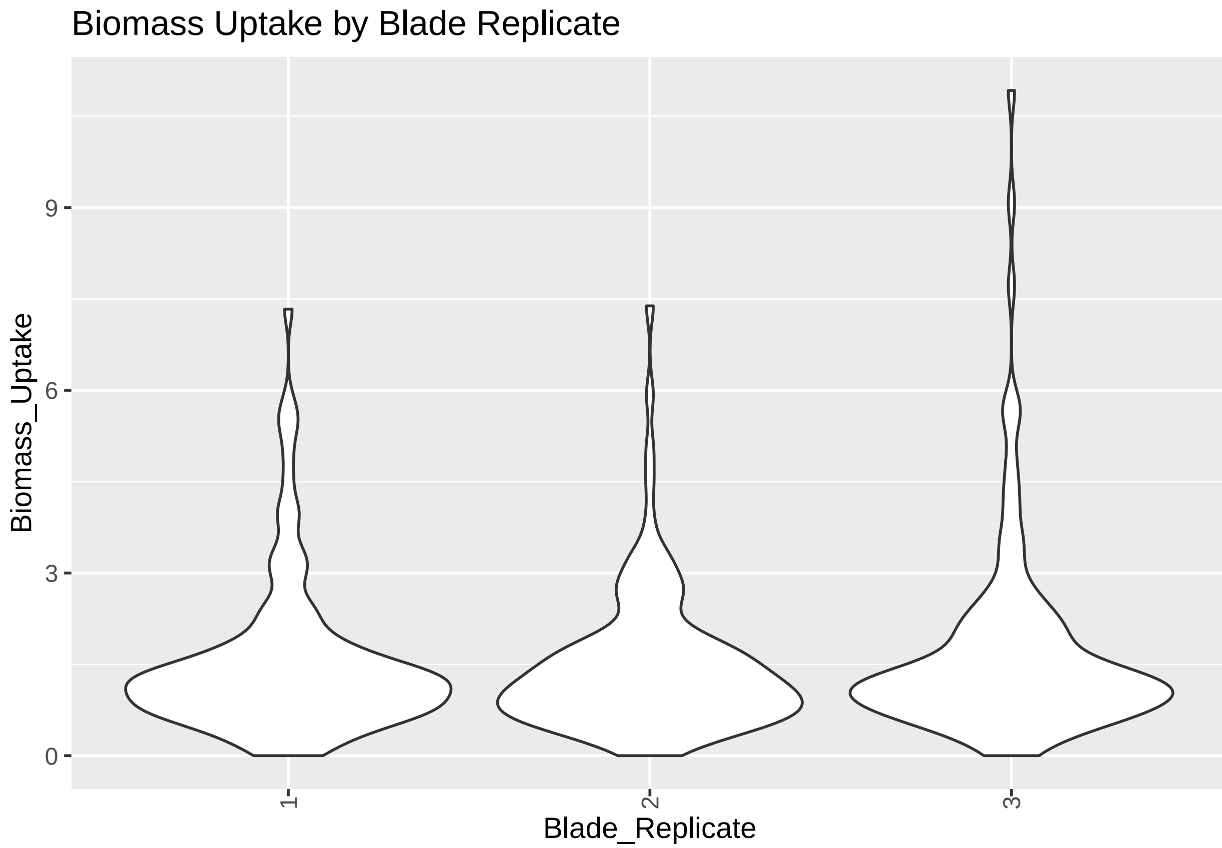
Biomass Uptake by Length of Exposure
Biomass_Uptake
9
6
3
0
1
5
15
45
Time



Uptake Rate (V(hr1)) by Day Replicate
Uptake_Rate
0.04
0.02
0.00
1
2
3
4
5
Day_Replicate


Biomass Uptake by Day Replicate
Biomass_Uptake
0
3
6
9
1
2
3
4
5
Day_Replicate


Uptake Rate (V(hr1)) by Blade Replicate
Uptake_Rate
0.04
0.02
0.00
1
2
3
Blade_Replicate


Biomass Uptake by Blade Replicate
Biomass_Uptake
0
3
6
9
Blade_Replicate
1
2
3

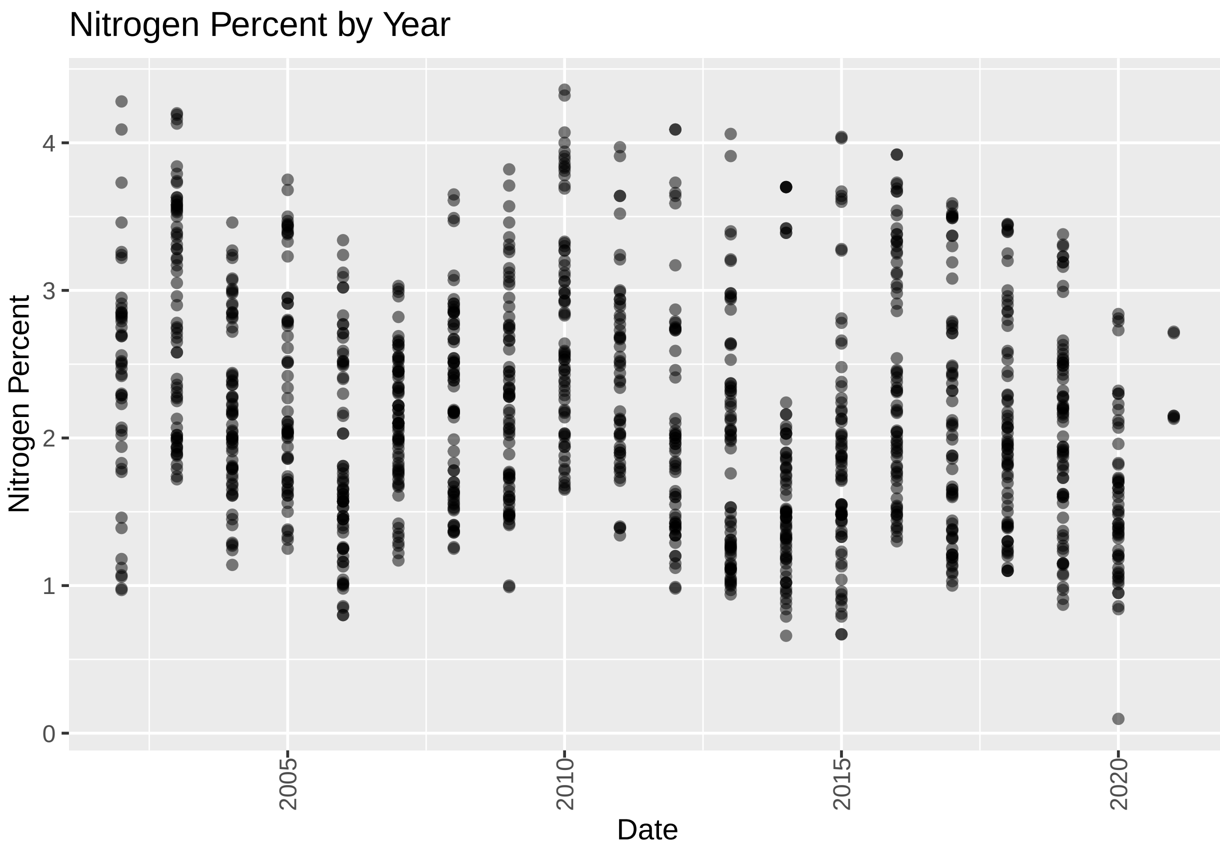
The last part of the exploratory analysis focused on an overview of nitrogen concentration amount over the last twenty years. A summary was used on the entire data set as well as on the nitrogen concentration column to gain a general sense of what amounts were present.

```
##        X           Sample_Number        Year          Month       
##  Min.   :   3.0   Min.   :  1.0   Min.   :2002   Min.   : 1.000  
##  1st Qu.: 337.2   1st Qu.:176.0   1st Qu.:2006   1st Qu.: 4.000  
##  Median : 665.5   Median :352.0   Median :2011   Median : 7.000  
##  Mean   : 671.5   Mean   :352.1   Mean   :2011   Mean   : 6.602  
##  3rd Qu.:1007.8   3rd Qu.:513.0   3rd Qu.:2016   3rd Qu.:10.000  
##  Max.   :1334.0   Max.   :910.0   Max.   :2021   Max.   :12.000  
##                                                                  
##          Date         Site     Number_of_Samples Sample_Replicate
##  2014-03-12:   6   ABUR :434   Min.   : 8.00     Min.   :1.0     
##  2003-01-16:   4   ABUR :  2   1st Qu.:15.00     1st Qu.:1.0     
##  2003-02-18:   4   AQUE :410   Median :15.00     Median :1.5     
##  2003-03-05:   4   MOHK :436   Mean   :14.67     Mean   :1.5     
##  2007-01-03:   4               3rd Qu.:15.00     3rd Qu.:2.0     
##  2007-02-06:   4               Max.   :16.00     Max.   :2.0     
##  (Other)   :1256                                                 
##    Wet_Weight          Dry_Weight        Ratio_Dry_to_Wet  
##  Min.   :-99999.00   Min.   :-99999.00   Min.   :-99999.00  
##  1st Qu.:     5.88   1st Qu.:     0.48   1st Qu.:     0.07  
##  Median :     7.02   Median :     0.66   Median :     0.09  
##  Mean   :  -616.79   Mean   :  -779.33   Mean   :  -779.93  
##  3rd Qu.:     8.53   3rd Qu.:     0.86   3rd Qu.:     0.11  
##  Max.   :    17.19   Max.   :     2.79   Max.   :     0.38  
##                                                             
##  Analytical_Dry_Weight Carbon_Percent  Hydrogen_Percent    Nitrogen_Percent
##  Min.   :1797          Min.   :20.25   Min.   :-99999.00   Min.   :0.097   
##  1st Qu.:2155          1st Qu.:28.39   1st Qu.:     4.01   1st Qu.:1.570   
##  Median :2310          Median :31.33   Median :     4.72   Median :2.063   
##  Mean   :2394          Mean   :32.17   Mean   : -4675.62   Mean   :2.174   
##  3rd Qu.:2517          3rd Qu.:35.27   3rd Qu.:     5.27   3rd Qu.:2.710   
##  Max.   :4770          Max.   :44.52   Max.   :     7.57   Max.   :4.360   
##                                                                            
##  Carbon_Nitrogen_Ratio
##  Min.   : 6.64        
##  1st Qu.:11.43        
##  Median :14.94        
##  Mean   :16.89        
##  3rd Qu.:20.86        
##  Max.   :48.16        
##                       
##                                                          Notes     
##                                                             :1247  
##  dry_wet ratio very large, possible processing error        :   6  
##  reproducibility and replicate data noisy.  Will reanalyze.:   6  
##  missing dry wt                                             :   4  
##  used average of individual plants                          :   4  
##  Average of 10 composite samples                            :   2  
##  (Other)                                                    :  13  
##           NewSites  
##  Arroyo Burro  :436  
```

```
##   Arroyo Quemado:410
##   Mohawk        :436
##
##
##
##
```

```
##    Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
##   0.097   1.570   2.063   2.174   2.710   4.360
```

A scatter plot was used to visualize the relationship between year and nitrogen concentration amount.



Lastly, a boxplot, see below, was used to visualize the relationship between sites and nitrogen concentration. Looking at this data, it appeared concentration amount was not too different by site. Looking at the scatter plot for year, it looked like nitrogen decreased slightly. This was then explored further in the Data Analysis section.

```r
#Data Exploration Part 3

NitrogenYears_Box <- ggplot(NitrogenYears, aes(x=NewSites, y=Nitrogen_Percent))+
  geom_boxplot()+
  labs(title="Nitrogen Percent by Site", x="Site", y="Nitrogen Percent")

print(NitrogenYears_Box)
```

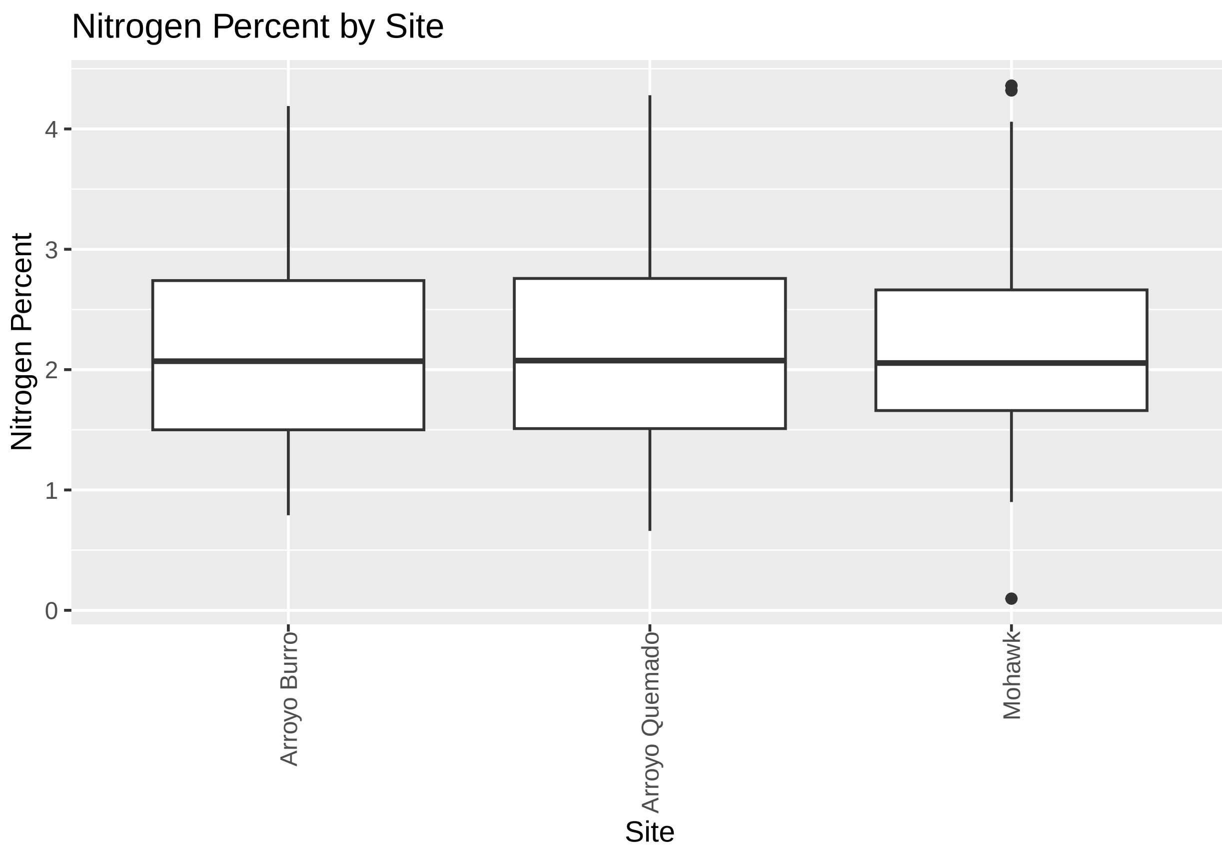


Figure 1: Exploratory Analysis for Nitrogen Concentration by Site

Analysis

Question 1: Does giant kelp nitrogen percent vary over year or season?

For the first question, we wanted to understand the relationship between nitrogen concentration and time. Linear regression and normal distribution tests were run for both the year and the specific date of collection. The box plot below shows the nitrogen concentrations over the years, starting with 2002.

H0 : There is no significant difference of nitrogen percent over the past twenty years. HA : There is significant difference of nitrogen percent over the past twenty years.

The interaction between nitrogen concentration and year is significant ($p < 2.2e-16$). The interaction between nitrogen concentration and collection date is significant ($p < 0.001$). We can reject the null hypothesis and accept that there is significant difference of nitrogen percent from 2002 to 2021. The R-squared is .974, so a high amount of nitrogen concentration variance is in response to date change. Below is a box plot showing change in nitrogen concentration over time.

```r
#2. LM for Date
NitrogenRegressionDate <- lm(NitrogenYears$Nitrogen_Percent ~ NitrogenYears$Date)

#Linear regression on the nitrogen percent amount by year. P-value is less than .05. Which means there
summary(NitrogenRegressionDate)
```

```
##
## Call:
## lm(formula = NitrogenYears$Nitrogen_Percent ~ NitrogenYears$Date)
##
## Residuals:
##    Min     1Q Median     3Q    Max
## -0.965 -0.030  0.000  0.030  0.985
##
## Coefficients:
##                               Estimate Std. Error t value Pr(>|t|)
## (Intercept)                  2.800e+00  1.165e-01  24.033  < 2e-16 ***
## NitrogenYears$Date2002-05-10 -2.450e-01  1.648e-01  -1.487 0.137461
## NitrogenYears$Date2002-05-15  7.950e-01  1.648e-01   4.825 1.71e-06 ***
## NitrogenYears$Date2002-06-10 -1.020e+00  1.648e-01  -6.191 1.00e-09 ***
## NitrogenYears$Date2002-06-12  2.150e-01  1.648e-01   1.305 0.192348
## NitrogenYears$Date2002-06-13  1.385e+00  1.648e-01   8.406 2.23e-16 ***
## NitrogenYears$Date2002-07-10 -3.100e-01  1.648e-01  -1.881 0.060310 .
## NitrogenYears$Date2002-07-11 -1.735e+00  1.648e-01 -10.530  < 2e-16 ***
## NitrogenYears$Date2002-07-12 -6.750e-01  1.648e-01  -4.097 4.66e-05 ***
## NitrogenYears$Date2002-08-07 -9.150e-01  1.648e-01  -5.553 3.93e-08 ***
## NitrogenYears$Date2002-08-08 -7.400e-01  1.648e-01  -4.491 8.23e-06 ***
## NitrogenYears$Date2002-08-09  3.500e-02  1.648e-01   0.212 0.831838
## NitrogenYears$Date2002-09-04 -1.650e+00  1.648e-01 -10.014  < 2e-16 ***
## NitrogenYears$Date2002-09-05 -5.200e-01  1.648e-01  -3.156 0.001666 **
## NitrogenYears$Date2002-09-10 -3.050e-01  1.648e-01  -1.851 0.064560 .
## NitrogenYears$Date2002-10-09 -1.375e+00  1.648e-01  -8.345 3.57e-16 ***
## NitrogenYears$Date2002-10-10 -1.825e+00  1.648e-01 -11.076  < 2e-16 ***
## NitrogenYears$Date2002-10-11  5.000e-02  1.648e-01   0.303 0.761627
## NitrogenYears$Date2002-11-20  4.500e-01  1.648e-01   2.731 0.006465 **
## NitrogenYears$Date2002-11-21 -7.500e-02  1.648e-01  -0.455 0.649109
## NitrogenYears$Date2002-11-22  1.000e-01  1.648e-01   0.607 0.544095
```

```
## NitrogenYears$Date2002-12-06 -2.900e-01  1.648e-01  -1.760 0.078817 .
## NitrogenYears$Date2002-12-09 -5.050e-01  1.648e-01  -3.065 0.002258 **
## NitrogenYears$Date2002-12-10  2.000e-02  1.648e-01   0.121 0.903421
## NitrogenYears$Date2003-01-14 -2.200e-01  1.648e-01  -1.335 0.182222
## NitrogenYears$Date2003-01-16 -4.550e-01  1.427e-01  -3.189 0.001490 **
## NitrogenYears$Date2003-02-18 -8.475e-01  1.427e-01  -5.939 4.43e-09 ***
## NitrogenYears$Date2003-02-21 -9.950e-01  1.648e-01  -6.039 2.47e-09 ***
## NitrogenYears$Date2003-03-05 -6.250e-02  1.427e-01  -0.438 0.661512
## NitrogenYears$Date2003-03-06 -7.550e-01  1.648e-01  -4.582 5.41e-06 ***
## NitrogenYears$Date2003-04-08  5.350e-01  1.648e-01   3.247 0.001220 **
## NitrogenYears$Date2003-04-10  2.900e-01  1.648e-01   1.760 0.078817 .
## NitrogenYears$Date2003-04-15  1.380e+00  1.648e-01   8.375 2.82e-16 ***
## NitrogenYears$Date2003-05-06  8.300e-01  1.648e-01   5.037 5.96e-07 ***
## NitrogenYears$Date2003-05-12  7.400e-01  1.648e-01   4.491 8.23e-06 ***
## NitrogenYears$Date2003-05-13  3.950e-01  1.648e-01   2.397 0.016766 *
## NitrogenYears$Date2003-06-03  9.350e-01  1.648e-01   5.675 2.01e-08 ***
## NitrogenYears$Date2003-06-10 -6.000e-01  1.648e-01  -3.642 0.000290 ***
## NitrogenYears$Date2003-06-11  1.360e+00  1.648e-01   8.254 7.18e-16 ***
## NitrogenYears$Date2003-07-02  1.015e+00  1.648e-01   6.160 1.20e-09 ***
## NitrogenYears$Date2003-07-07 -1.070e+00  1.648e-01  -6.494 1.55e-10 ***
## NitrogenYears$Date2003-07-15 -5.200e-01  1.648e-01  -3.156 0.001666 **
## NitrogenYears$Date2003-08-05 -1.200e-01  1.648e-01  -0.728 0.466663
## NitrogenYears$Date2003-08-06  6.450e-01  1.648e-01   3.915 9.90e-05 ***
## NitrogenYears$Date2003-08-08  7.800e-01  1.648e-01   4.734 2.65e-06 ***
## NitrogenYears$Date2003-09-02  7.850e-01  1.648e-01   4.764 2.29e-06 ***
## NitrogenYears$Date2003-09-04  7.500e-01  1.648e-01   4.552 6.23e-06 ***
## NitrogenYears$Date2003-09-05  5.700e-01  1.648e-01   3.459 0.000573 ***
## NitrogenYears$Date2003-10-01  1.300e-01  1.648e-01   0.789 0.430373
## NitrogenYears$Date2003-11-06  4.600e-01  1.648e-01   2.792 0.005379 **
## NitrogenYears$Date2003-11-13 -7.900e-01  1.648e-01  -4.795 1.98e-06 ***
## NitrogenYears$Date2003-11-14 -8.150e-01  1.648e-01  -4.946 9.40e-07 ***
## NitrogenYears$Date2003-12-03 -9.000e-01  1.648e-01  -5.462 6.46e-08 ***
## NitrogenYears$Date2003-12-05  6.650e-01  1.648e-01   4.036 6.01e-05 ***
## NitrogenYears$Date2003-12-08 -9.150e-01  1.648e-01  -5.553 3.93e-08 ***
## NitrogenYears$Date2004-01-07  7.000e-02  1.648e-01   0.425 0.671077
## NitrogenYears$Date2004-01-09  4.450e-01  1.648e-01   2.701 0.007078 **
## NitrogenYears$Date2004-02-02  8.000e-02  1.648e-01   0.486 0.627444
## NitrogenYears$Date2004-02-06  1.950e-01  1.648e-01   1.183 0.237001
## NitrogenYears$Date2004-02-12  1.950e-01  1.648e-01   1.183 0.237001
## NitrogenYears$Date2004-03-08 -3.700e-01  1.648e-01  -2.246 0.025029 *
## NitrogenYears$Date2004-03-10 -8.200e-01  1.648e-01  -4.977 8.08e-07 ***
## NitrogenYears$Date2004-03-12 -5.400e-01  1.648e-01  -3.277 0.001098 **
## NitrogenYears$Date2004-04-05 -1.335e+00  1.648e-01  -8.102 2.27e-15 ***
## NitrogenYears$Date2004-04-07 -1.185e+00  1.648e-01  -7.192 1.59e-12 ***
## NitrogenYears$Date2004-04-12 -6.250e-01  1.648e-01  -3.793 0.000161 ***
## NitrogenYears$Date2004-05-07 -6.250e-01  1.648e-01  -3.793 0.000161 ***
## NitrogenYears$Date2004-05-15 -4.150e-01  1.648e-01  -2.519 0.011992 *
## NitrogenYears$Date2004-05-19  3.000e-02  1.648e-01   0.182 0.855574
## NitrogenYears$Date2004-06-02 -1.065e+00  1.648e-01  -6.464 1.87e-10 ***
## NitrogenYears$Date2004-06-16  2.750e-01  1.648e-01   1.669 0.095543 .
## NitrogenYears$Date2004-06-21  5.500e-01  1.648e-01   3.338 0.000887 ***
## NitrogenYears$Date2004-07-07 -5.500e-01  1.648e-01  -3.338 0.000887 ***
## NitrogenYears$Date2004-07-09 -2.600e-01  1.648e-01  -1.578 0.115003
## NitrogenYears$Date2004-07-16 -5.500e-01  1.648e-01  -3.338 0.000887 ***
```

```
## NitrogenYears$Date2004-08-03 -1.500e-02  1.648e-01  -0.091 0.927488
## NitrogenYears$Date2004-08-05 -8.050e-01  1.648e-01  -4.886 1.27e-06 ***
## NitrogenYears$Date2004-08-06 -7.000e-01  1.648e-01  -4.248 2.43e-05 ***
## NitrogenYears$Date2004-09-01 -4.800e-01  1.648e-01  -2.913 0.003687 **
## NitrogenYears$Date2004-09-02 -8.000e-01  1.648e-01  -4.855 1.47e-06 ***
## NitrogenYears$Date2004-09-07 -1.450e+00  1.648e-01  -8.800  < 2e-16 ***
## NitrogenYears$Date2004-10-06 -1.525e+00  1.648e-01  -9.255  < 2e-16 ***
## NitrogenYears$Date2004-10-07 -9.600e-01  1.648e-01  -5.826 8.50e-09 ***
## NitrogenYears$Date2004-10-14 -8.350e-01  1.648e-01  -5.068 5.11e-07 ***
## NitrogenYears$Date2004-11-03 -1.000e+00  1.648e-01  -6.069 2.07e-09 ***
## NitrogenYears$Date2004-11-04 -8.900e-01  1.648e-01  -5.402 8.95e-08 ***
## NitrogenYears$Date2004-11-10 -1.610e+00  1.648e-01  -9.771  < 2e-16 ***
## NitrogenYears$Date2004-12-01 -1.170e+00  1.648e-01  -7.101 2.95e-12 ***
## NitrogenYears$Date2004-12-02 -1.030e+00  1.648e-01  -6.251 6.93e-10 ***
## NitrogenYears$Date2004-12-03 -1.040e+00  1.648e-01  -6.312 4.79e-10 ***
## NitrogenYears$Date2005-02-07 -6.900e-01  1.648e-01  -4.188 3.16e-05 ***
## NitrogenYears$Date2005-02-08 -1.250e+00  1.648e-01  -7.586 1.01e-13 ***
## NitrogenYears$Date2005-02-09 -7.800e-01  1.648e-01  -4.734 2.65e-06 ***
## NitrogenYears$Date2005-03-14 -7.800e-01  1.648e-01  -4.734 2.65e-06 ***
## NitrogenYears$Date2005-03-16 -1.115e+00  1.648e-01  -6.767 2.70e-11 ***
## NitrogenYears$Date2005-03-17 -1.190e+00  1.648e-01  -7.222 1.29e-12 ***
## NitrogenYears$Date2005-04-18  1.500e-01  1.648e-01   0.910 0.362925
## NitrogenYears$Date2005-04-19  6.100e-01  1.648e-01   3.702 0.000230 ***
## NitrogenYears$Date2005-04-20 -2.500e-02  1.648e-01  -0.152 0.879442
## NitrogenYears$Date2005-05-09  5.950e-01  1.648e-01   3.611 0.000326 ***
## NitrogenYears$Date2005-05-10  6.850e-01  1.648e-01   4.157 3.60e-05 ***
## NitrogenYears$Date2005-05-12  6.150e-01  1.648e-01   3.733 0.000204 ***
## NitrogenYears$Date2005-06-06 -5.000e-03  1.648e-01  -0.030 0.975800
## NitrogenYears$Date2005-06-08  9.150e-01  1.648e-01   5.553 3.93e-08 ***
## NitrogenYears$Date2005-06-09  6.450e-01  1.648e-01   3.915 9.90e-05 ***
## NitrogenYears$Date2005-07-01 -2.400e-01  1.648e-01  -1.457 0.145657
## NitrogenYears$Date2005-07-05  1.100e-01  1.648e-01   0.668 0.504594
## NitrogenYears$Date2005-07-06  4.800e-01  1.648e-01   2.913 0.003687 **
## NitrogenYears$Date2005-08-02 -2.850e-01  1.648e-01  -1.730 0.084105 .
## NitrogenYears$Date2005-08-04 -6.500e-02  1.648e-01  -0.394 0.693330
## NitrogenYears$Date2005-08-08 -7.300e-01  1.648e-01  -4.431 1.08e-05 ***
## NitrogenYears$Date2005-09-06 -4.200e-01  1.648e-01  -2.549 0.011006 *
## NitrogenYears$Date2005-09-07 -7.650e-01  1.648e-01  -4.643 4.08e-06 ***
## NitrogenYears$Date2005-09-13 -1.520e+00  1.648e-01  -9.225  < 2e-16 ***
## NitrogenYears$Date2005-10-05 -9.000e-01  1.648e-01  -5.462 6.46e-08 ***
## NitrogenYears$Date2005-10-11 -1.270e+00  1.648e-01  -7.708 4.20e-14 ***
## NitrogenYears$Date2005-11-03 -1.120e+00  1.648e-01  -6.797 2.22e-11 ***
## NitrogenYears$Date2005-11-04 -1.450e+00  1.648e-01  -8.800  < 2e-16 ***
## NitrogenYears$Date2005-11-07 -9.350e-01  1.648e-01  -5.675 2.01e-08 ***
## NitrogenYears$Date2005-12-01 -6.900e-01  1.648e-01  -4.188 3.16e-05 ***
## NitrogenYears$Date2005-12-02 -6.350e-01  1.648e-01  -3.854 0.000127 ***
## NitrogenYears$Date2005-12-05 -1.125e+00  1.648e-01  -6.828 1.82e-11 ***
## NitrogenYears$Date2006-01-12  3.050e-01  1.648e-01   1.851 0.064560 .
## NitrogenYears$Date2006-01-18 -1.165e+00  1.648e-01  -7.071 3.62e-12 ***
## NitrogenYears$Date2006-01-24 -2.900e-01  1.648e-01  -1.760 0.078817 .
## NitrogenYears$Date2006-02-07 -1.600e-01  1.648e-01  -0.971 0.331837
## NitrogenYears$Date2006-02-10 -1.115e+00  1.648e-01  -6.767 2.70e-11 ***
## NitrogenYears$Date2006-02-21 -1.055e+00  1.648e-01  -6.403 2.73e-10 ***
## NitrogenYears$Date2006-03-08 -9.900e-01  1.648e-01  -6.008 2.96e-09 ***
```

```
## NitrogenYears$Date2006-03-14  4.900e-01  1.648e-01   2.974 0.003038 **
## NitrogenYears$Date2006-03-20 -6.000e-02  1.648e-01  -0.364 0.715851
## NitrogenYears$Date2006-04-10  2.200e-01  1.648e-01   1.335 0.182222
## NitrogenYears$Date2006-04-18 -8.798e-14  1.648e-01   0.000 1.000000
## NitrogenYears$Date2006-04-20 -2.550e-01  1.648e-01  -1.548 0.122143
## NitrogenYears$Date2006-05-02 -2.450e-01  1.648e-01  -1.487 0.137461
## NitrogenYears$Date2006-05-08 -7.100e-01  1.648e-01  -4.309 1.86e-05 ***
## NitrogenYears$Date2006-05-10 -1.140e+00  1.648e-01  -6.919 9.99e-12 ***
## NitrogenYears$Date2006-06-01 -3.550e-01  1.648e-01  -2.155 0.031524 *
## NitrogenYears$Date2006-06-06 -7.000e-01  1.648e-01  -4.248 2.43e-05 ***
## NitrogenYears$Date2006-06-07 -3.950e-01  1.648e-01  -2.397 0.016766 *
## NitrogenYears$Date2006-07-01 -1.330e+00  1.648e-01  -8.072 2.86e-15 ***
## NitrogenYears$Date2006-07-03 -1.230e+00  1.648e-01  -7.465 2.38e-13 ***
## NitrogenYears$Date2006-07-11 -1.230e+00  1.648e-01  -7.465 2.38e-13 ***
## NitrogenYears$Date2006-08-02 -1.350e+00  1.648e-01  -8.193 1.14e-15 ***
## NitrogenYears$Date2006-08-03 -1.550e+00  1.648e-01  -9.407  < 2e-16 ***
## NitrogenYears$Date2006-08-04 -2.000e+00  1.648e-01 -12.138  < 2e-16 ***
## NitrogenYears$Date2006-09-01 -1.795e+00  1.648e-01 -10.894  < 2e-16 ***
## NitrogenYears$Date2006-09-02 -1.620e+00  1.648e-01  -9.832  < 2e-16 ***
## NitrogenYears$Date2006-09-05 -1.655e+00  1.648e-01 -10.044  < 2e-16 ***
## NitrogenYears$Date2006-10-03 -1.805e+00  1.648e-01 -10.955  < 2e-16 ***
## NitrogenYears$Date2006-10-04 -1.545e+00  1.648e-01  -9.377  < 2e-16 ***
## NitrogenYears$Date2006-10-05 -1.225e+00  1.648e-01  -7.435 2.95e-13 ***
## NitrogenYears$Date2006-11-01 -1.945e+00  1.648e-01 -11.805  < 2e-16 ***
## NitrogenYears$Date2006-11-02 -1.770e+00  1.648e-01 -10.742  < 2e-16 ***
## NitrogenYears$Date2006-11-03 -1.400e+00  1.648e-01  -8.497  < 2e-16 ***
## NitrogenYears$Date2006-12-01 -1.205e+00  1.648e-01  -7.313 6.89e-13 ***
## NitrogenYears$Date2006-12-04 -1.395e+00  1.648e-01  -8.467  < 2e-16 ***
## NitrogenYears$Date2006-12-07 -1.125e+00  1.648e-01  -6.828 1.82e-11 ***
## NitrogenYears$Date2007-01-03 -4.500e-01  1.427e-01  -3.154 0.001679 **
## NitrogenYears$Date2007-01-09 -1.035e+00  1.648e-01  -6.282 5.76e-10 ***
## NitrogenYears$Date2007-02-06 -2.375e-01  1.427e-01  -1.664 0.096459 .
## NitrogenYears$Date2007-02-15 -5.800e-01  1.648e-01  -3.520 0.000458 ***
## NitrogenYears$Date2007-03-02 -2.200e-01  1.648e-01  -1.335 0.182222
## NitrogenYears$Date2007-03-05 -7.600e-01  1.648e-01  -4.613 4.70e-06 ***
## NitrogenYears$Date2007-03-06  2.000e-01  1.648e-01   1.214 0.225204
## NitrogenYears$Date2007-04-03 -7.000e-01  1.648e-01  -4.248 2.43e-05 ***
## NitrogenYears$Date2007-04-04 -3.050e-01  1.427e-01  -2.137 0.032893 *
## NitrogenYears$Date2007-05-01 -6.350e-01  1.648e-01  -3.854 0.000127 ***
## NitrogenYears$Date2007-05-02 -2.850e-01  1.648e-01  -1.730 0.084105 .
## NitrogenYears$Date2007-05-08  1.950e-01  1.648e-01   1.183 0.237001
## NitrogenYears$Date2007-06-04 -7.425e-01  1.427e-01  -5.204 2.55e-07 ***
## NitrogenYears$Date2007-06-07 -4.500e-02  1.648e-01  -0.273 0.784844
## NitrogenYears$Date2007-07-02 -4.150e-01  1.648e-01  -2.519 0.011992 *
## NitrogenYears$Date2007-07-09 -7.950e-01  1.648e-01  -4.825 1.71e-06 ***
## NitrogenYears$Date2007-07-12 -3.700e-01  1.648e-01  -2.246 0.025029 *
## NitrogenYears$Date2007-08-01 -1.043e+00  1.427e-01  -7.306 7.25e-13 ***
## NitrogenYears$Date2007-08-02 -8.600e-01  1.648e-01  -5.219 2.34e-07 ***
## NitrogenYears$Date2007-09-01 -1.555e+00  1.648e-01  -9.438  < 2e-16 ***
## NitrogenYears$Date2007-09-05 -1.430e+00  1.648e-01  -8.679  < 2e-16 ***
## NitrogenYears$Date2007-09-07 -1.105e+00  1.648e-01  -6.706 4.00e-11 ***
## NitrogenYears$Date2007-09-29 -1.498e+00  1.427e-01 -10.495  < 2e-16 ***
## NitrogenYears$Date2007-10-08 -1.075e+00  1.648e-01  -6.524 1.28e-10 ***
## NitrogenYears$Date2007-11-05 -6.875e-01  1.427e-01  -4.818 1.76e-06 ***
```

```
## NitrogenYears$Date2007-11-07 -6.000e-01  1.648e-01  -3.642 0.000290 ***
## NitrogenYears$Date2007-12-03 -8.700e-01  1.427e-01  -6.097 1.75e-09 ***
## NitrogenYears$Date2007-12-10 -4.100e-01  1.648e-01  -2.488 0.013056 *
## NitrogenYears$Date2008-01-02 -2.925e-01  1.427e-01  -2.050 0.040735 *
## NitrogenYears$Date2008-01-03 -3.800e-01  1.648e-01  -2.306 0.021375 *
## NitrogenYears$Date2008-02-01  2.000e-02  1.648e-01   0.121 0.903421
## NitrogenYears$Date2008-02-07 -9.750e-02  1.427e-01  -0.683 0.494642
## NitrogenYears$Date2008-03-04 -2.275e-01  1.427e-01  -1.594 0.111294
## NitrogenYears$Date2008-03-05 -4.000e-02  1.648e-01  -0.243 0.808254
## NitrogenYears$Date2008-04-01  2.850e-01  1.648e-01   1.730 0.084105 .
## NitrogenYears$Date2008-04-03  7.550e-01  1.427e-01   5.291 1.61e-07 ***
## NitrogenYears$Date2008-05-01 -6.350e-01  1.427e-01  -4.450 9.93e-06 ***
## NitrogenYears$Date2008-05-02  1.150e-01  1.648e-01   0.698 0.485428
## NitrogenYears$Date2008-06-02  2.500e-02  1.648e-01   0.152 0.879442
## NitrogenYears$Date2008-06-03 -2.750e-01  1.648e-01  -1.669 0.095543 .
## NitrogenYears$Date2008-06-12 -2.050e-01  1.648e-01  -1.244 0.213833
## NitrogenYears$Date2008-07-01 -1.075e+00  1.648e-01  -6.524 1.28e-10 ***
## NitrogenYears$Date2008-07-08 -1.130e+00  1.648e-01  -6.858 1.49e-11 ***
## NitrogenYears$Date2008-07-10 -1.195e+00  1.648e-01  -7.253 1.05e-12 ***
## NitrogenYears$Date2008-08-07 -1.138e+00  1.427e-01  -7.972 6.05e-15 ***
## NitrogenYears$Date2008-08-08 -1.225e+00  1.648e-01  -7.435 2.95e-13 ***
## NitrogenYears$Date2008-09-03 -1.415e+00  1.648e-01  -8.588  < 2e-16 ***
## NitrogenYears$Date2008-09-04 -1.240e+00  1.427e-01  -8.690  < 2e-16 ***
## NitrogenYears$Date2008-09-29 -1.200e+00  1.648e-01  -7.283 8.50e-13 ***
## NitrogenYears$Date2008-10-01 -1.545e+00  1.648e-01  -9.377  < 2e-16 ***
## NitrogenYears$Date2008-10-02 -1.435e+00  1.648e-01  -8.709  < 2e-16 ***
## NitrogenYears$Date2008-11-06 -1.415e+00  1.648e-01  -8.588  < 2e-16 ***
## NitrogenYears$Date2008-11-07 -6.200e-01  1.427e-01  -4.345 1.59e-05 ***
## NitrogenYears$Date2008-12-03  8.000e-02  1.648e-01   0.486 0.627444
## NitrogenYears$Date2008-12-04 -6.250e-01  1.648e-01  -3.793 0.000161 ***
## NitrogenYears$Date2008-12-05 -6.150e-01  1.648e-01  -3.733 0.000204 ***
## NitrogenYears$Date2009-01-06 -1.250e-01  1.648e-01  -0.759 0.448309
## NitrogenYears$Date2009-01-12 -3.350e-01  1.648e-01  -2.033 0.042397 *
## NitrogenYears$Date2009-01-15 -1.340e+00  1.648e-01  -8.133 1.81e-15 ***
## NitrogenYears$Date2009-02-02 -1.045e+00  1.648e-01  -6.342 3.97e-10 ***
## NitrogenYears$Date2009-02-03 -3.275e-01  1.427e-01  -2.295 0.022008 *
## NitrogenYears$Date2009-03-02  3.050e-01  1.648e-01   1.851 0.064560 .
## NitrogenYears$Date2009-03-09 -1.000e-02  1.648e-01  -0.061 0.951621
## NitrogenYears$Date2009-03-10  1.950e-01  1.648e-01   1.183 0.237001
## NitrogenYears$Date2009-03-31  1.500e-02  1.648e-01   0.091 0.927488
## NitrogenYears$Date2009-04-02  3.050e-01  1.648e-01   1.851 0.064560 .
## NitrogenYears$Date2009-04-07  5.200e-01  1.648e-01   3.156 0.001666 **
## NitrogenYears$Date2009-05-01  9.650e-01  1.648e-01   5.857 7.14e-09 ***
## NitrogenYears$Date2009-05-04  7.150e-01  1.648e-01   4.339 1.63e-05 ***
## NitrogenYears$Date2009-05-05  4.850e-01  1.648e-01   2.944 0.003348 **
## NitrogenYears$Date2009-05-27 -4.400e-02  1.648e-01  -0.267 0.789511
## NitrogenYears$Date2009-06-02 -7.500e-01  1.648e-01  -4.552 6.23e-06 ***
## NitrogenYears$Date2009-06-04 -7.175e-01  1.648e-01  -4.355 1.52e-05 ***
## NitrogenYears$Date2009-07-01 -7.855e-01  1.427e-01  -5.505 5.12e-08 ***
## NitrogenYears$Date2009-07-02 -5.580e-01  1.648e-01  -3.387 0.000746 ***
## NitrogenYears$Date2009-08-05 -1.070e+00  1.648e-01  -6.494 1.55e-10 ***
## NitrogenYears$Date2009-08-06 -8.575e-01  1.427e-01  -6.009 2.94e-09 ***
## NitrogenYears$Date2009-09-01 -7.550e-01  1.648e-01  -4.582 5.41e-06 ***
## NitrogenYears$Date2009-09-02 -5.750e-01  1.648e-01  -3.490 0.000513 ***
```

```
## NitrogenYears$Date2009-09-09 -1.150e+00  1.648e-01  -6.980 6.67e-12 ***
## NitrogenYears$Date2009-10-01 -4.350e-01  1.648e-01  -2.640 0.008466 **
## NitrogenYears$Date2009-10-05 -9.800e-01  1.648e-01  -5.948 4.22e-09 ***
## NitrogenYears$Date2009-10-07 -5.200e-01  1.648e-01  -3.156 0.001666 **
## NitrogenYears$Date2009-11-02 -1.350e+00  1.648e-01  -8.193 1.14e-15 ***
## NitrogenYears$Date2009-11-03 -1.320e+00  1.648e-01  -8.011 4.50e-15 ***
## NitrogenYears$Date2009-11-06 -1.270e+00  1.648e-01  -7.708 4.20e-14 ***
## NitrogenYears$Date2009-12-01 -1.805e+00  1.648e-01 -10.955  < 2e-16 ***
## NitrogenYears$Date2009-12-03 -1.260e+00  1.427e-01  -8.830  < 2e-16 ***
## NitrogenYears$Date2010-01-05 -2.000e-01  1.648e-01  -1.214 0.225204
## NitrogenYears$Date2010-01-07 -6.250e-01  1.427e-01  -4.380 1.36e-05 ***
## NitrogenYears$Date2010-02-01 -5.850e-01  1.648e-01  -3.550 0.000409 ***
## NitrogenYears$Date2010-02-02 -2.400e-01  1.648e-01  -1.457 0.145657
## NitrogenYears$Date2010-02-04 -5.650e-01  1.648e-01  -3.429 0.000640 ***
## NitrogenYears$Date2010-03-02 -6.350e-01  1.648e-01  -3.854 0.000127 ***
## NitrogenYears$Date2010-03-05 -3.550e-01  1.648e-01  -2.155 0.031524 *
## NitrogenYears$Date2010-03-08  5.000e-01  1.648e-01   3.035 0.002494 **
## NitrogenYears$Date2010-04-06  1.115e+00  1.648e-01   6.767 2.70e-11 ***
## NitrogenYears$Date2010-04-08  1.387e+00  1.427e-01   9.724  < 2e-16 ***
## NitrogenYears$Date2010-05-03  9.850e-01  1.427e-01   6.903 1.11e-11 ***
## NitrogenYears$Date2010-05-07  1.900e-01  1.648e-01   1.153 0.249230
## NitrogenYears$Date2010-06-01  3.500e-02  1.648e-01   0.212 0.831838
## NitrogenYears$Date2010-06-04  1.022e+00  1.427e-01   7.166 1.90e-12 ***
## NitrogenYears$Date2010-07-01 -8.500e-01  1.648e-01  -5.159 3.21e-07 ***
## NitrogenYears$Date2010-07-02 -8.200e-01  1.648e-01  -4.977 8.08e-07 ***
## NitrogenYears$Date2010-07-08  8.500e-02  1.648e-01   0.516 0.606095
## NitrogenYears$Date2010-08-03 -1.093e+00  1.427e-01  -7.656 6.10e-14 ***
## NitrogenYears$Date2010-08-09 -1.110e+00  1.648e-01  -6.737 3.29e-11 ***
## NitrogenYears$Date2010-09-01 -3.575e-01  1.427e-01  -2.505 0.012449 *
## NitrogenYears$Date2010-09-09 -7.800e-01  1.648e-01  -4.734 2.65e-06 ***
## NitrogenYears$Date2010-10-04  4.850e-01  1.648e-01   2.944 0.003348 **
## NitrogenYears$Date2010-10-08 -8.450e-01  1.648e-01  -5.128 3.75e-07 ***
## NitrogenYears$Date2010-10-11  2.500e-01  1.648e-01   1.517 0.129626
## NitrogenYears$Date2010-11-01 -4.450e-01  1.648e-01  -2.701 0.007078 **
## NitrogenYears$Date2010-11-02 -2.750e-01  1.648e-01  -1.669 0.095543 .
## NitrogenYears$Date2010-11-05  4.100e-01  1.648e-01   2.488 0.013056 *
## NitrogenYears$Date2010-12-02  2.600e-01  1.648e-01   1.578 0.115003
## NitrogenYears$Date2010-12-03  3.600e-01  1.648e-01   2.185 0.029214 *
## NitrogenYears$Date2010-12-07  1.550e-01  1.648e-01   0.941 0.347159
## NitrogenYears$Date2011-01-04  7.000e-02  1.648e-01   0.425 0.671077
## NitrogenYears$Date2011-01-07  8.400e-01  1.648e-01   5.098 4.38e-07 ***
## NitrogenYears$Date2011-01-11  1.700e-01  1.648e-01   1.032 0.302527
## NitrogenYears$Date2011-02-01 -1.000e+00  1.648e-01  -6.069 2.07e-09 ***
## NitrogenYears$Date2011-02-08 -8.000e-02  1.648e-01  -0.486 0.627444
## NitrogenYears$Date2011-02-10 -9.100e-01  1.648e-01  -5.523 4.64e-08 ***
## NitrogenYears$Date2011-03-01 -4.050e-01  1.648e-01  -2.458 0.014203 *
## NitrogenYears$Date2011-03-03  1.140e+00  1.648e-01   6.919 9.99e-12 ***
## NitrogenYears$Date2011-03-04 -4.350e-01  1.648e-01  -2.640 0.008466 **
## NitrogenYears$Date2011-04-01 -8.750e-02  1.427e-01  -0.613 0.539931
## NitrogenYears$Date2011-05-01 -1.200e-01  1.648e-01  -0.728 0.466663
## NitrogenYears$Date2011-05-02  1.650e-01  1.648e-01   1.001 0.316959
## NitrogenYears$Date2011-06-02  2.200e-01  1.648e-01   1.335 0.182222
## NitrogenYears$Date2011-06-07 -3.900e-01  1.648e-01  -2.367 0.018195 *
## NitrogenYears$Date2011-07-07 -8.450e-01  1.427e-01  -5.922 4.91e-09 ***
```

```
## NitrogenYears$Date2011-08-03 -5.950e-01  1.427e-01  -4.170 3.42e-05 ***
## NitrogenYears$Date2011-09-06 -8.900e-01  1.427e-01  -6.237 7.55e-10 ***
## NitrogenYears$Date2011-10-04 -1.410e+00  1.648e-01  -8.558  < 2e-16 ***
## NitrogenYears$Date2011-10-07 -1.430e+00  1.648e-01  -8.679  < 2e-16 ***
## NitrogenYears$Date2011-11-01 -5.850e-01  1.427e-01  -4.100 4.60e-05 ***
## NitrogenYears$Date2011-12-05  4.250e-01  1.648e-01   2.579 0.010092 *
## NitrogenYears$Date2011-12-06 -7.850e-01  1.648e-01  -4.764 2.29e-06 ***
## NitrogenYears$Date2012-01-10  8.950e-01  1.648e-01   5.432 7.61e-08 ***
## NitrogenYears$Date2012-01-11 -8.550e-01  1.648e-01  -5.189 2.74e-07 ***
## NitrogenYears$Date2012-02-06 -1.010e+00  1.648e-01  -6.130 1.44e-09 ***
## NitrogenYears$Date2012-02-15 -7.250e-01  1.648e-01  -4.400 1.24e-05 ***
## NitrogenYears$Date2012-03-05 -4.000e-02  1.648e-01  -0.243 0.808254
## NitrogenYears$Date2012-03-08  8.150e-01  1.648e-01   4.946 9.40e-07 ***
## NitrogenYears$Date2012-04-03  1.000e-02  1.648e-01   0.061 0.951621
## NitrogenYears$Date2012-04-10 -3.500e-02  1.648e-01  -0.212 0.831838
## NitrogenYears$Date2012-05-02  1.290e+00  1.648e-01   7.829 1.73e-14 ***
## NitrogenYears$Date2012-05-04  8.000e-02  1.648e-01   0.486 0.627444
## NitrogenYears$Date2012-06-01 -8.100e-01  1.648e-01  -4.916 1.09e-06 ***
## NitrogenYears$Date2012-06-07 -3.650e-01  1.648e-01  -2.215 0.027052 *
## NitrogenYears$Date2012-07-02 -1.360e+00  1.648e-01  -8.254 7.18e-16 ***
## NitrogenYears$Date2012-07-03 -8.300e-01  1.648e-01  -5.037 5.96e-07 ***
## NitrogenYears$Date2012-07-10 -9.900e-01  1.648e-01  -6.008 2.96e-09 ***
## NitrogenYears$Date2012-08-03 -1.603e+00  1.427e-01 -11.230  < 2e-16 ***
## NitrogenYears$Date2012-08-08 -1.200e+00  1.648e-01  -7.283 8.50e-13 ***
## NitrogenYears$Date2012-09-06 -1.335e+00  1.427e-01  -9.356  < 2e-16 ***
## NitrogenYears$Date2012-09-07 -1.600e+00  1.648e-01  -9.711  < 2e-16 ***
## NitrogenYears$Date2012-10-03 -1.460e+00  1.648e-01  -8.861  < 2e-16 ***
## NitrogenYears$Date2012-10-10 -1.540e+00  1.427e-01 -10.792  < 2e-16 ***
## NitrogenYears$Date2012-11-02 -1.485e+00  1.648e-01  -9.013  < 2e-16 ***
## NitrogenYears$Date2012-11-05 -8.125e-01  1.427e-01  -5.694 1.80e-08 ***
## NitrogenYears$Date2012-12-05 -4.300e-01  1.427e-01  -3.013 0.002672 **
## NitrogenYears$Date2012-12-11 -1.170e+00  1.648e-01  -7.101 2.95e-12 ***
## NitrogenYears$Date2013-01-03 -3.375e-01  1.427e-01  -2.365 0.018280 *
## NitrogenYears$Date2013-01-19  1.600e-01  1.648e-01   0.971 0.331837
## NitrogenYears$Date2013-02-07  5.900e-01  1.648e-01   3.581 0.000365 ***
## NitrogenYears$Date2013-02-11  1.400e-01  1.427e-01   0.981 0.326854
## NitrogenYears$Date2013-03-05  1.185e+00  1.648e-01   7.192 1.59e-12 ***
## NitrogenYears$Date2013-03-11 -7.450e-01  1.648e-01  -4.522 7.16e-06 ***
## NitrogenYears$Date2013-03-12  4.050e-01  1.648e-01   2.458 0.014203 *
## NitrogenYears$Date2013-04-02 -1.405e+00  1.648e-01  -8.527  < 2e-16 ***
## NitrogenYears$Date2013-04-04 -7.950e-01  1.648e-01  -4.825 1.71e-06 ***
## NitrogenYears$Date2013-04-10 -1.600e-01  1.648e-01  -0.971 0.331837
## NitrogenYears$Date2013-05-01 -5.700e-01  1.648e-01  -3.459 0.000573 ***
## NitrogenYears$Date2013-05-02 -5.350e-01  1.648e-01  -3.247 0.001220 **
## NitrogenYears$Date2013-05-09 -7.700e-01  1.648e-01  -4.673 3.53e-06 ***
## NitrogenYears$Date2013-06-04 -4.550e-01  1.648e-01  -2.761 0.005899 **
## NitrogenYears$Date2013-06-05 -1.290e+00  1.648e-01  -7.829 1.73e-14 ***
## NitrogenYears$Date2013-06-10 -1.425e+00  1.648e-01  -8.649  < 2e-16 ***
## NitrogenYears$Date2013-07-01 -1.535e+00  1.648e-01  -9.316  < 2e-16 ***
## NitrogenYears$Date2013-07-02 -6.650e-01  1.648e-01  -4.036 6.01e-05 ***
## NitrogenYears$Date2013-07-03 -4.550e-01  1.648e-01  -2.761 0.005899 **
## NitrogenYears$Date2013-08-05 -9.300e-01  1.648e-01  -5.644 2.38e-08 ***
## NitrogenYears$Date2013-08-06 -7.700e-01  1.648e-01  -4.673 3.53e-06 ***
## NitrogenYears$Date2013-08-08 -1.530e+00  1.648e-01  -9.286  < 2e-16 ***
```

```
## NitrogenYears$Date2013-09-03 -1.705e+00  1.427e-01 -11.949  < 2e-16 ***
## NitrogenYears$Date2013-09-04 -1.680e+00  1.648e-01 -10.196  < 2e-16 ***
## NitrogenYears$Date2013-09-30 -1.560e+00  1.427e-01 -10.933  < 2e-16 ***
## NitrogenYears$Date2013-10-04 -1.500e+00  1.648e-01  -9.104  < 2e-16 ***
## NitrogenYears$Date2013-11-04 -1.700e+00  1.648e-01 -10.318  < 2e-16 ***
## NitrogenYears$Date2013-11-05 -1.555e+00  1.648e-01  -9.438  < 2e-16 ***
## NitrogenYears$Date2013-11-07 -1.590e+00  1.648e-01  -9.650  < 2e-16 ***
## NitrogenYears$Date2013-12-03 -1.768e+00  1.427e-01 -12.387  < 2e-16 ***
## NitrogenYears$Date2013-12-06 -1.785e+00  1.648e-01 -10.833  < 2e-16 ***
## NitrogenYears$Date2014-01-03 -1.588e+00  1.427e-01 -11.125  < 2e-16 ***
## NitrogenYears$Date2014-01-07 -1.295e+00  1.648e-01  -7.860 1.39e-14 ***
## NitrogenYears$Date2014-02-03 -9.000e-01  1.648e-01  -5.462 6.46e-08 ***
## NitrogenYears$Date2014-02-04 -6.400e-01  1.648e-01  -3.884 0.000112 ***
## NitrogenYears$Date2014-02-06 -1.100e+00  1.648e-01  -6.676 4.87e-11 ***
## NitrogenYears$Date2014-03-12 -1.237e+00  1.345e-01  -9.192  < 2e-16 ***
## NitrogenYears$Date2014-04-02  9.000e-01  1.648e-01   5.462 6.46e-08 ***
## NitrogenYears$Date2014-04-08 -7.050e-01  1.648e-01  -4.279 2.13e-05 ***
## NitrogenYears$Date2014-04-09  6.050e-01  1.648e-01   3.672 0.000258 ***
## NitrogenYears$Date2014-05-01  9.000e-01  1.648e-01   5.462 6.46e-08 ***
## NitrogenYears$Date2014-05-02 -7.050e-01  1.648e-01  -4.279 2.13e-05 ***
## NitrogenYears$Date2014-05-09  6.050e-01  1.648e-01   3.672 0.000258 ***
## NitrogenYears$Date2014-06-02 -1.800e+00  1.648e-01 -10.925  < 2e-16 ***
## NitrogenYears$Date2014-06-03 -1.025e+00  1.648e-01  -6.221 8.33e-10 ***
## NitrogenYears$Date2014-06-06 -1.245e+00  1.648e-01  -7.556 1.25e-13 ***
## NitrogenYears$Date2014-07-02 -1.493e+00  1.427e-01 -10.460  < 2e-16 ***
## NitrogenYears$Date2014-07-08 -1.410e+00  1.648e-01  -8.558  < 2e-16 ***
## NitrogenYears$Date2014-08-01 -1.375e+00  1.648e-01  -8.345 3.57e-16 ***
## NitrogenYears$Date2014-08-04 -9.450e-01  1.648e-01  -5.735 1.43e-08 ***
## NitrogenYears$Date2014-08-05 -1.885e+00  1.648e-01 -11.440  < 2e-16 ***
## NitrogenYears$Date2014-09-02 -1.615e+00  1.648e-01  -9.802  < 2e-16 ***
## NitrogenYears$Date2014-09-05 -1.925e+00  1.648e-01 -11.683  < 2e-16 ***
## NitrogenYears$Date2014-09-09 -1.375e+00  1.648e-01  -8.345 3.57e-16 ***
## NitrogenYears$Date2014-10-09 -1.570e+00  1.648e-01  -9.529  < 2e-16 ***
## NitrogenYears$Date2014-10-10 -2.075e+00  1.648e-01 -12.594  < 2e-16 ***
## NitrogenYears$Date2014-10-13 -1.635e+00  1.648e-01  -9.923  < 2e-16 ***
## NitrogenYears$Date2014-11-04 -1.375e+00  1.648e-01  -8.345 3.57e-16 ***
## NitrogenYears$Date2014-11-10 -1.470e+00  1.648e-01  -8.922  < 2e-16 ***
## NitrogenYears$Date2014-11-13 -1.780e+00  1.648e-01 -10.803  < 2e-16 ***
## NitrogenYears$Date2014-12-01 -9.300e-01  1.427e-01  -6.518 1.33e-10 ***
## NitrogenYears$Date2014-12-05 -1.005e+00  1.648e-01  -6.100 1.73e-09 ***
## NitrogenYears$Date2015-01-06 -1.415e+00  1.648e-01  -8.588  < 2e-16 ***
## NitrogenYears$Date2015-01-07 -5.750e-01  1.427e-01  -4.030 6.17e-05 ***
## NitrogenYears$Date2015-02-03 -1.320e+00  1.648e-01  -8.011 4.50e-15 ***
## NitrogenYears$Date2015-02-05 -1.215e+00  1.648e-01  -7.374 4.51e-13 ***
## NitrogenYears$Date2015-02-07 -6.400e-01  1.648e-01  -3.884 0.000112 ***
## NitrogenYears$Date2015-03-04 -5.000e-03  1.648e-01  -0.030 0.975800
## NitrogenYears$Date2015-03-06 -2.130e+00  1.648e-01 -12.927  < 2e-16 ***
## NitrogenYears$Date2015-03-09 -8.700e-01  1.648e-01  -5.280 1.71e-07 ***
## NitrogenYears$Date2015-04-06 -1.075e+00  1.648e-01  -6.524 1.28e-10 ***
## NitrogenYears$Date2015-04-08 -1.375e+00  1.648e-01  -8.345 3.57e-16 ***
## NitrogenYears$Date2015-04-13  4.750e-01  1.648e-01   2.883 0.004057 **
## NitrogenYears$Date2015-05-04  8.450e-01  1.648e-01   5.128 3.75e-07 ***
## NitrogenYears$Date2015-05-07  8.200e-01  1.648e-01   4.977 8.08e-07 ***
## NitrogenYears$Date2015-05-12  1.235e+00  1.648e-01   7.495 1.92e-13 ***
```

```
## NitrogenYears$Date2015-06-02 -7.750e-01  1.648e-01  -4.704 3.06e-06 ***
## NitrogenYears$Date2015-06-04 -7.000e-01  1.648e-01  -4.248 2.43e-05 ***
## NitrogenYears$Date2015-06-09 -9.000e-01  1.648e-01  -5.462 6.46e-08 ***
## NitrogenYears$Date2015-07-02 -1.105e+00  1.648e-01  -6.706 4.00e-11 ***
## NitrogenYears$Date2015-07-08 -1.800e+00  1.648e-01 -10.925  < 2e-16 ***
## NitrogenYears$Date2015-07-13 -1.290e+00  1.648e-01  -7.829 1.73e-14 ***
## NitrogenYears$Date2015-08-03 -1.915e+00  1.648e-01 -11.622  < 2e-16 ***
## NitrogenYears$Date2015-08-05 -1.340e+00  1.648e-01  -8.133 1.81e-15 ***
## NitrogenYears$Date2015-08-06 -1.630e+00  1.648e-01  -9.893  < 2e-16 ***
## NitrogenYears$Date2015-09-02 -1.250e+00  1.648e-01  -7.586 1.01e-13 ***
## NitrogenYears$Date2015-09-03 -1.610e+00  1.648e-01  -9.771  < 2e-16 ***
## NitrogenYears$Date2015-09-04 -2.000e+00  1.648e-01 -12.138  < 2e-16 ***
## NitrogenYears$Date2015-10-01 -1.305e+00  1.648e-01  -7.920 8.87e-15 ***
## NitrogenYears$Date2015-10-02 -1.880e+00  1.648e-01 -11.410  < 2e-16 ***
## NitrogenYears$Date2015-10-05 -1.415e+00  1.648e-01  -8.588  < 2e-16 ***
## NitrogenYears$Date2015-11-05 -6.800e-01  1.648e-01  -4.127 4.10e-05 ***
## NitrogenYears$Date2015-11-09 -8.800e-01  1.648e-01  -5.341 1.24e-07 ***
## NitrogenYears$Date2015-11-11 -1.500e-01  1.648e-01  -0.910 0.362925
## NitrogenYears$Date2015-12-02 -9.825e-01  1.427e-01  -6.885 1.25e-11 ***
## NitrogenYears$Date2015-12-03 -5.050e-01  1.648e-01  -3.065 0.002258 **
## NitrogenYears$Date2016-01-09  1.200e-01  1.648e-01   0.728 0.466663
## NitrogenYears$Date2016-01-10  2.750e-01  1.648e-01   1.669 0.095543 .
## NitrogenYears$Date2016-01-11  5.350e-01  1.648e-01   3.247 0.001220 **
## NitrogenYears$Date2016-02-07  8.175e-01  1.427e-01   5.729 1.48e-08 ***
## NitrogenYears$Date2016-02-09  8.800e-01  1.648e-01   5.341 1.24e-07 ***
## NitrogenYears$Date2016-03-09 -4.550e-01  1.648e-01  -2.761 0.005899 **
## NitrogenYears$Date2016-03-10 -1.098e+00  1.427e-01  -7.691 4.73e-14 ***
## NitrogenYears$Date2016-04-05  9.250e-01  1.648e-01   5.614 2.81e-08 ***
## NitrogenYears$Date2016-04-07  5.100e-01  1.427e-01   3.574 0.000375 ***
## NitrogenYears$Date2016-05-03  6.800e-01  1.427e-01   4.765 2.27e-06 ***
## NitrogenYears$Date2016-05-05  1.650e-01  1.648e-01   1.001 0.316959
## NitrogenYears$Date2016-06-01  4.800e-01  1.648e-01   2.913 0.003687 **
## NitrogenYears$Date2016-06-07 -8.250e-01  1.648e-01  -5.007 6.94e-07 ***
## NitrogenYears$Date2016-06-11 -6.850e-01  1.648e-01  -4.157 3.60e-05 ***
## NitrogenYears$Date2016-07-07 -1.245e+00  1.648e-01  -7.556 1.25e-13 ***
## NitrogenYears$Date2016-07-08 -1.375e+00  1.648e-01  -8.345 3.57e-16 ***
## NitrogenYears$Date2016-07-11 -4.350e-01  1.648e-01  -2.640 0.008466 **
## NitrogenYears$Date2016-08-02 -1.485e+00  1.648e-01  -9.013  < 2e-16 ***
## NitrogenYears$Date2016-08-04 -1.235e+00  1.648e-01  -7.495 1.92e-13 ***
## NitrogenYears$Date2016-08-08 -4.900e-01  1.648e-01  -2.974 0.003038 **
## NitrogenYears$Date2016-09-01 -6.950e-01  1.648e-01  -4.218 2.77e-05 ***
## NitrogenYears$Date2016-09-07 -1.035e+00  1.648e-01  -6.282 5.76e-10 ***
## NitrogenYears$Date2016-09-08 -9.450e-01  1.648e-01  -5.735 1.43e-08 ***
## NitrogenYears$Date2016-10-03 -8.750e-01  1.648e-01  -5.311 1.45e-07 ***
## NitrogenYears$Date2016-10-04 -7.550e-01  1.648e-01  -4.582 5.41e-06 ***
## NitrogenYears$Date2016-10-06 -4.700e-01  1.648e-01  -2.853 0.004460 **
## NitrogenYears$Date2016-11-01 -4.350e-01  1.648e-01  -2.640 0.008466 **
## NitrogenYears$Date2016-11-02 -1.210e+00  1.648e-01  -7.344 5.58e-13 ***
## NitrogenYears$Date2016-11-04 -1.315e+00  1.648e-01  -7.981 5.65e-15 ***
## NitrogenYears$Date2016-12-02 -1.025e+00  1.648e-01  -6.221 8.33e-10 ***
## NitrogenYears$Date2016-12-06 -1.385e+00  1.648e-01  -8.406 2.23e-16 ***
## NitrogenYears$Date2016-12-08 -3.450e-01  1.648e-01  -2.094 0.036617 *
## NitrogenYears$Date2017-01-04 -2.100e-01  1.427e-01  -1.472 0.141535
## NitrogenYears$Date2017-01-10 -1.150e+00  1.648e-01  -6.980 6.67e-12 ***
```

```
## NitrogenYears$Date2017-02-01 -4.850e-01  1.427e-01  -3.399 0.000713 ***
## NitrogenYears$Date2017-02-09 -5.500e-02  1.648e-01  -0.334 0.738623
## NitrogenYears$Date2017-03-07  4.800e-01  1.427e-01   3.364 0.000809 ***
## NitrogenYears$Date2017-03-10 -3.700e-01  1.648e-01  -2.246 0.025029 *
## NitrogenYears$Date2017-04-04  7.550e-01  1.648e-01   4.582 5.41e-06 ***
## NitrogenYears$Date2017-04-11  7.050e-01  1.648e-01   4.279 2.13e-05 ***
## NitrogenYears$Date2017-05-03  7.300e-01  1.648e-01   4.431 1.08e-05 ***
## NitrogenYears$Date2017-05-04  6.950e-01  1.648e-01   4.218 2.77e-05 ***
## NitrogenYears$Date2017-06-01  4.000e-02  1.648e-01   0.243 0.808254
## NitrogenYears$Date2017-06-06 -2.500e-02  1.648e-01  -0.152 0.879442
## NitrogenYears$Date2017-07-07 -1.220e+00  1.427e-01  -8.550  < 2e-16 ***
## NitrogenYears$Date2017-07-11 -6.900e-01  1.648e-01  -4.188 3.16e-05 ***
## NitrogenYears$Date2017-08-01 -1.533e+00  1.427e-01 -10.740  < 2e-16 ***
## NitrogenYears$Date2017-08-03 -1.445e+00  1.648e-01  -8.770  < 2e-16 ***
## NitrogenYears$Date2017-09-07 -1.735e+00  1.427e-01 -12.159  < 2e-16 ***
## NitrogenYears$Date2017-09-10 -1.425e+00  1.648e-01  -8.649  < 2e-16 ***
## NitrogenYears$Date2017-10-02 -1.610e+00  1.648e-01  -9.771  < 2e-16 ***
## NitrogenYears$Date2017-10-03 -1.245e+00  1.427e-01  -8.725  < 2e-16 ***
## NitrogenYears$Date2017-11-02 -1.590e+00  1.648e-01  -9.650  < 2e-16 ***
## NitrogenYears$Date2017-11-03 -1.223e+00  1.427e-01  -8.567  < 2e-16 ***
## NitrogenYears$Date2017-12-06 -1.185e+00  1.648e-01  -7.192 1.59e-12 ***
## NitrogenYears$Date2017-12-07 -8.225e-01  1.427e-01  -5.764 1.21e-08 ***
## NitrogenYears$Date2018-01-23 -1.690e+00  1.648e-01 -10.257  < 2e-16 ***
## NitrogenYears$Date2018-01-24 -6.600e-01  1.648e-01  -4.006 6.82e-05 ***
## NitrogenYears$Date2018-01-25 -9.850e-01  1.648e-01  -5.978 3.53e-09 ***
## NitrogenYears$Date2018-02-15 -1.450e+00  1.648e-01  -8.800  < 2e-16 ***
## NitrogenYears$Date2018-02-16 -1.575e+00  1.427e-01 -11.038  < 2e-16 ***
## NitrogenYears$Date2018-03-07  5.225e-01  1.427e-01   3.662 0.000269 ***
## NitrogenYears$Date2018-03-12 -2.000e-02  1.648e-01  -0.121 0.903421
## NitrogenYears$Date2018-04-03  6.300e-01  1.648e-01   3.824 0.000143 ***
## NitrogenYears$Date2018-04-05  1.800e-01  1.648e-01   1.092 0.274996
## NitrogenYears$Date2018-04-06 -2.400e-01  1.648e-01  -1.457 0.145657
## NitrogenYears$Date2018-05-02 -5.883e-01  1.648e-01  -3.570 0.000380 ***
## NitrogenYears$Date2018-05-04 -8.295e-01  1.427e-01  -5.813 9.16e-09 ***
## NitrogenYears$Date2018-06-04 -1.041e-01  1.427e-01  -0.730 0.465777
## NitrogenYears$Date2018-06-06  6.209e-01  1.648e-01   3.768 0.000178 ***
## NitrogenYears$Date2018-07-05 -1.287e+00  1.648e-01  -7.813 1.95e-14 ***
## NitrogenYears$Date2018-07-06 -1.453e+00  1.648e-01  -8.819  < 2e-16 ***
## NitrogenYears$Date2018-07-10  9.197e-02  1.648e-01   0.558 0.576896
## NitrogenYears$Date2018-08-06 -9.366e-01  1.648e-01  -5.684 1.90e-08 ***
## NitrogenYears$Date2018-08-13 -8.452e-01  1.427e-01  -5.923 4.86e-09 ***
## NitrogenYears$Date2018-09-06 -5.088e-01  1.648e-01  -3.088 0.002091 **
## NitrogenYears$Date2018-09-07 -6.591e-01  1.427e-01  -4.619 4.55e-06 ***
## NitrogenYears$Date2018-10-04 -1.030e+00  1.427e-01  -7.219 1.32e-12 ***
## NitrogenYears$Date2018-10-05 -1.400e+00  1.648e-01  -8.496  < 2e-16 ***
## NitrogenYears$Date2018-11-01 -1.565e+00  1.648e-01  -9.498  < 2e-16 ***
## NitrogenYears$Date2018-11-02 -1.438e+00  1.427e-01 -10.074  < 2e-16 ***
## NitrogenYears$Date2018-12-04 -7.850e-01  1.648e-01  -4.764 2.29e-06 ***
## NitrogenYears$Date2018-12-11 -1.055e+00  1.427e-01  -7.394 3.94e-13 ***
## NitrogenYears$Date2019-01-03 -1.290e+00  1.648e-01  -7.829 1.73e-14 ***
## NitrogenYears$Date2019-01-04 -1.158e+00  1.427e-01  -8.112 2.12e-15 ***
## NitrogenYears$Date2019-02-07 -5.500e-01  1.427e-01  -3.854 0.000126 ***
## NitrogenYears$Date2019-02-08 -1.850e-01  1.648e-01  -1.123 0.261893
## NitrogenYears$Date2019-03-04 -7.550e-01  1.427e-01  -5.291 1.61e-07 ***
```

```
## NitrogenYears$Date2019-03-05 -2.750e-01  1.648e-01  -1.669 0.095543 .
## NitrogenYears$Date2019-04-01 -7.250e-02  1.427e-01  -0.508 0.611547
## NitrogenYears$Date2019-04-04  4.350e-01  1.648e-01   2.640 0.008466 **
## NitrogenYears$Date2019-05-02  5.400e-01  1.648e-01   3.277 0.001098 **
## NitrogenYears$Date2019-05-03 -5.450e-01  1.427e-01  -3.819 0.000145 ***
## NitrogenYears$Date2019-06-04  3.250e-02  1.427e-01   0.228 0.819895
## NitrogenYears$Date2019-06-06  4.100e-01  1.648e-01   2.488 0.013056 *
## NitrogenYears$Date2019-07-02 -1.445e+00  1.648e-01  -8.770  < 2e-16 ***
## NitrogenYears$Date2019-07-08 -1.540e+00  1.648e-01  -9.347  < 2e-16 ***
## NitrogenYears$Date2019-07-10 -1.655e+00  1.648e-01 -10.044  < 2e-16 ***
## NitrogenYears$Date2019-08-02 -1.910e+00  1.648e-01 -11.592  < 2e-16 ***
## NitrogenYears$Date2019-08-05 -1.820e+00  1.648e-01 -11.046  < 2e-16 ***
## NitrogenYears$Date2019-08-09 -1.045e+00  1.648e-01  -6.342 3.97e-10 ***
## NitrogenYears$Date2019-09-06 -6.650e-01  1.648e-01  -4.036 6.01e-05 ***
## NitrogenYears$Date2019-09-12 -1.588e+00  1.427e-01 -11.125  < 2e-16 ***
## NitrogenYears$Date2019-10-02 -2.050e-01  1.648e-01  -1.244 0.213833
## NitrogenYears$Date2019-10-03 -8.400e-01  1.648e-01  -5.098 4.38e-07 ***
## NitrogenYears$Date2019-10-04 -9.200e-01  1.648e-01  -5.584 3.33e-08 ***
## NitrogenYears$Date2019-11-01 -1.725e+00  1.648e-01 -10.469  < 2e-16 ***
## NitrogenYears$Date2019-11-04 -1.195e+00  1.648e-01  -7.253 1.05e-12 ***
## NitrogenYears$Date2019-11-06 -8.800e-01  1.648e-01  -5.341 1.24e-07 ***
## NitrogenYears$Date2019-12-03 -6.000e-01  1.648e-01  -3.642 0.000290 ***
## NitrogenYears$Date2019-12-05 -2.700e-01  1.648e-01  -1.639 0.101712
## NitrogenYears$Date2019-12-06 -8.700e-01  1.648e-01  -5.280 1.71e-07 ***
## NitrogenYears$Date2020-01-07 -5.350e-01  1.648e-01  -3.247 0.001220 **
## NitrogenYears$Date2020-01-14 -1.478e+00  1.427e-01 -10.354  < 2e-16 ***
## NitrogenYears$Date2020-02-04 -1.410e+00  1.648e-01  -8.558  < 2e-16 ***
## NitrogenYears$Date2020-02-06 -9.950e-01  1.427e-01  -6.973 6.97e-12 ***
## NitrogenYears$Date2020-03-02 -1.780e+00  1.648e-01 -10.803  < 2e-16 ***
## NitrogenYears$Date2020-03-03 -1.590e+00  1.648e-01  -9.650  < 2e-16 ***
## NitrogenYears$Date2020-03-05 -2.227e+00  1.648e-01 -13.513  < 2e-16 ***
## NitrogenYears$Date2020-07-08 -4.900e-01  1.648e-01  -2.974 0.003038 **
## NitrogenYears$Date2020-07-10  2.500e-02  1.648e-01   0.152 0.879442
## NitrogenYears$Date2020-07-13 -1.765e+00  1.648e-01 -10.712  < 2e-16 ***
## NitrogenYears$Date2020-08-04 -1.415e+00  1.648e-01  -8.588  < 2e-16 ***
## NitrogenYears$Date2020-08-06 -1.275e+00  1.648e-01  -7.738 3.37e-14 ***
## NitrogenYears$Date2020-08-07 -1.075e+00  1.648e-01  -6.524 1.28e-10 ***
## NitrogenYears$Date2020-09-01 -1.140e+00  1.648e-01  -6.919 9.99e-12 ***
## NitrogenYears$Date2020-09-02 -1.353e+00  1.427e-01  -9.478  < 2e-16 ***
## NitrogenYears$Date2020-10-05 -1.483e+00  1.427e-01 -10.389  < 2e-16 ***
## NitrogenYears$Date2020-10-06 -1.095e+00  1.648e-01  -6.646 5.91e-11 ***
## NitrogenYears$Date2020-11-02 -1.715e+00  1.648e-01 -10.409  < 2e-16 ***
## NitrogenYears$Date2020-11-04 -1.200e+00  1.427e-01  -8.410  < 2e-16 ***
## NitrogenYears$Date2020-12-03 -7.050e-01  1.648e-01  -4.279 2.13e-05 ***
## NitrogenYears$Date2020-12-04 -9.200e-01  1.427e-01  -6.447 2.07e-10 ***
## NitrogenYears$Date2021-01-06 -6.550e-01  1.648e-01  -3.975 7.73e-05 ***
## NitrogenYears$Date2021-01-12 -3.725e-01  1.427e-01  -2.611 0.009227 **
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.1648 on 728 degrees of freedom
## Multiple R-squared:  0.974,  Adjusted R-squared:  0.9542
## F-statistic: 49.28 on 553 and 728 DF,  p-value: < 2.2e-16
```

```r
NitrogenYears$Year <- as.factor(NitrogenYears$Year)

NitrogenPlot <- ggplot(NitrogenYears, aes(x=Year, y=Nitrogen_Percent))+
  geom_boxplot()+
  labs(title="Nitrogen Concentration Percent by Year", x="Year", y="Nitrogen Concentration Percent")
print(NitrogenPlot)
```

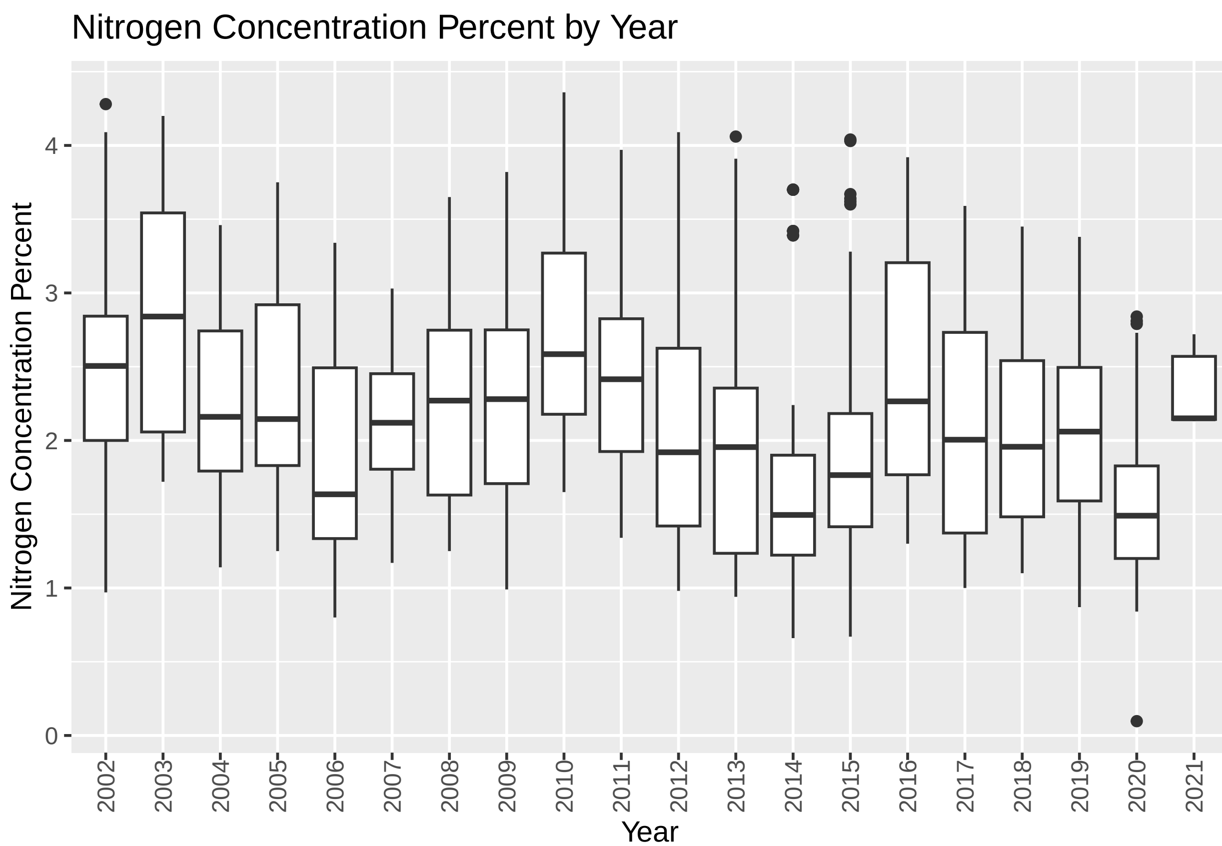


Figure 2: Nitrogen Concentration over the Years

Below are the normal distribution residuals charts for the linear regression of nitrogen concentration by date.

```r
par(mfrow = c(2,2), mar=c(2,2,2,2))
plot(NitrogenRegressionDate)
```

```r
par(mfrow = c(1,1))
```

A time series analysis was also completed to see how nitrogen concentration changes over time. The following plot displays the decomposed nitrogen concentration components of the time series run. As you can see, there is seasonality, which confirms our rejecting of the null hypothesis.

```r
#6. Season Plot #average the months
Nitrogen.monthly.preliminary <- NitrogenYears %>%
  mutate(CleanDate = my(paste0(Month,"-",Year)))
```

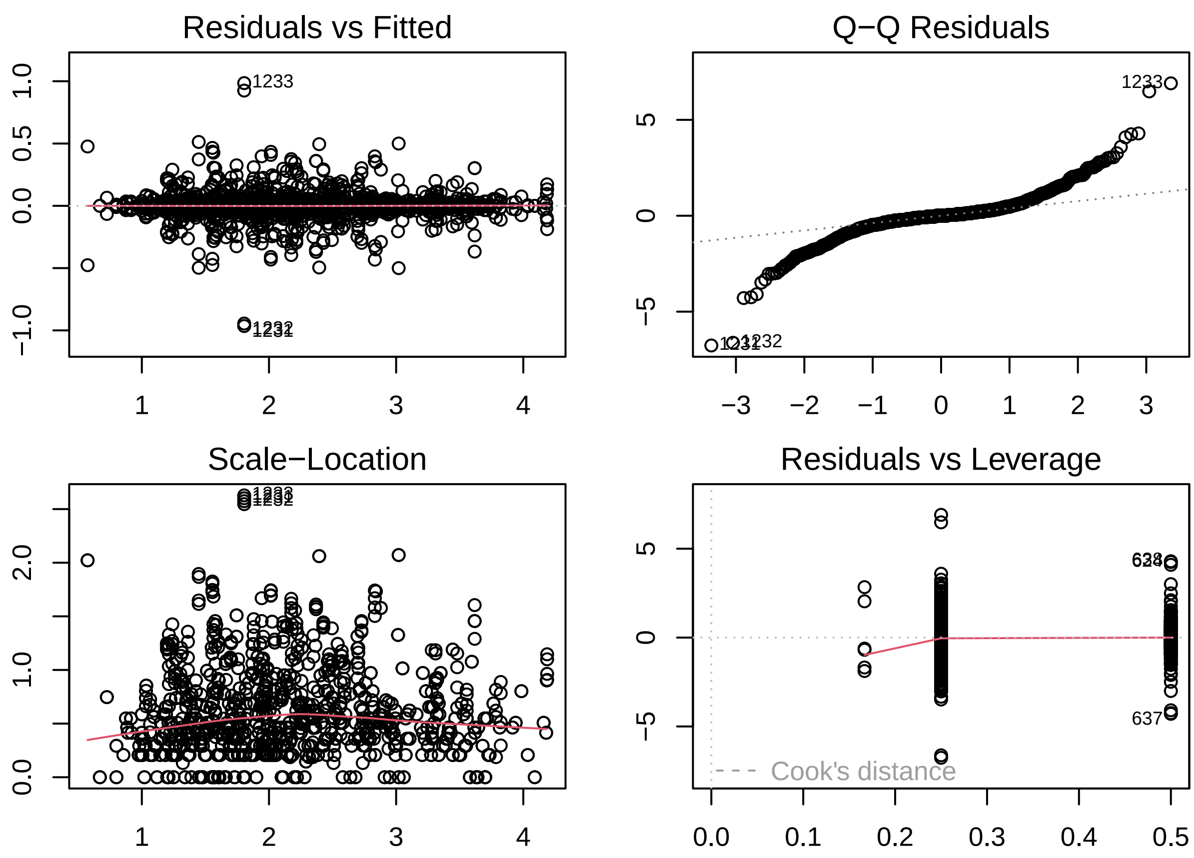


Figure 3: Nitrogen Concentration Resdiual Plots by Date

```
Nitrogen.monthly <-aggregate(Nitrogen.monthly.preliminary$Nitrogen_Percent,
                                  by=list(Nitrogen.monthly.preliminary$CleanDate),
                                  FUN=mean)

colnames(Nitrogen.monthly) <- c("Date", "Mean_NitrogenPercent")

#7. Generate time series monthly
f_monthmonthly <- month(first(Nitrogen.monthly$Date))
f_yearmonthly <- year(first(Nitrogen.monthly$Date))

Nitrogen.monthly.ts <- ts(Nitrogen.monthly$Mean_NitrogenPercent,
                   start=c(f_yearmonthly,f_monthmonthly),
                   frequency=12)

#Decompose monthly
Nitrogen.monthly.ts.decomp <- stl(Nitrogen.monthly.ts,s.window = "periodic")
plot(Nitrogen.monthly.ts.decomp)
```

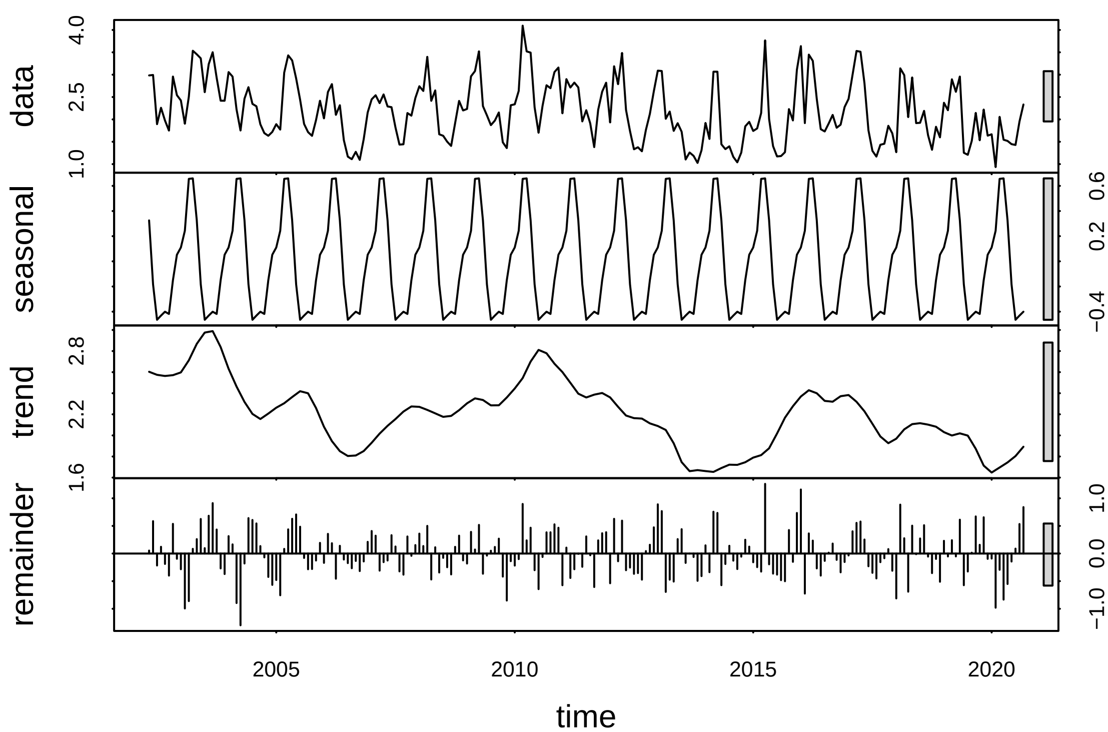


Figure 4: Nitrogen Concentration Residual Plots

The Mann-Kendall analysis performed on the nitrogen concentration non-seasonal time series produced a p-value of less than 0.05 (<.001, tau value of -0.19). As a result, the data displays a significant, decreasing trend for nitrogen concentration. The plot below displays the non-seasonal nitrogen concentration amount in the time series which was produced by removing the seasonal component from the time series.

```r
#12 Run SMK test monthly
Nitrogen_Monthly_SMK <- Kendall::SeasonalMannKendall(Nitrogen.monthly.ts)

Nitrogen_Monthly_SMK
```

```
## tau = -0.19, 2-sided pvalue =0.00011555
```

```r
summary(Nitrogen_Monthly_SMK)
```

```
## Score =  -365 , Var(Score) = 8963
## denominator =  1925.499
## tau = -0.19, 2-sided pvalue =0.00011555
```

```r
# 13 Visualization
Nitrogen_Plot <-
ggplot(Nitrogen.monthly, aes(x = Date, y = Mean_NitrogenPercent)) +
  geom_point() +
  geom_line() +
  labs("Mean Nitrogen (percent)", title="Nitrogen Concentration Percent over Time") +
  geom_smooth( method = lm )

print(Nitrogen_Plot)
```

```r
#taking out seasonal
NitrogenComponents <- as.data.frame(Nitrogen.monthly.ts.decomp$time.series[,1:3])

Nitrogen_NoSeasonal <-NitrogenComponents$trend+NitrogenComponents$remainder

#16 Run MK test monthly
Nitrogen_Monthly_MK <- Kendall::MannKendall(Nitrogen_NoSeasonal)

Nitrogen_Monthly_MK
```

```
## tau = -0.188, 2-sided pvalue =3.0712e-05
```

```r
summary(Nitrogen_Monthly_MK)
```

```
## Score =  -4581 , Var(Score) = 1207396
## denominator =  24309.5
## tau = -0.188, 2-sided pvalue =3.0712e-05
```

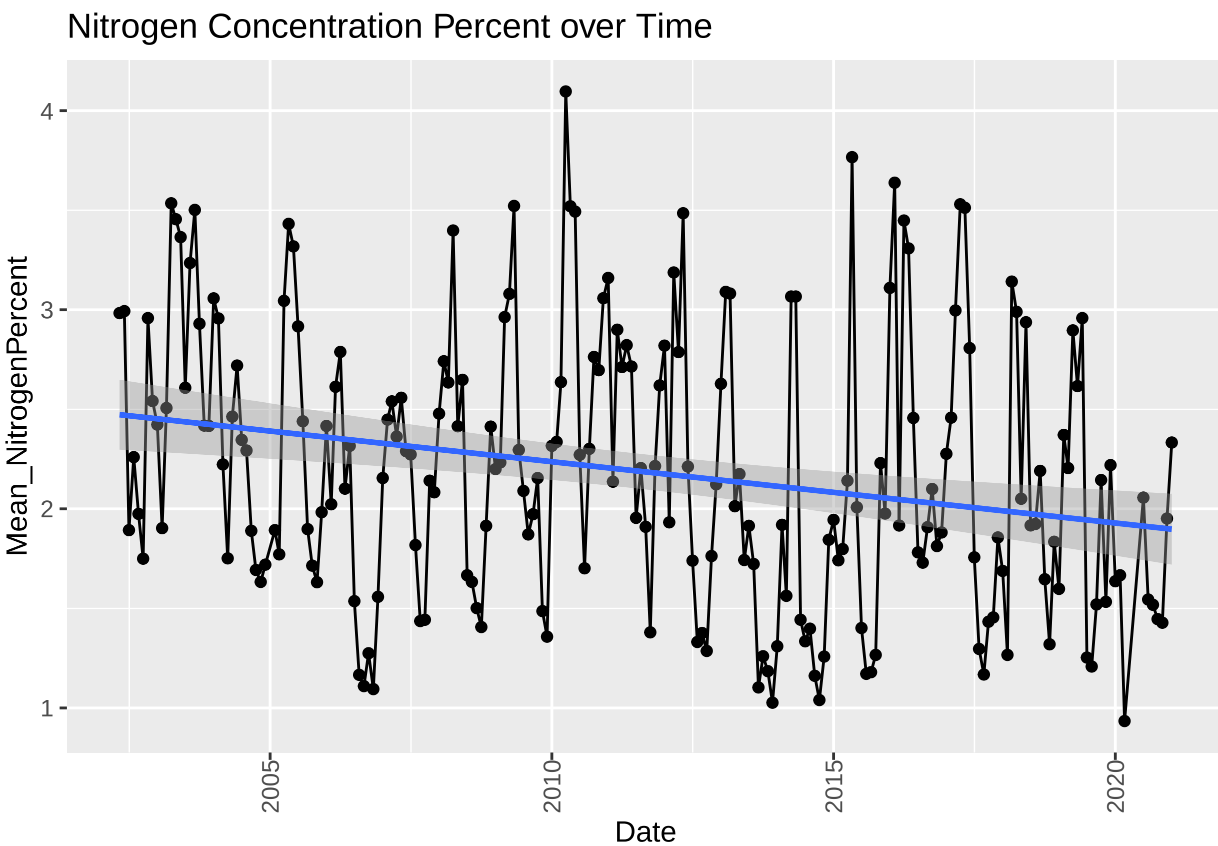


Figure 5: Time Series Analysis for Nitrgoen Concentration

Question 2: Does giant kelp nitrogen concentration amount vary by season?

For the second question, we wanted to know the relationship between nitrogen concentration and season. Winter is defined as beggining of December through February, Spring is beginning of March through May, Summer is June through August, and Fall is September through November.

H0 : There is no significant difference of nitrogen concentration by season. HA : There is significant difference of nitrogen concentration by season.

The interaction between nitrogen concentration and season is significant because the p-value is $< .05$ (p $< 2.2e-16$). We can reject the null hypothesis and accept that there is significant difference of nitrogen concentration by season.The box plot below shows the change in nitrogen concentration over seasons.

```
##
## Call:
## lm(formula = NitrogenYears$Nitrogen_Percent ~ NitrogenYears$SeasonNames)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -2.64975 -0.49742 -0.05865  0.43835  2.19235
##
## Coefficients:
##                                 Estimate Std. Error t value Pr(>|t|)
## (Intercept)                      2.18584    0.03784  57.764   <2e-16 ***
## NitrogenYears$SeasonNamesSpring  0.56091    0.05430  10.330   <2e-16 ***
## NitrogenYears$SeasonNamesSummer -0.09819    0.05335  -1.840   0.0659 .
## NitrogenYears$SeasonNamesFall   -0.46618    0.05319  -8.765   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.679 on 1278 degrees of freedom
## Multiple R-squared:  0.2242, Adjusted R-squared:  0.2224
## F-statistic: 123.1 on 3 and 1278 DF,  p-value: < 2.2e-16
```

```
Below are the normal distribution residuals charts for the linear regression of nitrogen concentration b
```

```r
#3. Normal Distribution
par(mfrow = c(2,2), mar=c(2,2,2,2))
plot(NitrogenRegressionSeason)
```

```r
par(mfrow = c(1,1))
```

```r
NitrogenSeasonPlot <- ggplot(NitrogenYears, aes(x=SeasonNames, y=Nitrogen_Percent))+
  geom_boxplot()+
  labs(title="Nitrogen Concentration Percent by Season", x="Season", y="Nitrogen Concentration Percent")

print(NitrogenSeasonPlot)
```

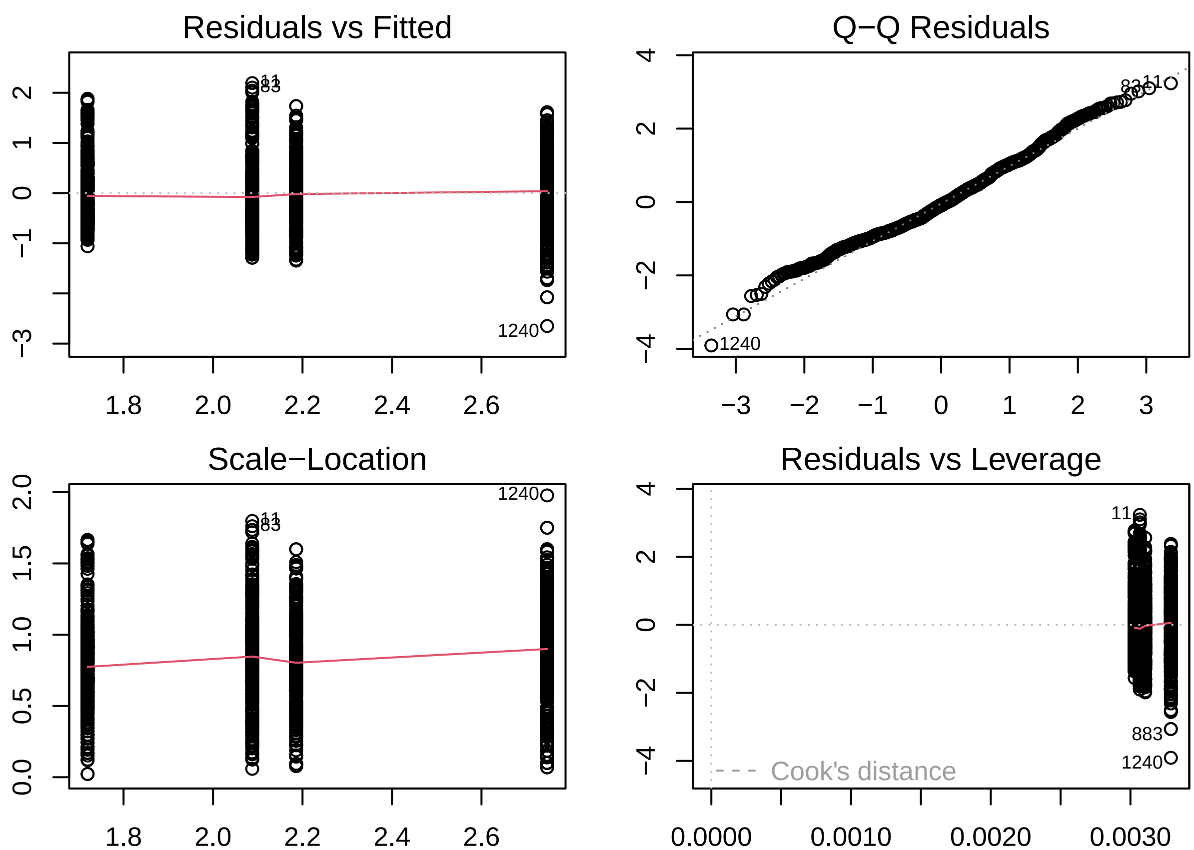


Figure 6: Nitrogen Concentration Residuals Plots for Season

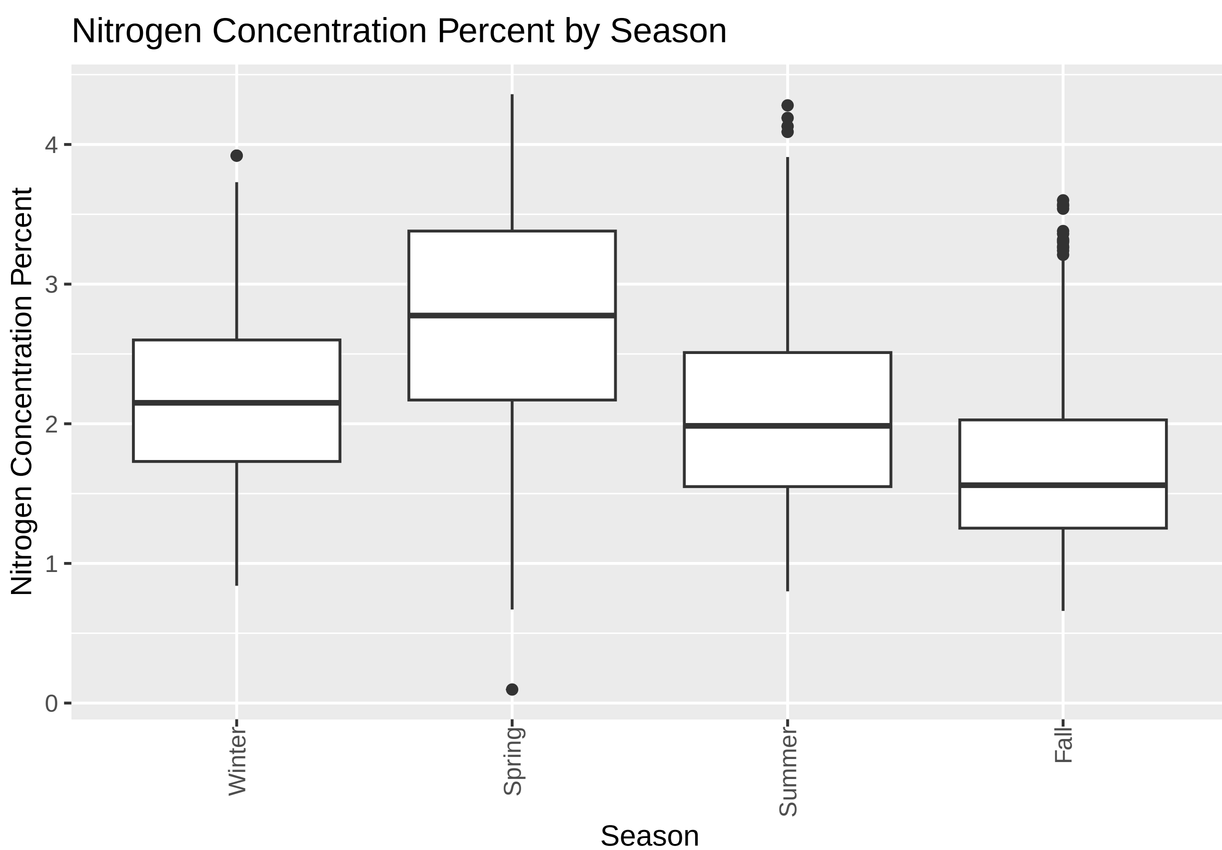


Figure 7: Nitrgoen Concentration over Seasons

Question 3: Does nitrogen surge uptake vary between the spring and summer seasons?

The last three questions focus on the experiment completed over five days in the spring and summer of 2019. Nitrogen was blasted for 45 minutes and data on nitrogen and biomass update was recorded.

The metadata indicates that the giant kelp blades studied were collected during the nitrate replete spring and the nitrate-deplete summer. The five replicate experiments were conducted in both spring and summer of 2019, which allows us to find potential differences in the nitrogen surge uptake of the two populations. The experimenters calculate uptake rate using a modified version of an equation by Legendre and Grosselin (1997) V= (nt - n0)/[t(ds-d0)] where nt is the atom percentage of Nitrogen-15 in the blade after incubation; n0 is the average concentration of isotope in the control blades; ds is the atom percentage of Nitrogen-15 in the seawater at the start of the incubation; d0 is the atom percentage of Nitrogen-15 in the nitrate pool before isotope tracer was added; and t is the length of the incubation time in minutes.

H0 : There is no significant difference of nitrogen surge uptake between spring and summer seasons. HA : There is significant difference of nitrogen surge uptake between spring and summer seasons.

The interaction between nitrogen uptake and season is significant because the p-value is < .05 (p < .0216). We can reject the null hypothesis and accept that there is significant difference of nitrogen surge uptake between spring and summer seasons.. The R-squared is .014, so a low amount of nitrogen uptake variance is in response to data being collected in the spring or summer. The box plot below shows the change in nitrogen concentration over seasons.

```
NitrogenSeasonBox <-
  ggplot(SurgeUptakeNitrogen, aes(x = Season, y = Uptake_Rate)) +
  geom_boxplot()+
  labs(title="Nitrogen Uptake Rate by Season", x="Season", y="Nitrogen Uptake Rate (V(hr1))")

print(NitrogenSeasonBox)
```

```
#ggsave(file=here('Output', 'Analysis','NitrogenBoxSeason.png'), width = 10, height = 10, units = #"cm"
```

The scatter plot below shows the change in nitrogen concentration over seasons by testing day replicate.

```
NitrogenSeasonPoint <-
  ggplot(SurgeUptakeNitrogen, aes(x = Day_Replicate, y = Uptake_Rate, color=Season)) +
  geom_point(alpha=.5)+
  labs(title="Nitrogen Uptake Rate by Day and Season", x="Days", y="Nitrogen Uptake Rate (V(hr1))")


print(NitrogenSeasonPoint)
```

```
#ggsave(file=here('Output', 'Analysis','NitrogenPointSeason.png'), width = 10, height = 10, units = #"c
```

```
##
## Call:
## lm(formula = SurgeUptakeNitrogen$Uptake_Rate ~ SurgeUptakeNitrogen$Season)
##
## Residuals:
##       Min        1Q    Median        3Q       Max
## -0.007419 -0.003936 -0.001798  0.001434  0.048773
```

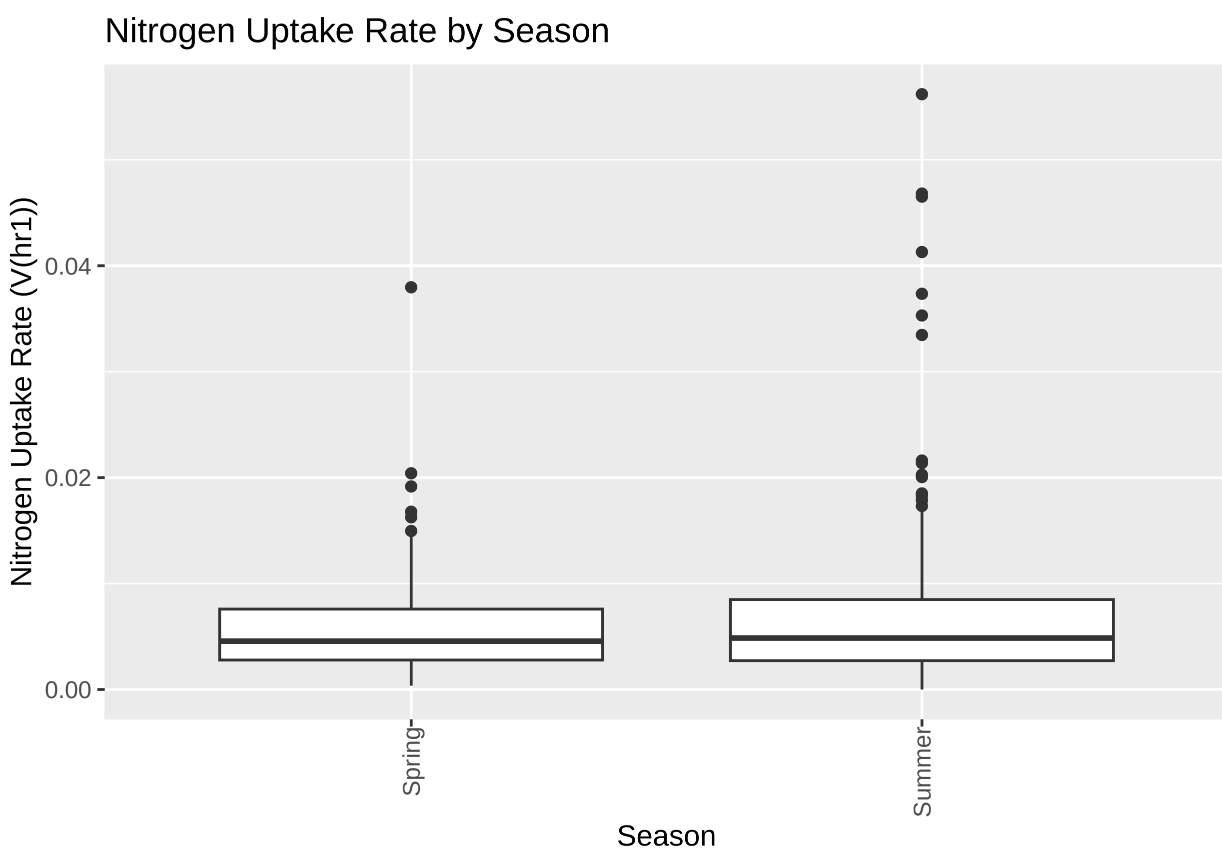


Figure 8: Nitrogen Uptake Rate by Season Box Plot

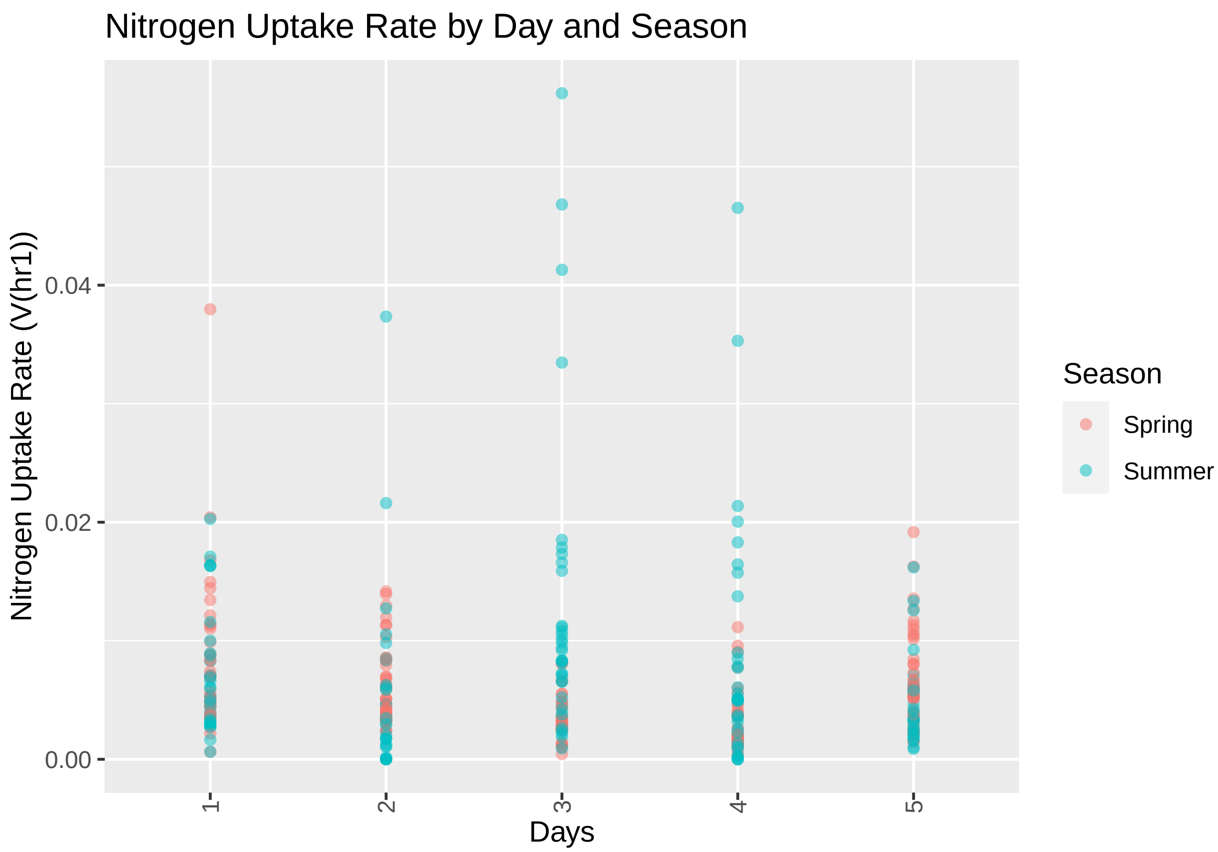


Figure 9: Nitrogen Uptake by Season Scatter Plot

```
##
## Coefficients:
##                                 Estimate Std. Error t value Pr(>|t|)
## (Intercept)                    0.0057806  0.0005195  11.127   <2e-16 ***
## SurgeUptakeNitrogen$SeasonSummer 0.0016387  0.0007336   2.234   0.0261 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.00695 on 357 degrees of freedom
## Multiple R-squared:  0.01378,    Adjusted R-squared:  0.01102
## F-statistic: 4.989 on 1 and 357 DF,  p-value: 0.02612
```

Question 4: Does giant kelp nitrogen surge uptake vary based on the amount of exposure?

H0 : There is no significant difference of nitrogen surge uptake between different exposure lengths. HA : There is significant difference of nitrogen surge uptake between different exposure lengths.

```
#can only put one plot at a time because of figure titles
```

newpage ## Question 5: Does uptake vary by type of nitrogen (ammonium, nitrate, and urea)? H0 : There is no significant difference of nitrogen surge uptake of different nitrogen types. HA : There is significant difference of nitrogen surge uptake between different nitrogen types.

The interaction between nitrogen uptake and season is significant because the p-value is $< .05$ ($p < 2.2e\text{-}16$). We can reject the null hypothesis and accept that there is significant difference of nitrogen surge uptake between spring and summer seasons.. The R-squared is .192, so a moderate amount of nitrogen uptake variance is in response to the nitrogen type being blasted. The box plot below shows the change in nitrogen uptake rate by nitrogen type.

```
# Creating a ggplot to compare uptake of various types of nitrogen

NitrogenUptaketype <-
  ggplot(SurgeUptakeNitrogen, aes(x = Nitrogen_Types, y = Uptake_Rate)) +
  geom_boxplot() +
  labs(title="Uptake Rate by Nitrogen Type", x="Nitrogen Types", y="Nitrogen Uptake Rate (V(hr1))")
print(NitrogenUptaketype)
```

```
ggsave(file=here('Output', 'Analysis','NitrogenUptakeBoxtype.png'), width = 10, height = 10, units = "c
# Creating a ggplot to compare biomass uptake of various types of nitrogen
```

The jitter plot below shows the change in biomass uptake rate by nitrogen type with day replicate added.

```
# Creating a ggplot to compare how nitrogen uptake varies per day per nitrogen type
NitrogenDayUptake <-
  ggplot(SurgeUptakeNitrogen, aes(x = Nitrogen_Types, y = Uptake_Rate, color = Day_Replicate)) +
  geom_jitter(alpha = 0.2) +
  scale_color_manual(values = c("#FF0000", "#BF003F", "#7F007F", "#3F00BF", "#0000FF"))+
  labs(title="Nitrogen Uptake per Day for Each Nitrogen Type",
       x="Nitrogen Types",
       y="Nitrogen Uptake Rate (V(hr1))", color = "Day")

print(NitrogenDayUptake)
```

```
ggsave(file=here('Output', 'Analysis','NitrogenUptakeJitterType.png'), width = 10, height = 10, units =
```

```
# Generalized Linear Model (GLM)
NitorgenLM <-lm(data = SurgeUptakeNitrogen, Uptake_Rate~Nitrogen_Types)
summary(NitorgenLM)
```

```
##
## Call:
## lm(formula = Uptake_Rate ~ Nitrogen_Types, data = SurgeUptakeNitrogen)
```

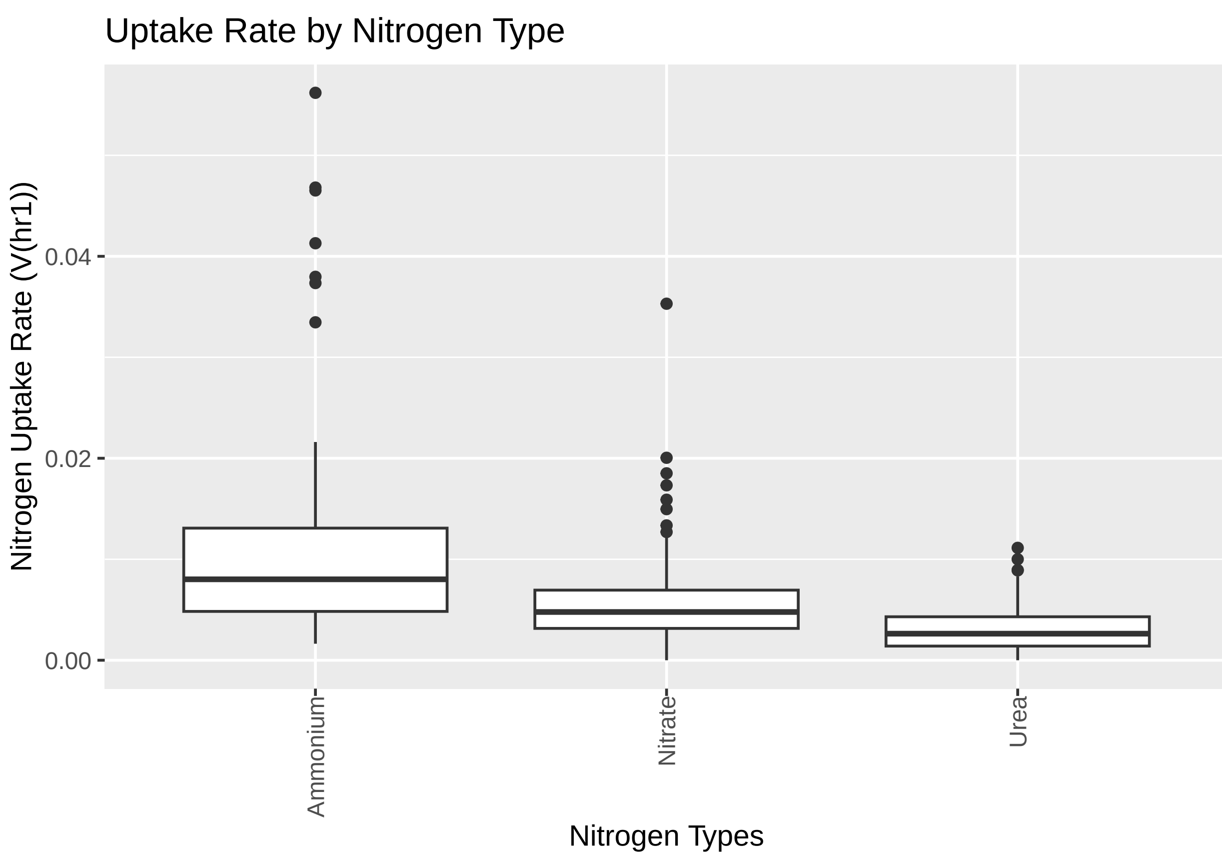


Figure 10: Nitrogen Uptake by Type Box Plot

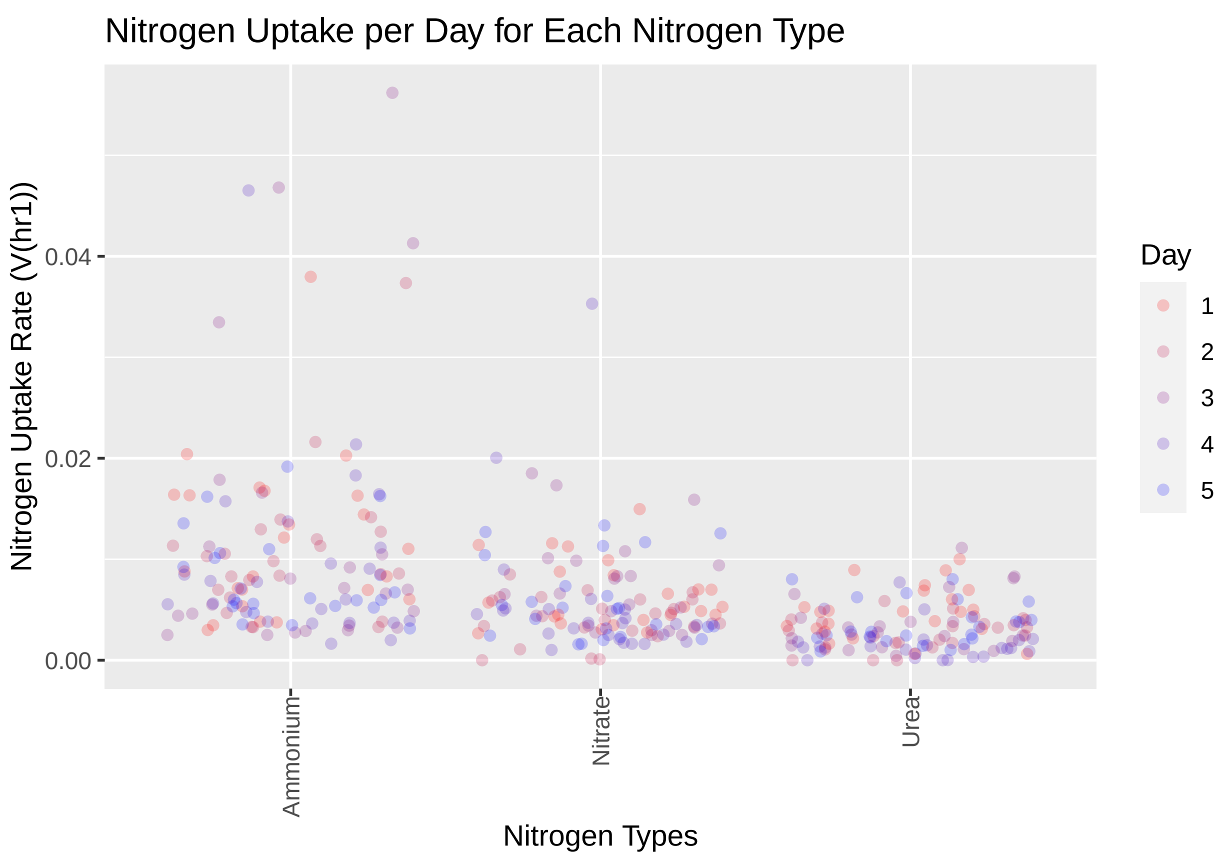


Figure 11: Nitrogen Uptake by Type Jigger Plot

```
##
## Residuals:
##       Min        1Q    Median        3Q       Max
## -0.009010 -0.002975 -0.001082  0.001395  0.045547
##
## Coefficients:
##                         Estimate Std. Error t value Pr(>|t|)
## (Intercept)            0.0106449  0.0005750  18.512  < 2e-16 ***
## Nitrogen_TypesNitrate -0.0047592  0.0008132  -5.852  1.1e-08 ***
## Nitrogen_TypesUrea    -0.0073967  0.0008149  -9.077  < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.006299 on 356 degrees of freedom
## Multiple R-squared:  0.1922, Adjusted R-squared:  0.1877
## F-statistic: 42.36 on 2 and 356 DF,  p-value: < 2.2e-16
```

```
# One-way ANOVA
#NitrogenAOV <- aov(data = SurgeUptakeNitrogen, Uptake_Rate~Nitrogen_Types)
#summary(NitrogenAOV)
#TukeyHSD(NitrogenAOV)

# AIC-based Model Selection:

NitrogenTypeAIC <- lm(data=SurgeUptakeNitrogen, Uptake_Rate~Nitrogen_Types+Season+Time)
step(NitrogenTypeAIC)
```

```
## Start:  AIC=-3667.7
## Uptake_Rate ~ Nitrogen_Types + Season + Time
##
##                  Df Sum of Sq      RSS     AIC
## <none>                        0.012625 -3667.7
## - Season          1 0.0002483 0.012873 -3662.7
## - Time            3 0.0012540 0.013879 -3639.7
## - Nitrogen_Types  2 0.0033740 0.015998 -3586.7
```

```
##
## Call:
## lm(formula = Uptake_Rate ~ Nitrogen_Types + Season + Time, data = SurgeUptakeNitrogen)
##
## Coefficients:
##           (Intercept)  Nitrogen_TypesNitrate     Nitrogen_TypesUrea
##              0.012720              -0.004759              -0.007413
##          SeasonSummer                  Time5                 Time15
##              0.001663              -0.002679              -0.003956
##                Time45
##             -0.004991
```

```
summary(NitrogenTypeAIC)
```

```
##
## Call:
```

```
## lm(formula = Uptake_Rate ~ Nitrogen_Types + Season + Time, data = SurgeUptakeNitrogen)
##
## Residuals:
##       Min        1Q    Median        3Q       Max
## -0.009974 -0.003295 -0.000467  0.001954  0.044488
##
## Coefficients:
##                         Estimate Std. Error t value Pr(>|t|)
## (Intercept)            0.0127198  0.0008351  15.232  < 2e-16 ***
## Nitrogen_TypesNitrate -0.0047592  0.0007731  -6.156 2.04e-09 ***
## Nitrogen_TypesUrea    -0.0074125  0.0007748  -9.567  < 2e-16 ***
## SeasonSummer           0.0016633  0.0006322   2.631  0.00888 **
## Time5                 -0.0026791  0.0008927  -3.001  0.00288 **
## Time15                -0.0039562  0.0008953  -4.419 1.32e-05 ***
## Time45                -0.0049909  0.0008927  -5.590 4.55e-08 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.005989 on 352 degrees of freedom
## Multiple R-squared:  0.278,  Adjusted R-squared:  0.2657
## F-statistic: 22.59 on 6 and 352 DF,  p-value: < 2.2e-16
```

```
# For biomass
#BiomassTypeAIC <- lm(data=SurgeUptakeNitrogen, Biomass_Uptake~Nitrogen_Types+Season+Time)
#step(NitrogenTypeAIC)
#summary(NitrogenTypeAIC)
```

Summary and Conclusions

Akaike information criterion (AIC) was performed for the final three questions to see if those three variables all contributed to the variation of nitrogen uptake. All three variables (season, nitrogen exposure lengths, and nitrogen type), contributed to the variance of nitrogen uptake rate.

What does these pvalues about the first data set tell us about the intro

What does the second set tell us about the intro as well as the data set (aka, more testing needs to be done, was a short experiment) Table 2: Significance Values

Research Question	P-Value
Question 1	$< 2.2e-16$
Question 2	$< 1.16e-4$
Question 3	.0216
Question 4	
Question 5	$< 2.2e-16$

References

Cedeno, T., Brzezinski, M., Miller, R., Reed, D. (2021). Santa Barbara Coastal LTER: Reef: Surge uptake capability in Macrocystis pyrifera in response to pulses of three different forms of nitrogen ver 1. Environmental Data Initiative. https://doi.org/10.6073/pasta/d079ff0e95defb71b87040f56235d755

Conroy, G. (2023). Why Earth's giant kelp forests are worth $500 billion a year. Nature. https://www.nature.com/articles/d41586-023-01307-3

Fernández, P.A., Gaitán-Espitia, J.D., Leal, P.P. et al. (2020). Nitrogen sufficiency enhances thermal tolerance in habitat-forming kelp: implications for acclimation under thermal stress. Scientific Reports 10, 3186.https://doi.org/10.1038/s41598-020-60104-4

Hurlimann, S. (2019, July 4). How kelp naturally combats global climate change. Science in the News.https://sitn.hms.harvard.edu/flash/2019/how-kelp-naturally-combats-global-climate-change/

Legendre, L., Gosselin, M., (1997). Estimation of N or C uptake rates by phytoplankton using 15N or 13C: revisiting the usual computation formulae. Journal of Plankton Research 19, Issue 2, Pages 263–271. https://academic.oup.com/plankt/article/19/2/263/1544362.

Wilson, S. (2019). Fires, floods and free parking: California's unending fight against climate change. The Washington Post. https://www.washingtonpost.com/graphics/2019/national/climate-environment/climate-change-california/

Santa Barbara Coastal LTER, Reed, D., Miller, R. (2021). SBC LTER: Reef: Macrocystis pyrifera CHN content (carbon, hydrogen, nitrogen), ongoing since 2002 ver 21. Environmental Data Initiative. https://doi.org/10.6073/pasta/48686fef076a23310a0e48f69d76260c (Accessed 2023-12-05).