Final Project

ENVIRON 872

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2025-12-05

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2. Dataset Information

The data set was collected through the National Estuarine Research Reserve System's (NERR) National Monitoring Program. NERR was established by the Coastal Zone Management Act and was in paid partnership with National Oceanic and Atmospheric Administration. The data set is public information and meets the quality assurance and quality control protocols of the Estuarine Reserve Division.

We collected the data from the National Estuarine Research Reserve System's Centralized Data Management Office. Specifically, we collected nutrient and water quality data from four stations in North Carolina: East Cribbing, Loosin Creek, Research Creek, and Zeke's Basin.

3. Exploration of Raw Data

Exploration of the raw data consisted of understanding the number of files and contents of those files for each Station. Originally, the water quality data and the nutrient data were separate for each station we are studying. We uploaded all of the files with nutrient and water quality data from the four stations we are studying for the years 2002-2024. We obtained a separate file with information about the stations in which the data was collected.

4. Data Wrangling

After the conclusion of exploring the raw data, we began to wrangle the data by choosing the variables we wished to keep for our study.

For the nutrient data sets we kept:

- Station Code
- Date and Time
- Orthophosphate (PO4F) (mg/L)
- Ammonnium Fluoride (NH4F) (mg/L)
- Nitryl Fluoride (NO2F) (mg/L)
- Fluorine Nitrate (NO3F) (mg/L)
- Nitrate + Nitrate (NO23F) (mg/L)
- Chlorophyll (ug/L)

For the water quality data sets we kept the variables:

- Station Code
- Date and Time
- Temperature (degrees Celsius)
- Salinity (ppt)
- Dissolved Oxygen (%)
- Dissolved Oxygen in milligrams per Liter (mg/L)
- Depth (m)
- pH (standard units)
- Turbidity (NTU)

After cleaning, preparing, and combining all of the files into one data set for nutrients and one data set for water quality, we added the sampling station data to each. This allowed us to create two large data sets which we will use for our study. With so multiple samples taken per day, we decided to get a monthly average of the data since our study focuses on the changes in nutrients and water quality over a 12 year period (2002-2024). Finally, we saved our new completed datasets as new csv files to ensure they were saved properly and could be used in future studies if need be.

5. Exploration of Processed Data

To explore the processed data, we begin our study by exploring the variables and identifying which are correlated and have varied throughout the 12 year period we are studying.

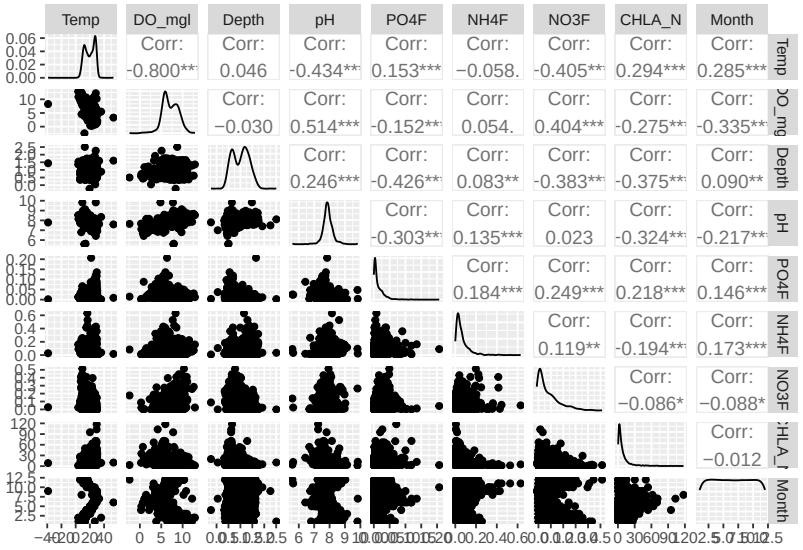


Figure 1: ggpairs

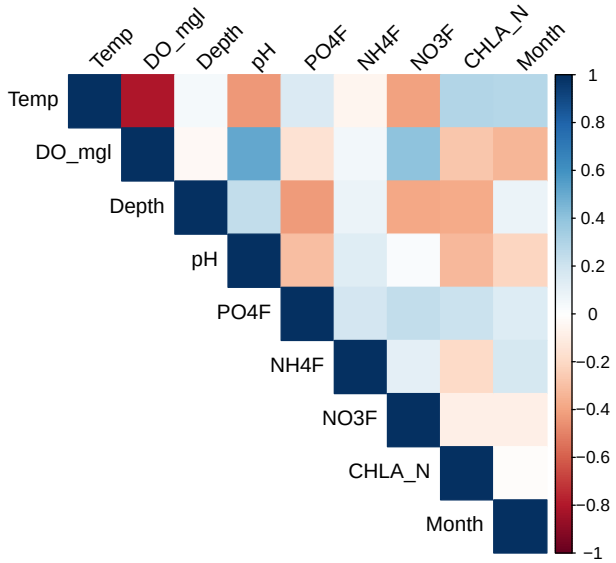


Figure 2: Corrplot

5.1 Dissolved Oxygen

Relationships between different nutrients is important to understand water quality and ecosystem health, so we will look at the different variables and see how they relate to each other based on our initial comparison. We're most interested in dissolved oxygen across the four monitoring stations. We will start with seeing how the other variables relate to dissolved oxygen. Is there consistent data for us to analyze? Could we identify trends over time?

Although plotting dissolved oxygen is helpful for seeing consistent patterns and concentrations across all four stations, let's look at them separately to see gaps and data coverage.

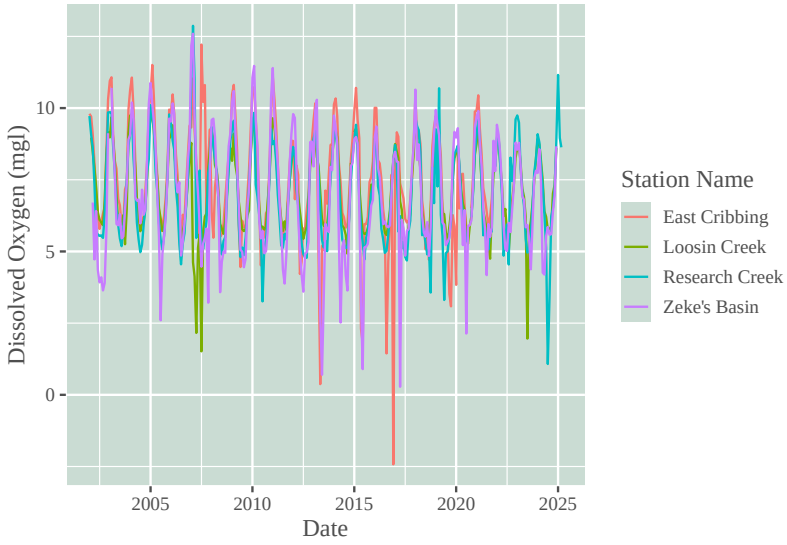


Figure 3: Dissolved oxygen over time for each station

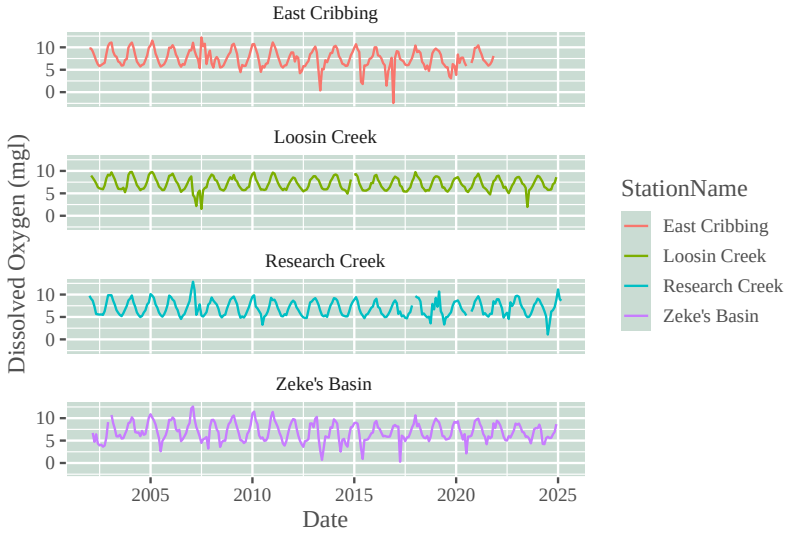


Figure 4: Dissolved oxygen over time for each station separately

It is important to note that the East Cribbing's data seems to end by 2022.

It seems that there's variation in dissolved oxygen across the year. What do the monthly spreads look like?

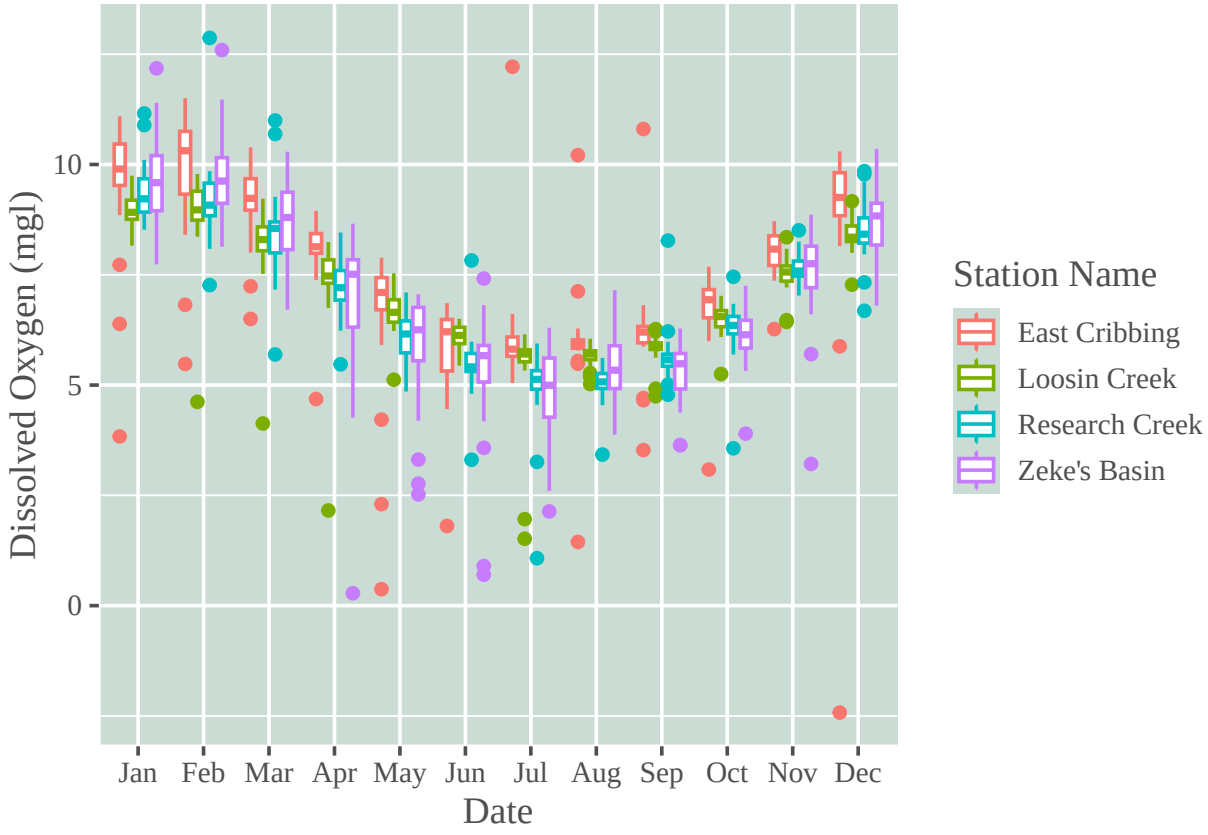


Figure 5: Dissolved oxygen monthly averages at each monitoring station

Now we want to look at how dissolved oxygen relates to the other variables.

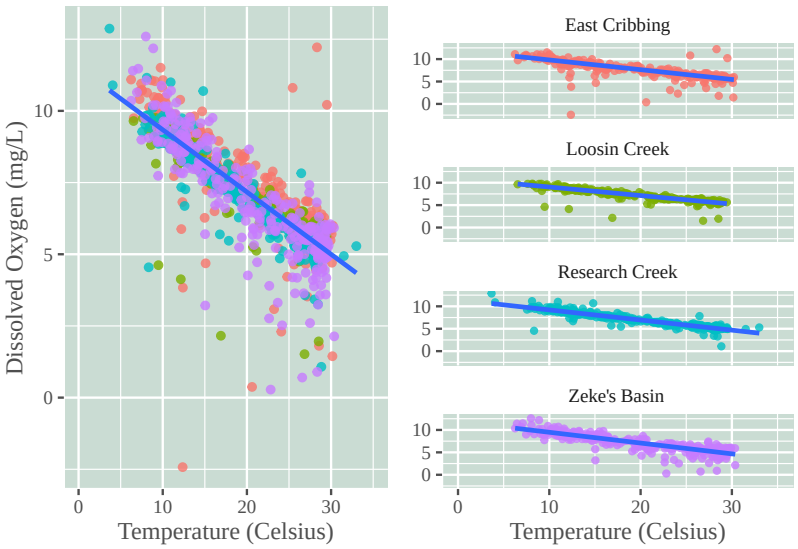


Figure 6: Relationship between temperature and dissolved oxygen

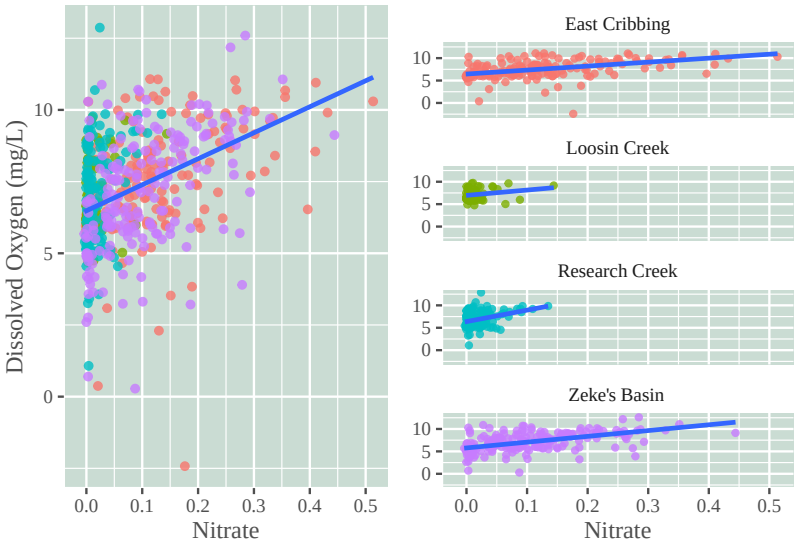


Figure 7: Relationship between nitrate and dissolved oxygen

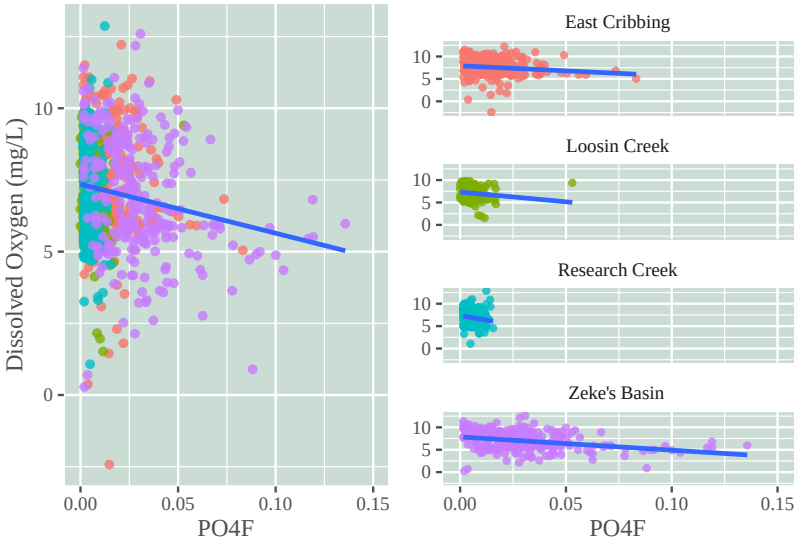


Figure 8: Relationship between phosphate and dissolved oxygen

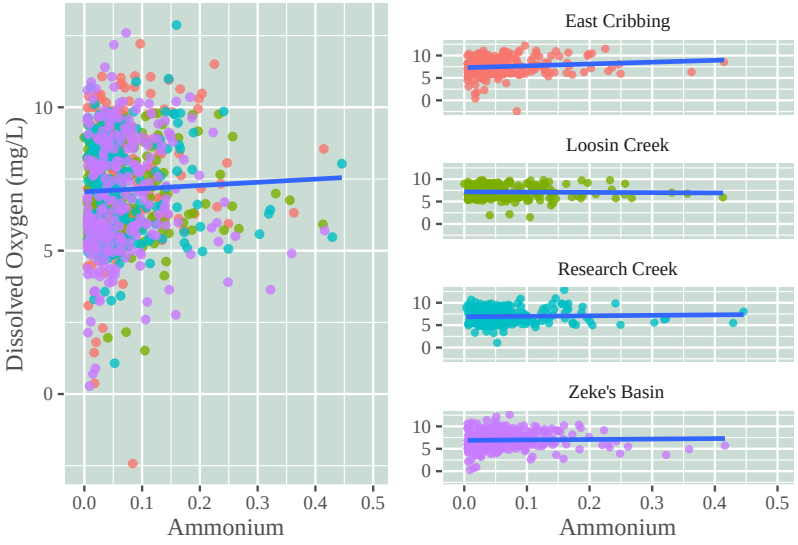


Figure 9: Relationship between Ammonium and dissolved oxygen

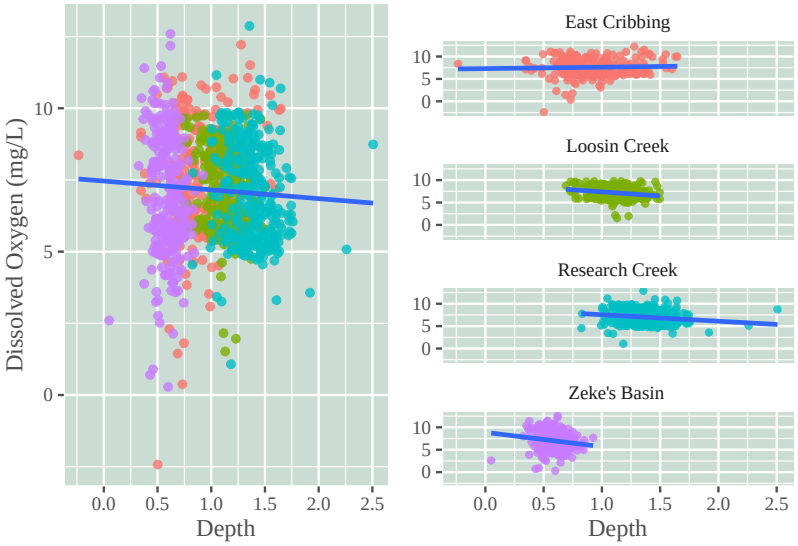


Figure 10: Relationship between depth and dissolved oxygen

5.2 Chlorophyll

The other variable we are interested in is chlorophyll. Chlorophyll is essential in many aquatic ecosystems as it is crucial for photosynthesis, is an indicator for algal blooms, and supports food chains.

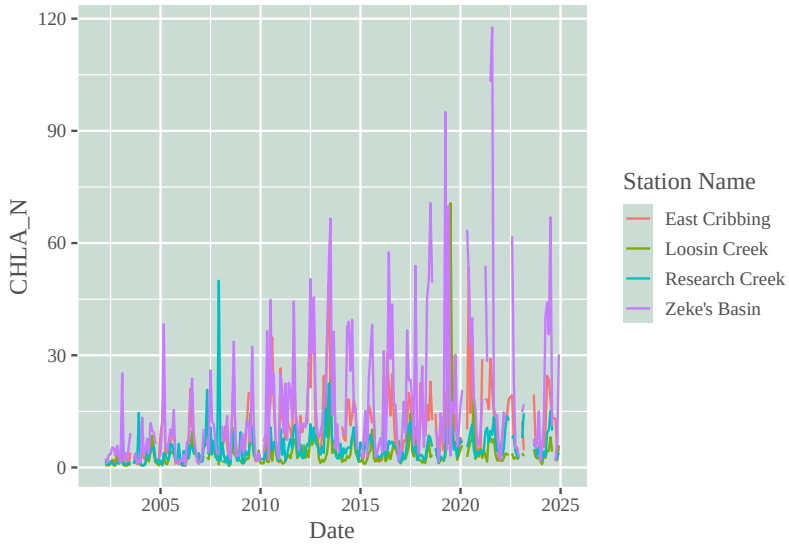


Figure 11: Chlorophyll concentrations from 2002-2024

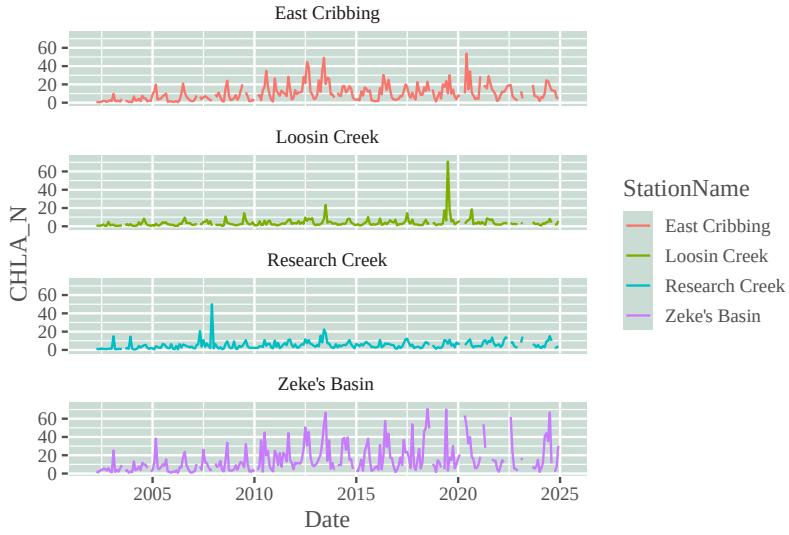


Figure 12: Chlorophyll concentrations from 2002-2024 for each monitoring station

Although plotting Chlorophyll is helpful for seeing consistent patterns and concentrations across all four stations, let's look at them separately to see gaps and data coverage.

Loosin Creek and Research Creek seem to have less fluctuation in their Chlorophyll than East Cribbbing and Zeke's Basin. Could it do with differences in depth or other variables?

It seems that there's variation in chlorophyll across the year. What do the monthly spreads look like?

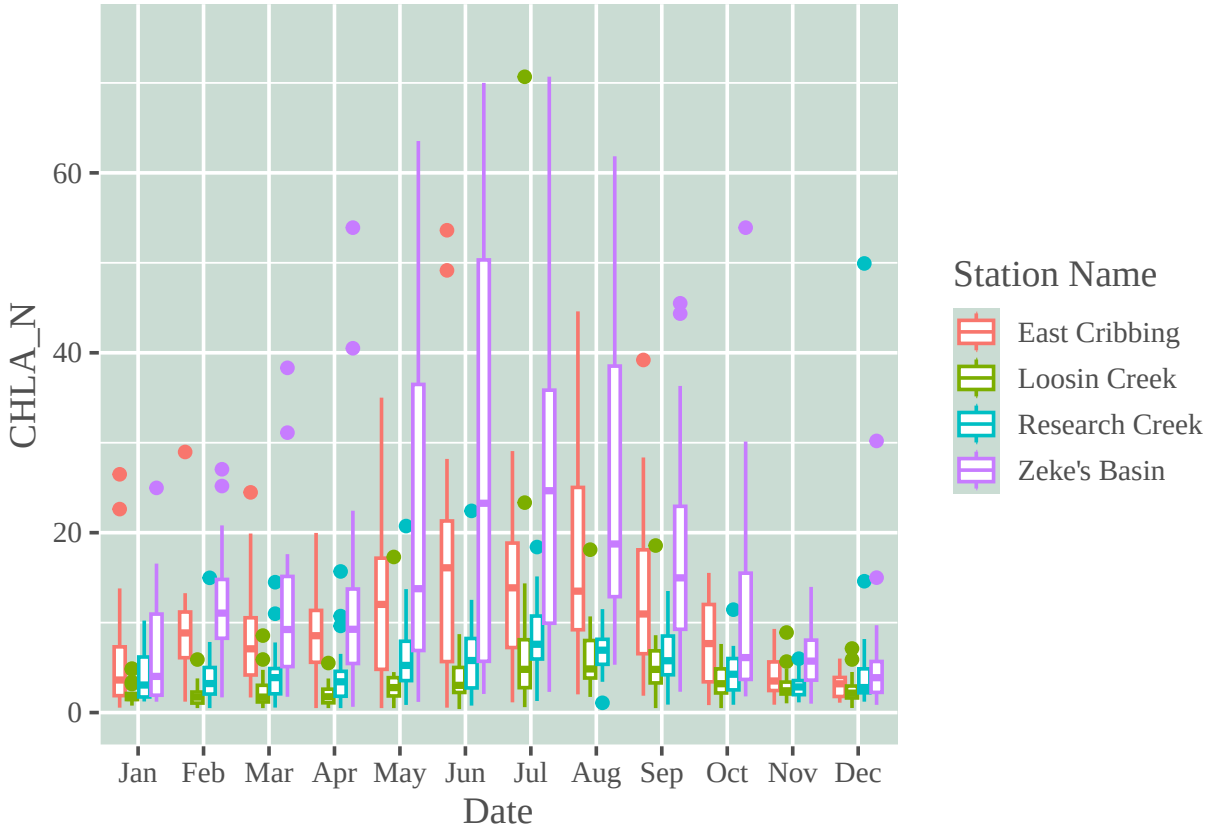


Figure 13: Chlorophyll monthly concentrations

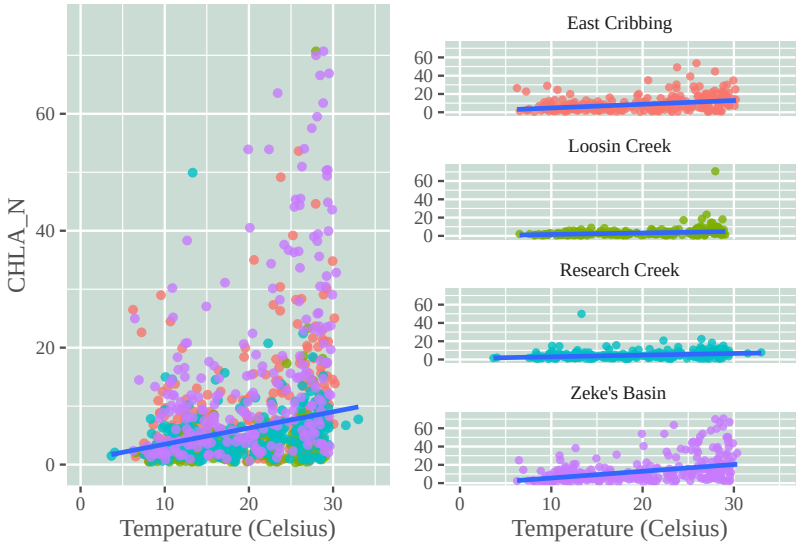


Figure 14: Relationship between temperature and chlorophyll

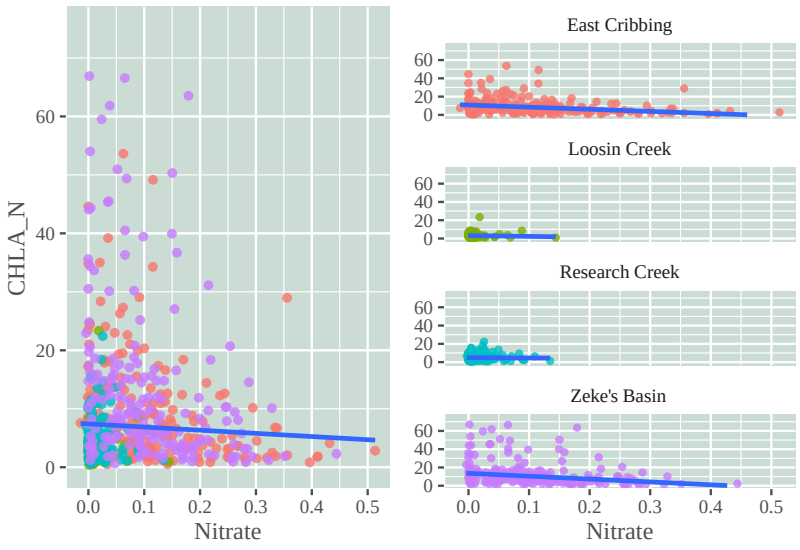


Figure 15: Relationship between nitrate and chlorophyll

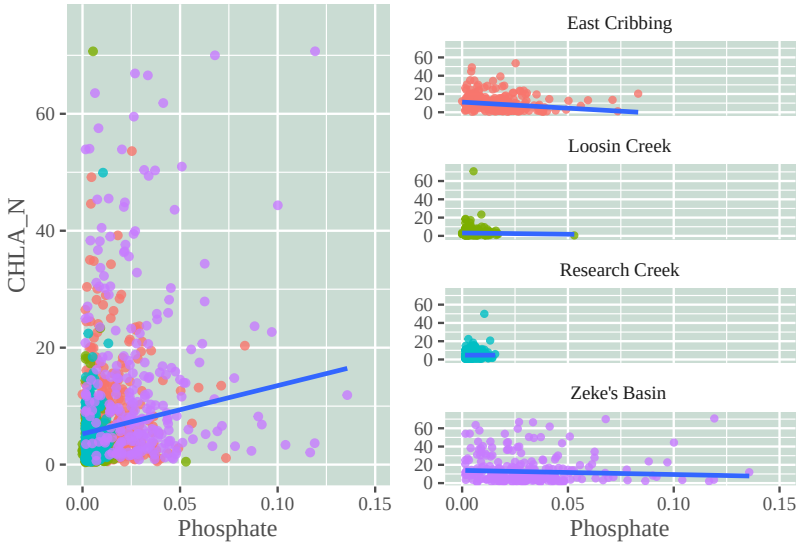


Figure 16: Relationship between phosphate and chlorophyll

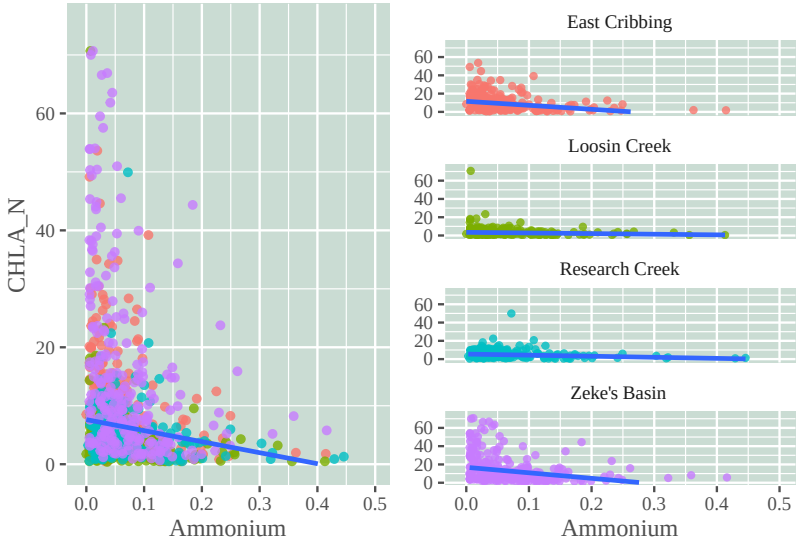


Figure 17: Relationship between ammonium and chlorophyll

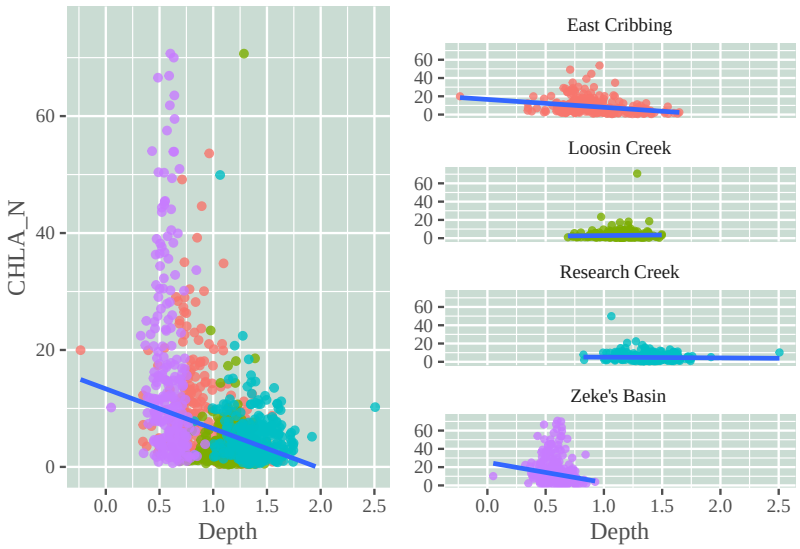


Figure 18: Relationship between depth and chlorophyll

Now to see if there is a relationship between the two variables we care the most about:

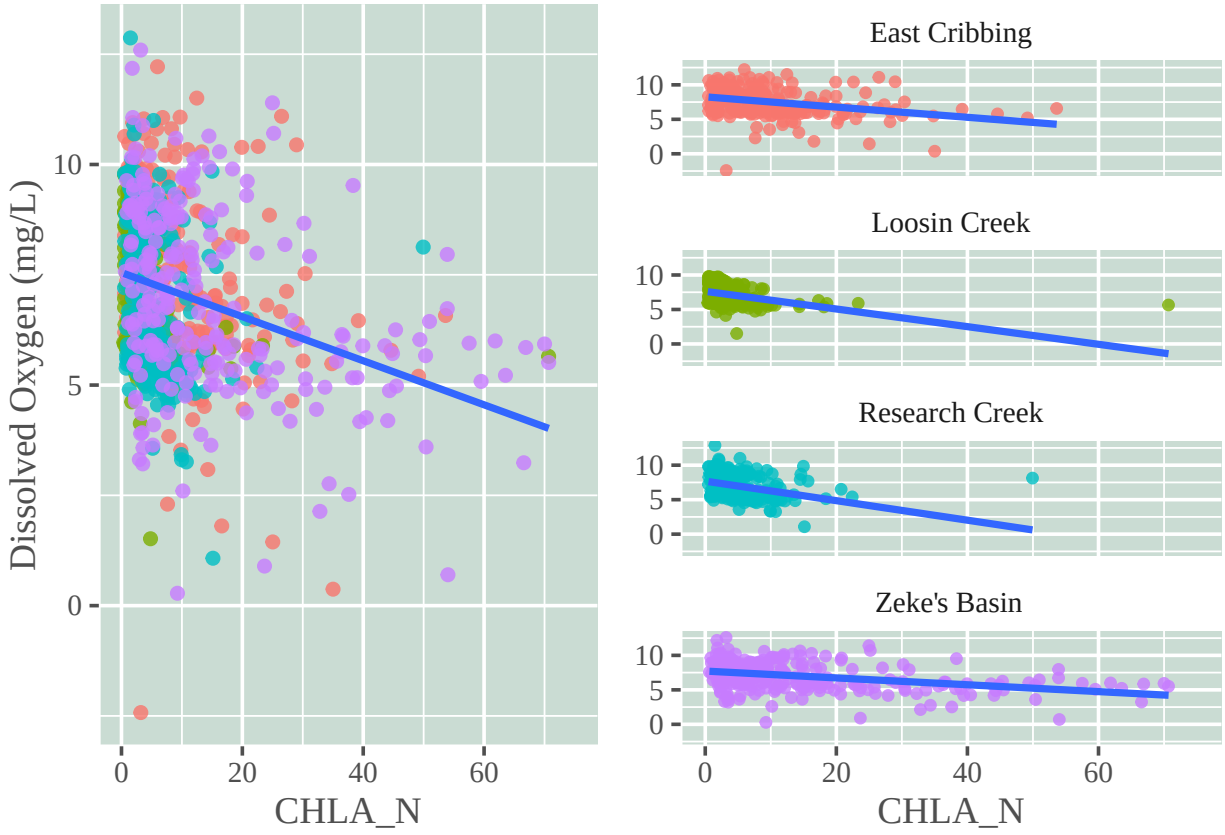


Figure 19: Relationship between dissolved oxygen and chlorophyll

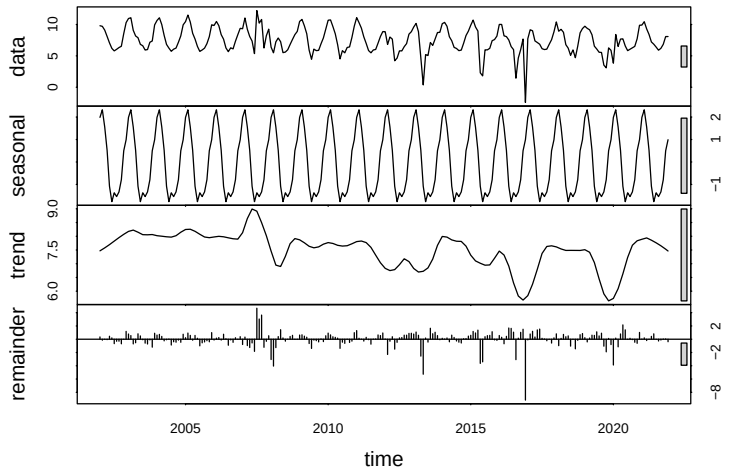
6. Analysis

We want to do two main things: 1) Identify if there is a trend in decreasing dissolved oxygen and increasing chlorophyll across time, and 2) identify the variables most strongly correlated with possible changes.

First, we must turn dissolved oxygen into a time series across each station.

6.1 Time Series Trend Analysis

East Cribbing

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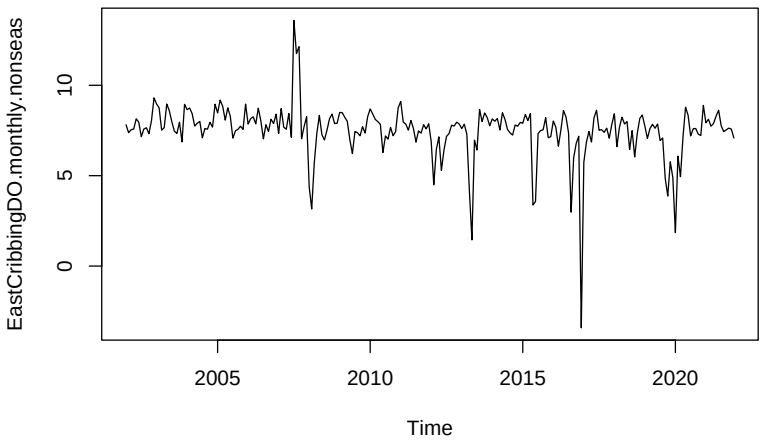
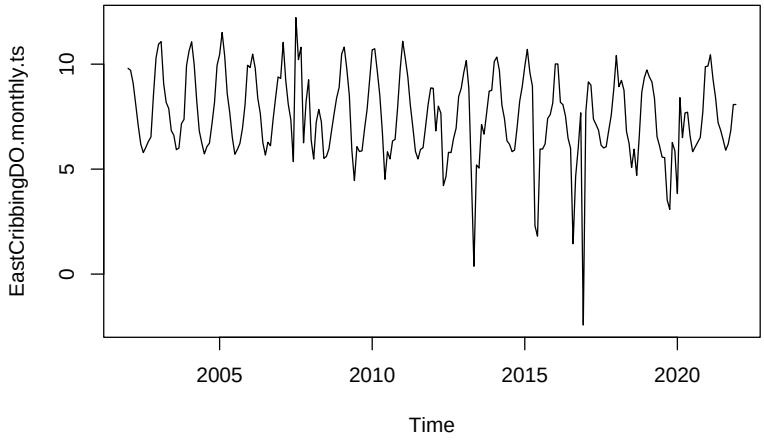
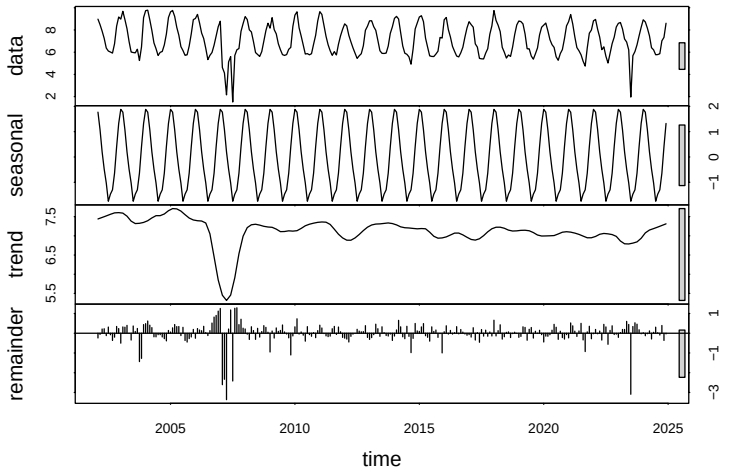
## Score =  -456 , Var(Score) = 11400
## denominator =  2280
## tau = -0.2, 2-sided pvalue =1.9475e-05
```



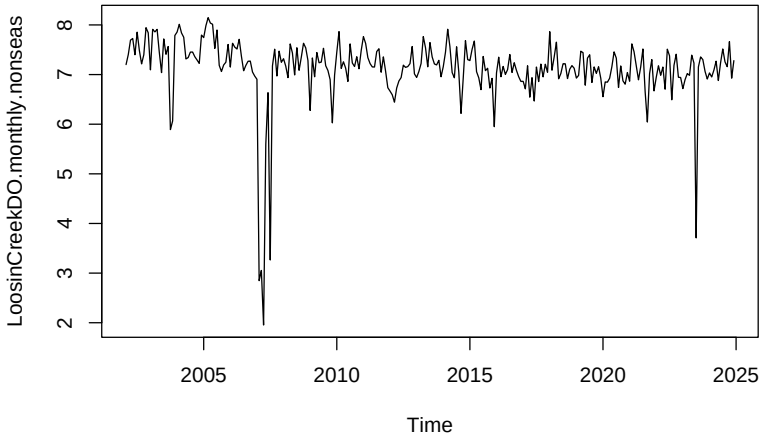


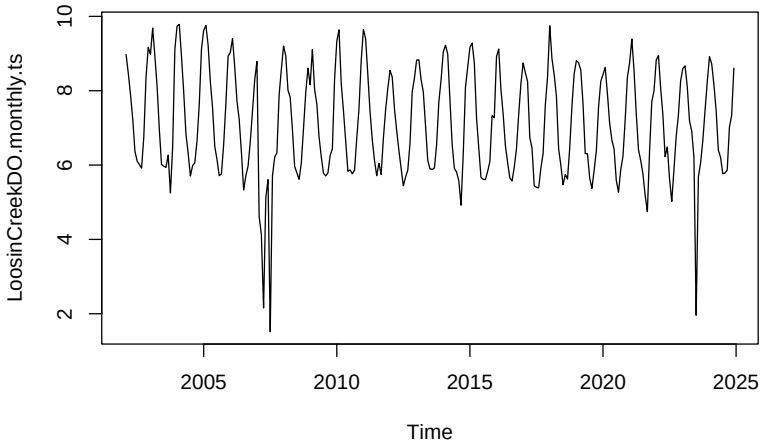

```
##
##  Mann-Kendall trend test
##
## data:  EastCribbingDO.monthly.nonseas
## z = -3.9037, n = 240, p-value = 9.475e-05
## alternative hypothesis: true S is not equal to 0
## sample estimates:
##             S          varS           tau
## -4.854000e+03  1.545533e+06 -1.692469e-01
```

Loosin Creek



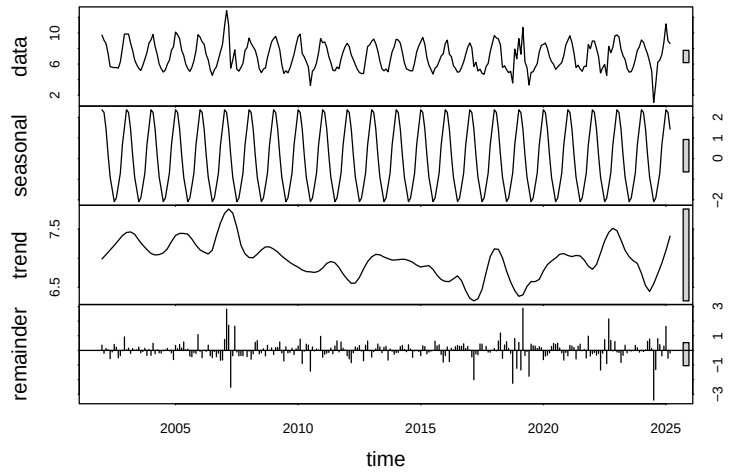

```
## Score =  -824 , Var(Score) = 17028
## denominator =  3014
## tau = -0.273, 2-sided pvalue =2.7087e-10
```



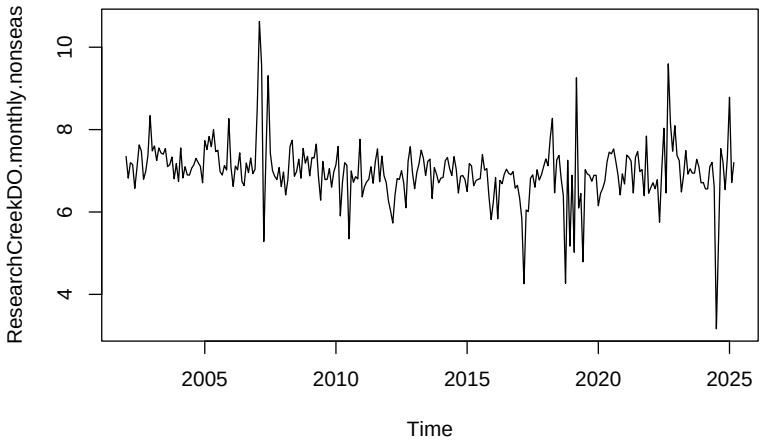


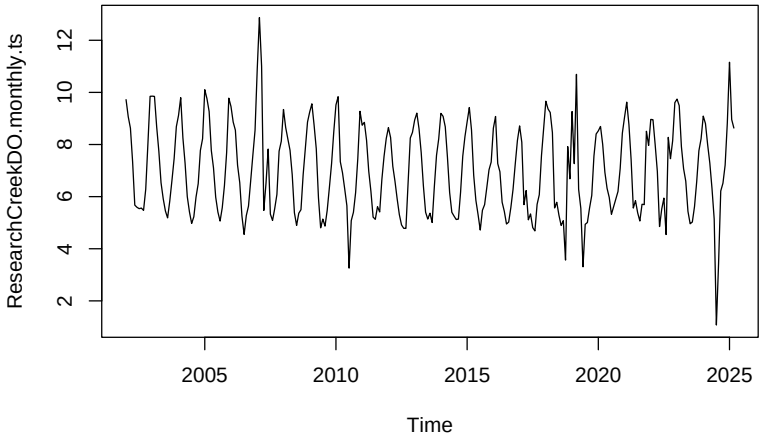

```
##
##  Mann-Kendall trend test
##
## data:  LoosinCreekDO.monthly.nonseas
## z = -6.0621, n = 275, p-value = 1.344e-09
## alternative hypothesis: true S is not equal to 0
## sample estimates:
##             S          varS           tau
## -9.241000e+03  2.323292e+06 -2.452820e-01
```

Research Creek



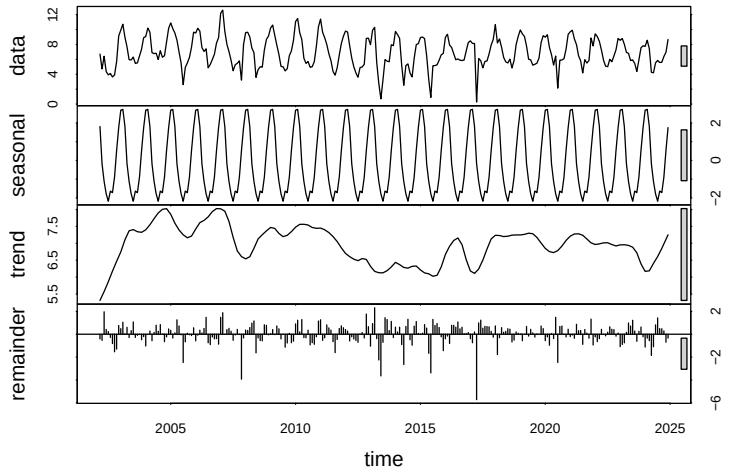

```
## Score =  -513 , Var(Score) = 17779
## denominator =  3105
## tau = -0.165, 2-sided pvalue =0.00011939
```



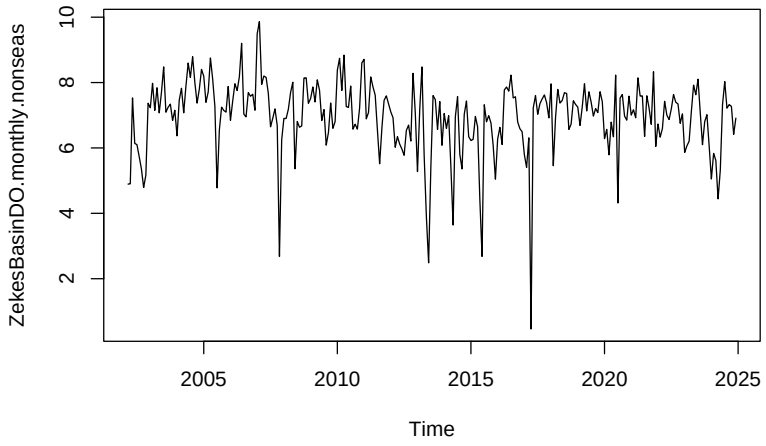


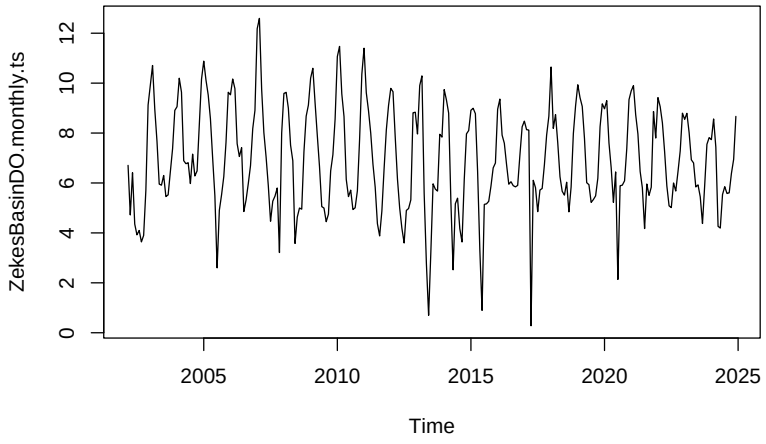

```
##
##  Mann-Kendall trend test
##
## data:  ResearchCreekDO.monthly.nonseas
## z = -3.8702, n = 279, p-value = 0.0001088
## alternative hypothesis: true S is not equal to 0
## sample estimates:
##             S          varS           tau
## -6.029000e+03  2.425967e+06 -1.554627e-01
```

Zeke's Basin




```
## Score =  -388 , Var(Score) = 16852
## denominator =  2992
## tau = -0.13, 2-sided pvalue =0.0028002
```



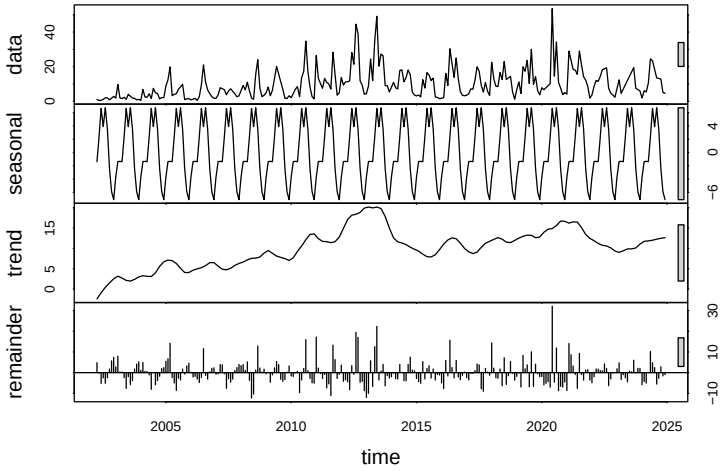



```
##
##  Mann-Kendall trend test
##
## data:  ZekesBasinDO.monthly.nonseas
## z = -2.8985, n = 274, p-value = 0.003749
## alternative hypothesis: true S is not equal to 0
## sample estimates:
##             S          varS           tau
## -4.395000e+03  2.298084e+06 -1.175102e-01
```

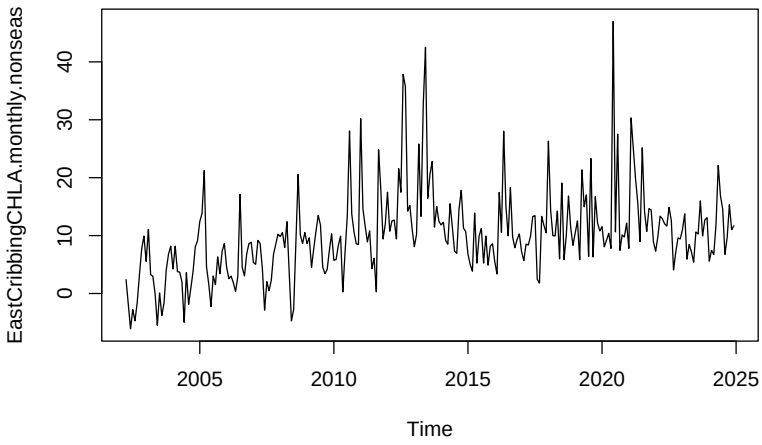
All Monitoring Stations have had statistically significant trends in their Dissolved Oxygen.

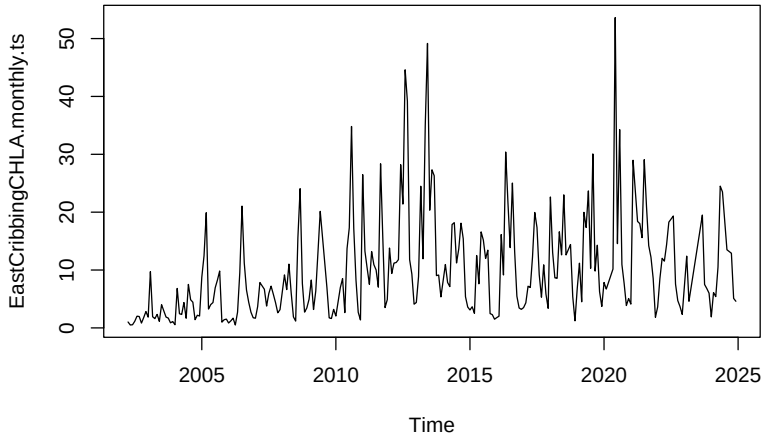
6.2 Significant Variables

East Cribbing



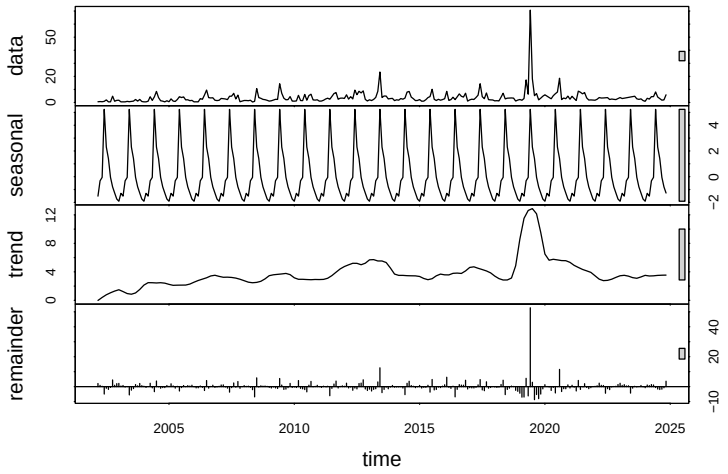

```
## Score =  1074 , Var(Score) = 16676
## denominator =  2970
## tau = 0.362, 2-sided pvalue =< 2.22e-16
```



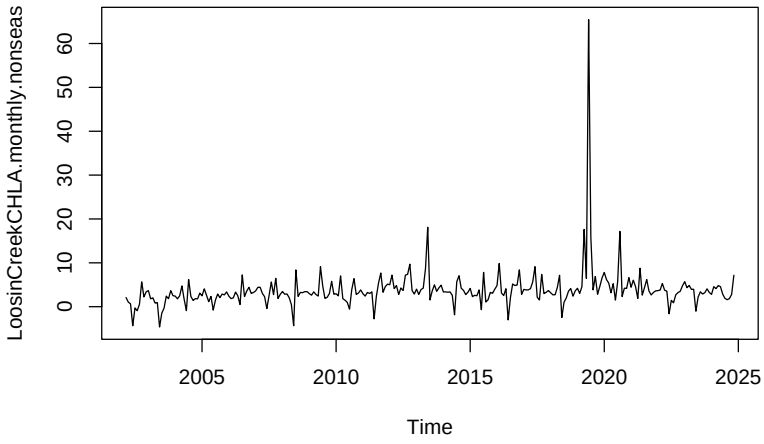


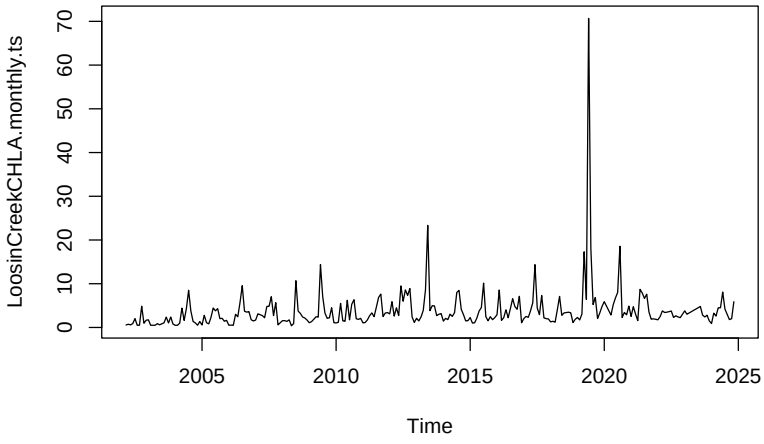

```
##
##  Mann-Kendall trend test
##
## data:  EastCribbingCHLA.monthly.nonseas
## z = 7.8432, n = 273, p-value = 4.39e-15
## alternative hypothesis: true S is not equal to 0
## sample estimates:
##            S         varS          tau
## 1.182600e+04 2.273059e+06 3.185197e-01
```

Loosin Creek



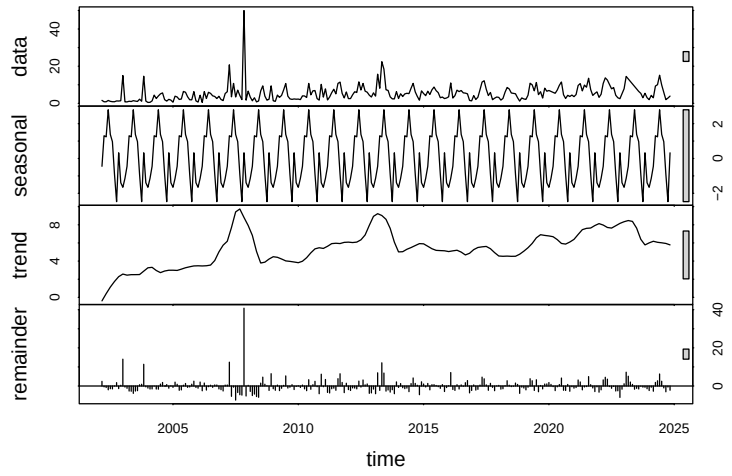

```
## Score =  842 , Var(Score) = 16666
## denominator =  2964.991
## tau = 0.284, 2-sided pvalue =6.9268e-11
```



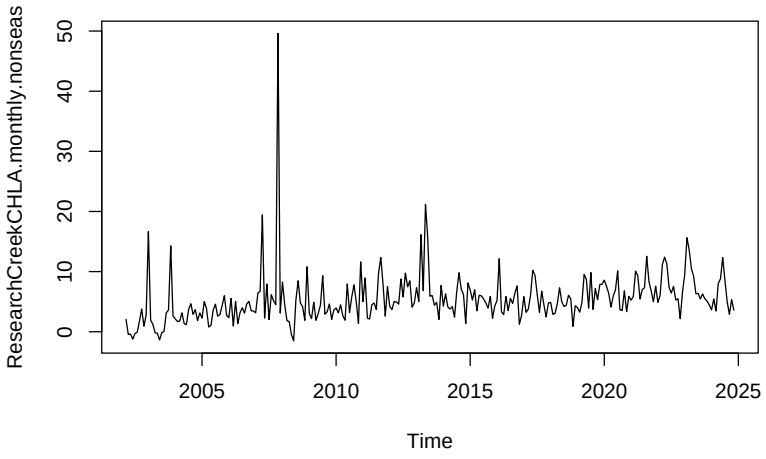


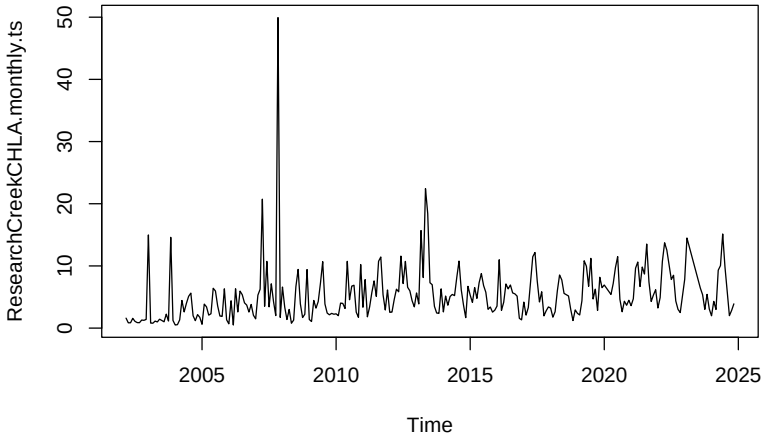

```
##
##  Mann-Kendall trend test
##
## data:  LoosinCreekCHLA.monthly.nonseas
## z = 5.7738, n = 273, p-value = 7.749e-09
## alternative hypothesis: true S is not equal to 0
## sample estimates:
##            S         varS          tau
## 8.706000e+03 2.273049e+06 2.345177e-01
```

Research Creek



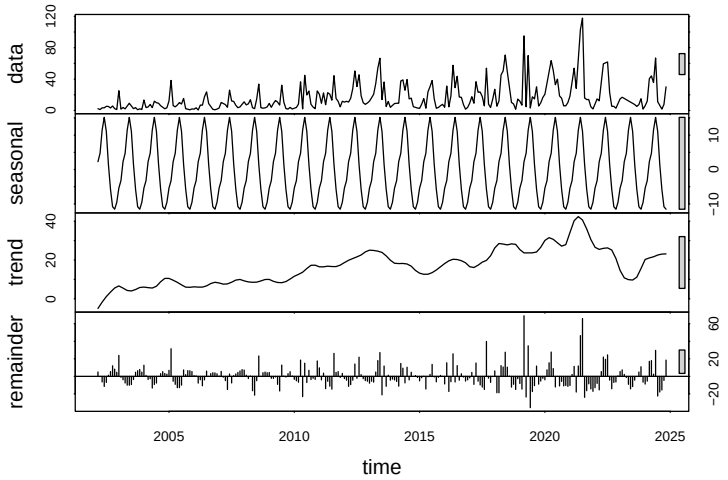

```
## Score =  1140 , Var(Score) = 16676
## denominator =  2970
## tau = 0.384, 2-sided pvalue =< 2.22e-16
```



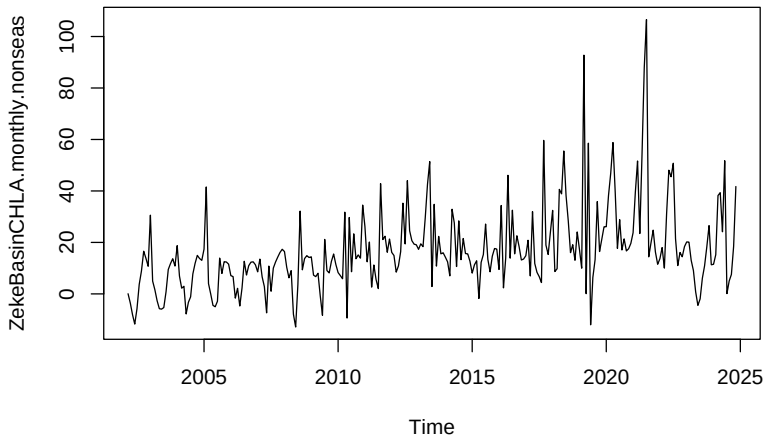


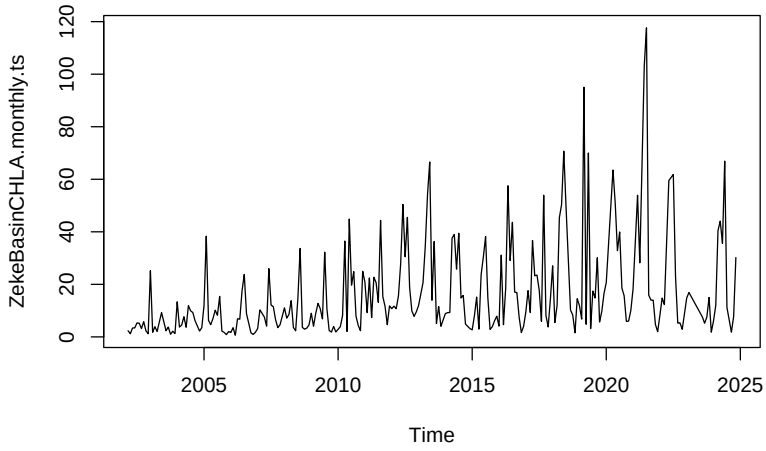

```
##
##  Mann-Kendall trend test
##
## data:  ResearchCreekCHLA.monthly.nonseas
## z = 8.342, n = 273, p-value < 2.2e-16
## alternative hypothesis: true S is not equal to 0
## sample estimates:
##            S         varS          tau
## 1.257800e+04 2.273059e+06 3.387740e-01
```

Zeke's Basin




```
## Score =  1106 , Var(Score) = 16676
## denominator =  2970
## tau = 0.372, 2-sided pvalue =< 2.22e-16
```






```
##
##  Mann-Kendall trend test
##
## data:  ZekeBasinCHLA.monthly.nonseas
## z = 8.0489, n = 273, p-value = 8.357e-16
## alternative hypothesis: true S is not equal to 0
## sample estimates:
##            S         varS          tau
## 1.213600e+04 2.273059e+06 3.268692e-01
```

All of the stations have statistically significant trends in their DO and Chlorophyll levels. So now we ask, which variables are most responsible for these changes?

```
## Start:  AIC=205.96
## DO_mgl ~ Temp + PO4F + NH4F + NO3F
##
```

```
##        Df Sum of Sq     RSS    AIC
## - NH4F  1      0.26  786.60 204.15
## <none>               786.34 205.96
## - PO4F  1      7.53  793.87 209.22
## - NO3F  1     24.34  810.68 220.76
## - Temp  1    791.98 1578.32 587.86
##
## Step:  AIC=204.15
## DO_mgl ~ Temp + PO4F + NO3F
##
##        Df Sum of Sq     RSS    AIC
## <none>               786.60 204.15
## - PO4F  1      7.27  793.87 207.22
## - NO3F  1     24.65  811.25 219.15
## - Temp  1    792.99 1579.59 586.31
```

```
##
## Call:
## lm(formula = DO_mgl ~ Temp + PO4F + NO3F, data = stations_wo_na)
##
## Coefficients:
## (Intercept)         Temp         PO4F         NO3F
##     10.7545      -0.1899      -6.3340       2.6928
```

```
##
## Call:
## lm(formula = DO_mgl ~ Temp + PO4F + NO3F, data = stations_wq_nutr_cleaned)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -11.2111  -0.2374   0.1538   0.5269   2.8577
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept) 10.715193   0.184085  58.208  < 2e-16 ***
## Temp        -0.188493   0.008049 -23.419  < 2e-16 ***
## PO4F        -6.363718   2.812901  -2.262   0.0241 *
## NO3F         2.816014   0.647443   4.349 1.62e-05 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 1.2 on 555 degrees of freedom
##   (541 observations deleted due to missingness)
## Multiple R-squared:  0.6032, Adjusted R-squared:  0.601
## F-statistic: 281.2 on 3 and 555 DF,  p-value: < 2.2e-16
```

```
CHLA.AIC <- lm(data = stations_wo_na, CHLA_N~ Temp + PO4F + NH4F + NO3F)
step(CHLA.AIC)
```

```
## Start:  AIC=2664.49
## CHLA_N ~ Temp + PO4F + NH4F + NO3F
##
##        Df Sum of Sq   RSS    AIC
```

```
## - NO3F  1      90.3 68231 2663.2
## <none>              68140 2664.5
## - PO4F  1     668.0 68808 2667.9
## - NH4F  1    4170.6 72311 2695.2
## - Temp  1    4676.3 72816 2699.1
##
## Step:  AIC=2663.22
## CHLA_N ~ Temp + PO4F + NH4F
##
##        Df Sum of Sq   RSS    AIC
## <none>              68231 2663.2
## - PO4F  1     899.9 69130 2668.4
## - NH4F  1    4120.1 72351 2693.5
## - Temp  1    5150.5 73381 2701.3

##
## Call:
## lm(formula = CHLA_N ~ Temp + PO4F + NH4F, data = stations_wo_na)
##
## Coefficients:
## (Intercept)         Temp         PO4F         NH4F
##      2.5118       0.4324      68.6214     -38.6696
```

```
CHLA.regression <- lm(data = stations_wq_nutr_cleaned, CHLA_N~ Temp + PO4F
                      + NH4F)
summary(CHLA.regression)
```

```
##
## Call:
## lm(formula = CHLA_N ~ Temp + PO4F + NH4F, data = stations_wq_nutr_cleaned)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -33.806  -5.134  -2.478   1.559  94.158
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)   1.19024    1.09055   1.091    0.275
## Temp          0.40908    0.04887   8.371  < 2e-16 ***
## PO4F        146.58494   19.64113   7.463 1.86e-13 ***
## NH4F        -39.84771    5.31967  -7.491 1.53e-13 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 10.85 on 978 degrees of freedom
##   (118 observations deleted due to missingness)
## Multiple R-squared:  0.1661, Adjusted R-squared:  0.1636
## F-statistic: 64.95 on 3 and 978 DF,  p-value: < 2.2e-16
```

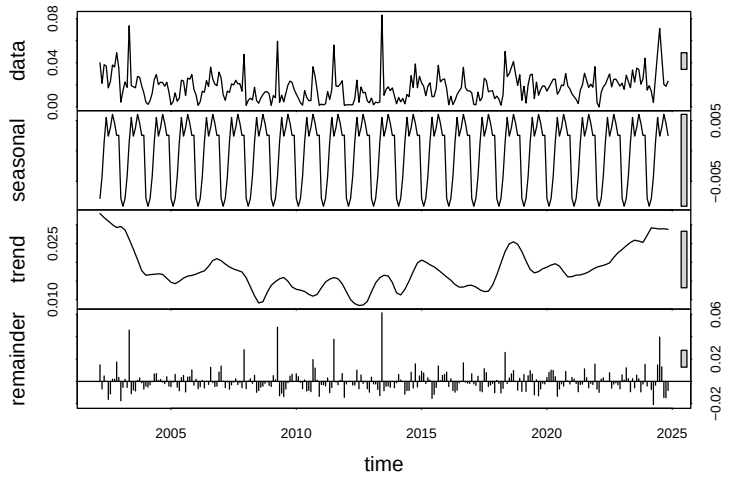
From these multiple regressions we find that temperature, phosphorus, and nitrate are the best variables for predicting DO and temperature, phosphorus, and ammonium are the best variables for predicting Chlorophyll. Both of these relationships are significant, although the R-squared for the Chlorophyll regression is 0.1661 which indicates a weaker correlation.

Temperature is the most impactful variable in both of the models, with PO4 being the least impactful.

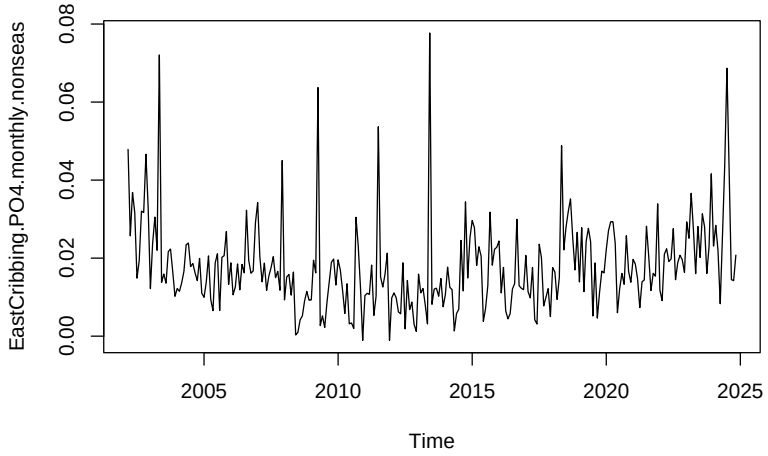
6.3 Second Time Series Analysis

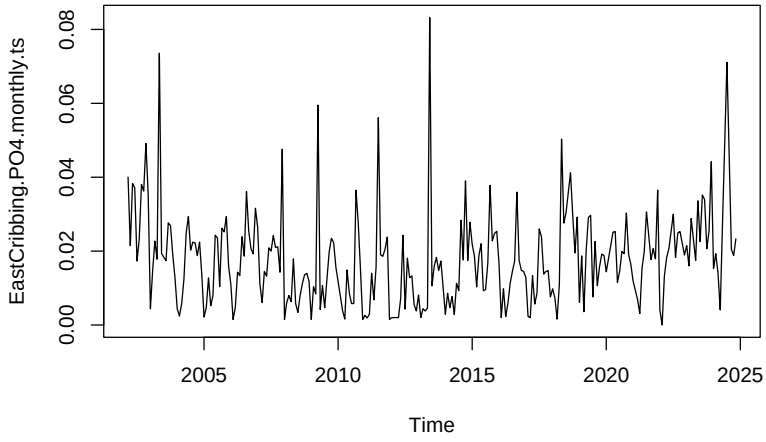
From here, we perform time series analyses on these variables to determine if their trends are in line with what we expect.

Here are the variables for **East Cribbing**.



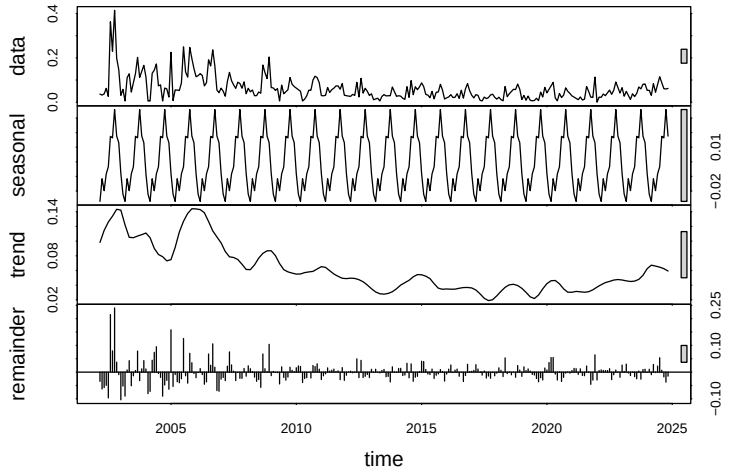

```
## Score =  239 , Var(Score) = 16664.33
## denominator =  2964.485
## tau = 0.0806, 2-sided pvalue =0.06411
```



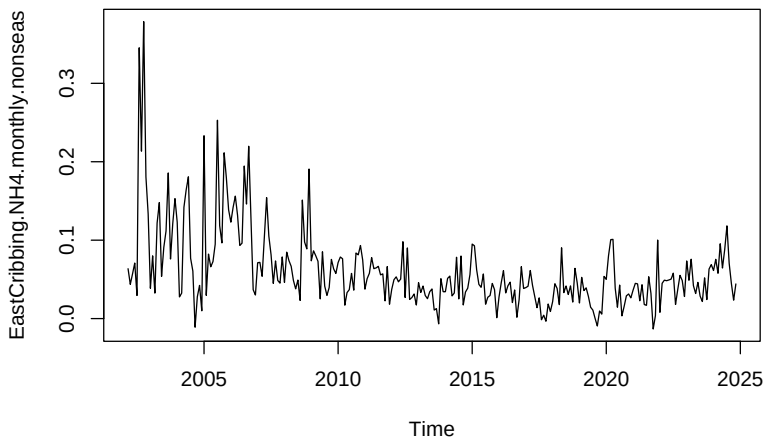


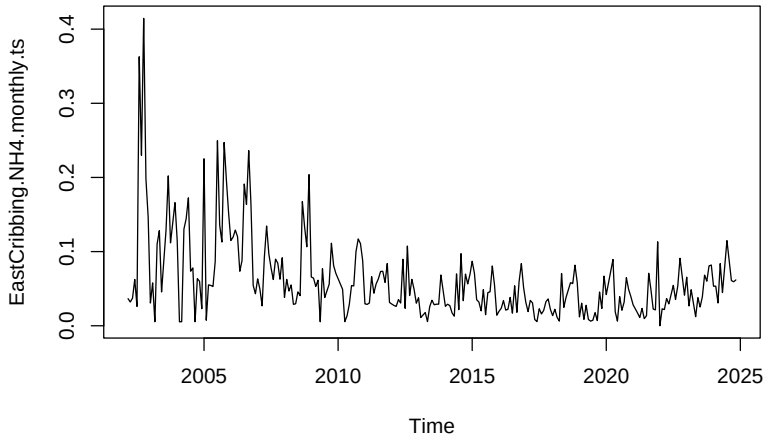

```
##
##  Mann-Kendall trend test
##
## data:  EastCribbing.PO4.monthly.nonseas
## z = 1.7391, n = 273, p-value = 0.08201
## alternative hypothesis: true S is not equal to 0
## sample estimates:
##            S         varS          tau
## 2.623000e+03 2.273047e+06 7.065796e-02
```

Increasing trend of PO4, significant.



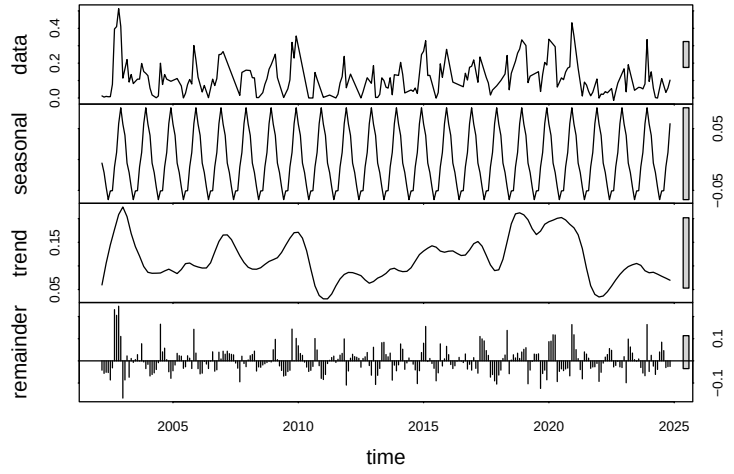

```
## Score =  -901 , Var(Score) = 16671
## denominator =  2967.496
## tau = -0.304, 2-sided pvalue =2.9896e-12
```



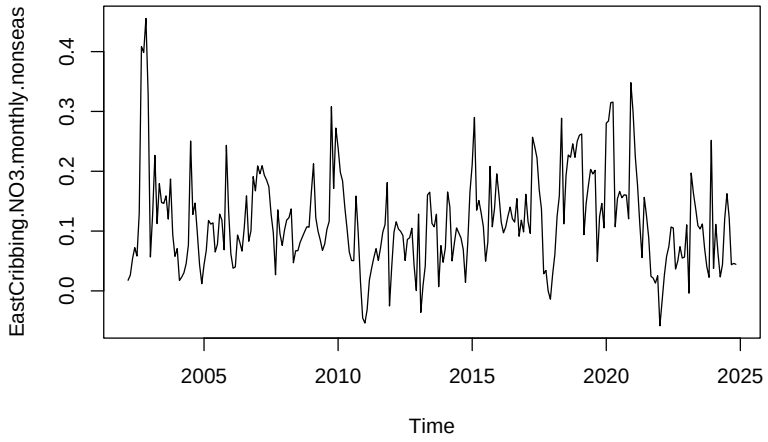


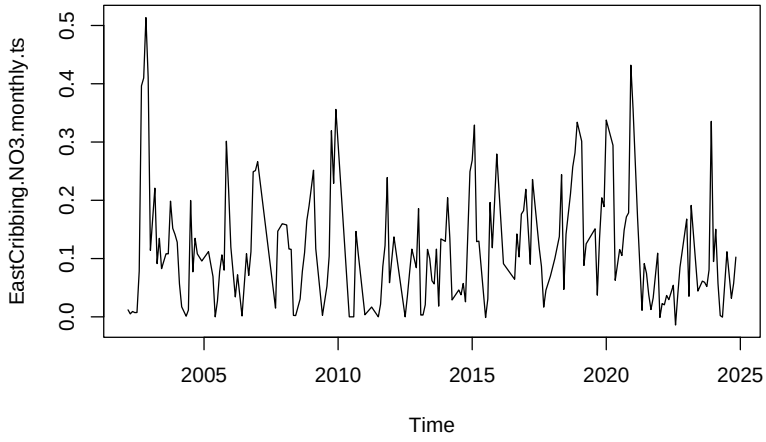

```
##
##  Mann-Kendall trend test
##
## data:  EastCribbing.NH4.monthly.nonseas
## z = -7.4546, n = 273, p-value = 9.016e-14
## alternative hypothesis: true S is not equal to 0
## sample estimates:
##             S          varS           tau
## -1.124000e+04  2.273054e+06 -3.027569e-01
```

Decreasing trend of NH4, significant.



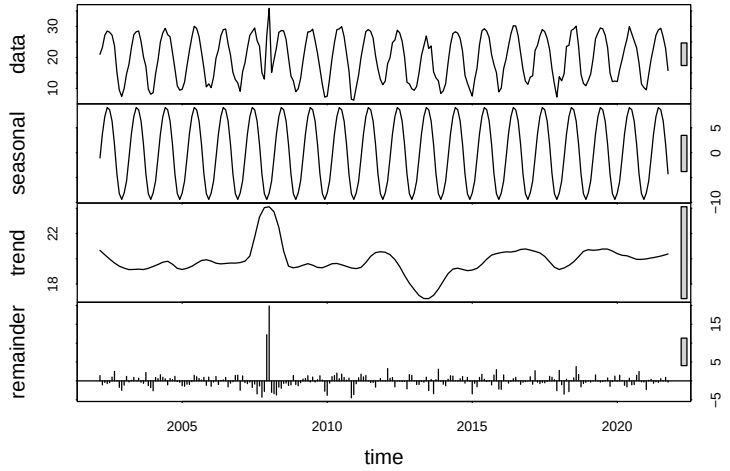

```
## Score =  90 , Var(Score) = 16669.33
## denominator =  2966.994
## tau = 0.0303, 2-sided pvalue =0.48575
```



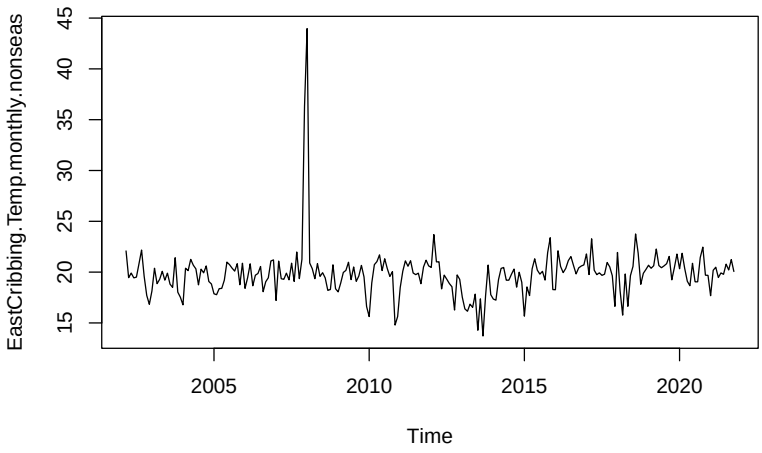


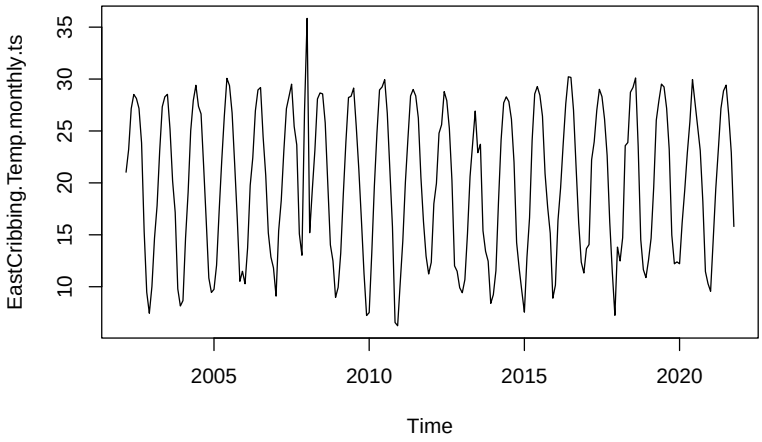

```
##
##  Mann-Kendall trend test
##
## data:  EastCribbing.NO3.monthly.nonseas
## z = 0.45832, n = 273, p-value = 0.6467
## alternative hypothesis: true S is not equal to 0
## sample estimates:
##            S         varS          tau
## 6.920000e+02 2.273052e+06 1.863973e-02
```

Insignificant trend.




```
## Score =  194 , Var(Score) = 10868
## denominator =  2204
## tau = 0.088, 2-sided pvalue =0.062756
```



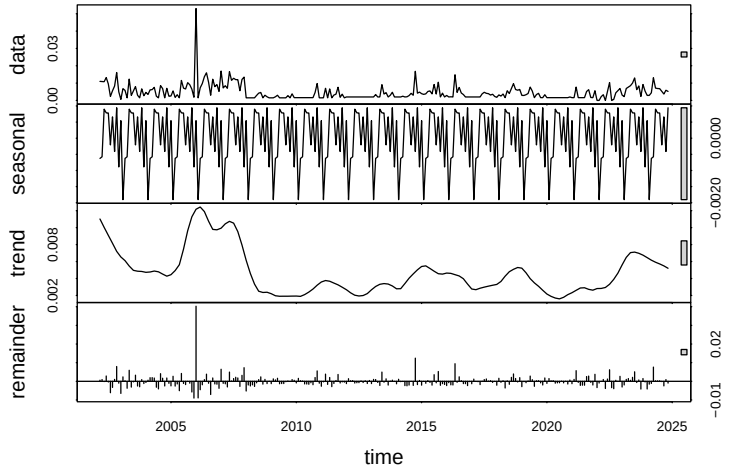



```
##
##  Mann-Kendall trend test
##
## data:  EastCribbing.Temp.monthly.nonseas
## z = 2.0564, n = 236, p-value = 0.03974
## alternative hypothesis: true S is not equal to 0
## sample estimates:
##            S         varS          tau
## 2.494000e+03 1.469690e+06 8.993869e-02
```

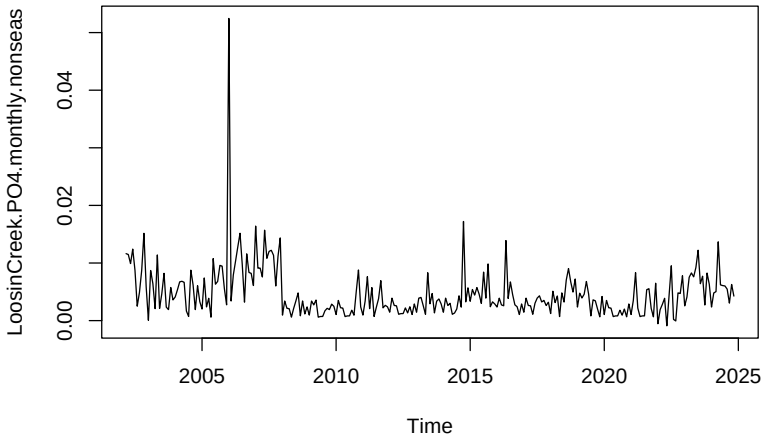
Insignificant trend.

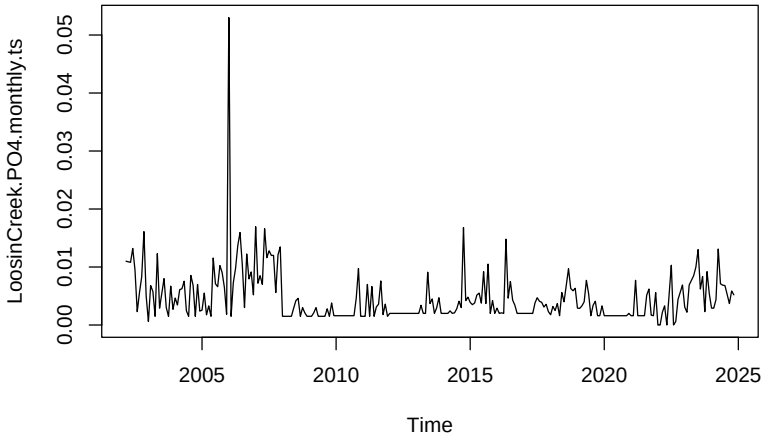
For East Cribbing, PO4 had a significant increasing trend and NH4 has a significant decreasing trend.

Now let's do **Loosin Creek**.



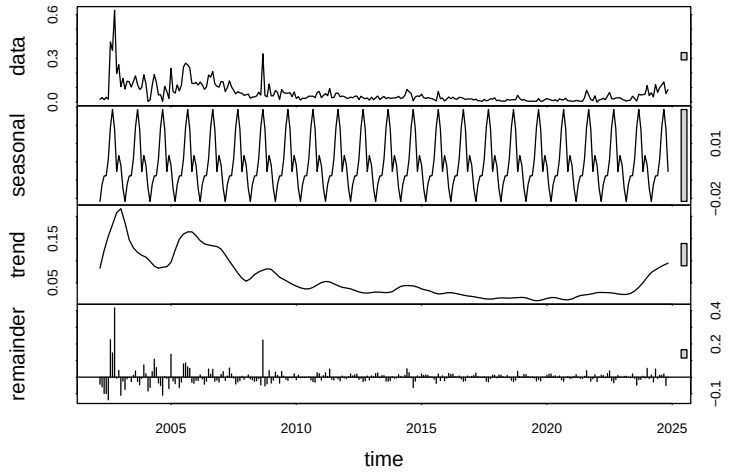

```
## Score =  -139 , Var(Score) = 16529
## denominator =  2914.783
## tau = -0.0477, 2-sided pvalue =0.27962
```



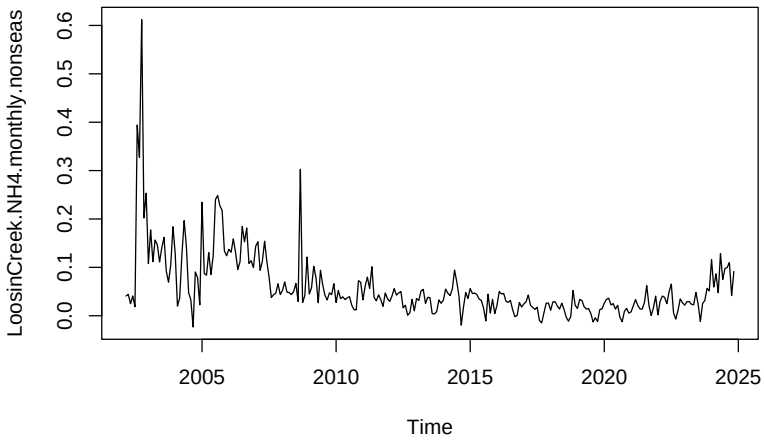


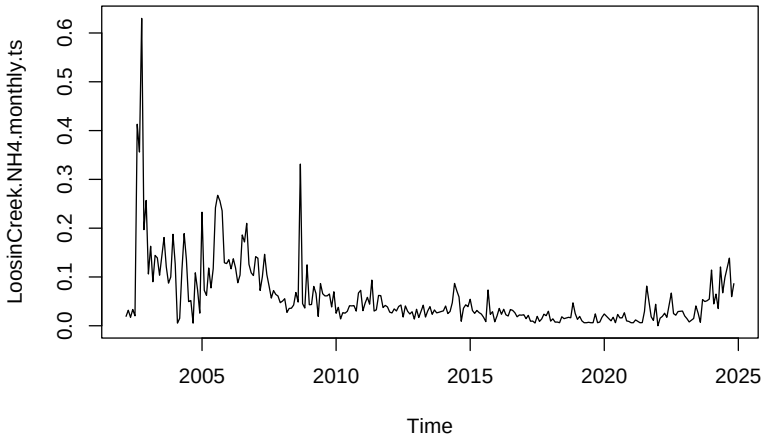

```
##
##  Mann-Kendall trend test
##
## data:  LoosinCreek.PO4.monthly.nonseas
## z = -2.0854, n = 273, p-value = 0.03703
## alternative hypothesis: true S is not equal to 0
## sample estimates:
##             S          varS           tau
## -3.145000e+03  2.272912e+06 -8.483158e-02
```

Non seasonal trend is significantly decreasing.



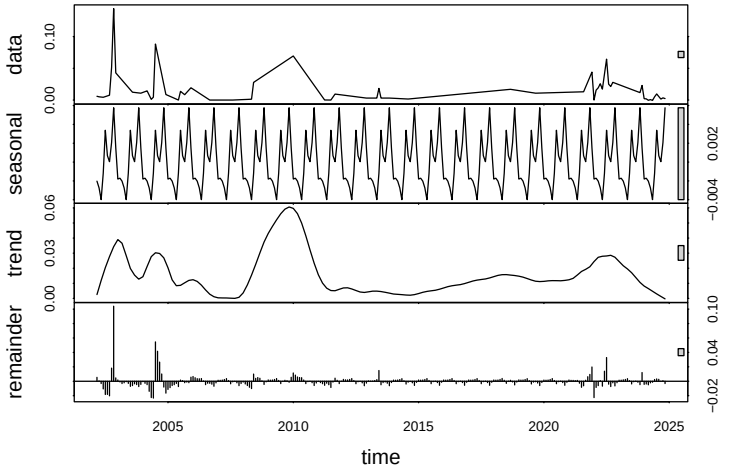

```
## Score =  -1345 , Var(Score) = 16668.33
## denominator =  2966.493
## tau = -0.453, 2-sided pvalue =< 2.22e-16
```



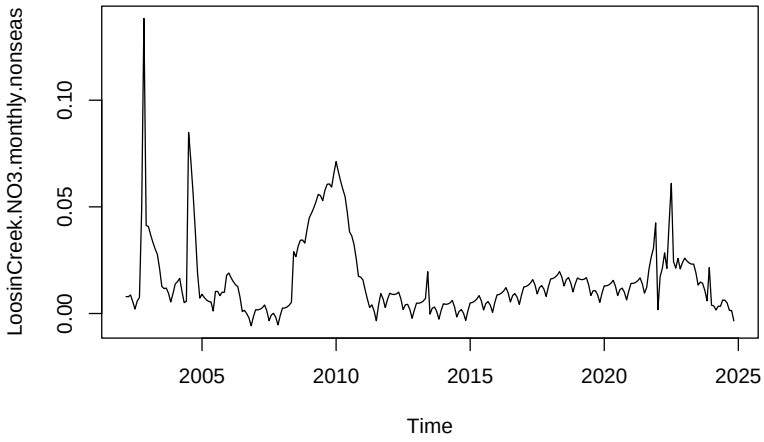


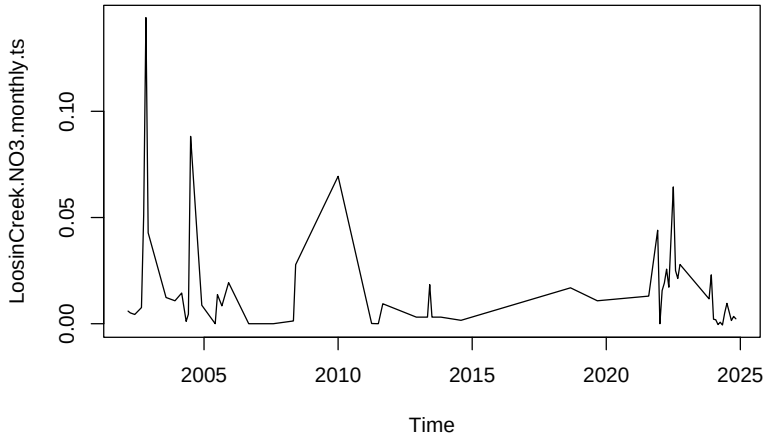

```
##
##  Mann-Kendall trend test
##
## data:  LoosinCreek.NH4.monthly.nonseas
## z = -9.9386, n = 273, p-value < 2.2e-16
## alternative hypothesis: true S is not equal to 0
## sample estimates:
##             S          varS           tau
## -1.498500e+04  2.273051e+06 -4.036418e-01
```

Decreasing trend, significant.



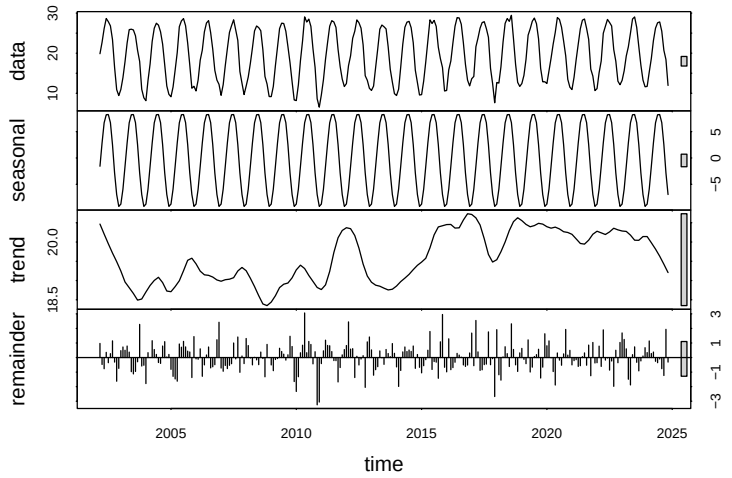

```
## Score =  255 , Var(Score) = 16673
## denominator =  2968.498
## tau = 0.0859, 2-sided pvalue =0.048286
```



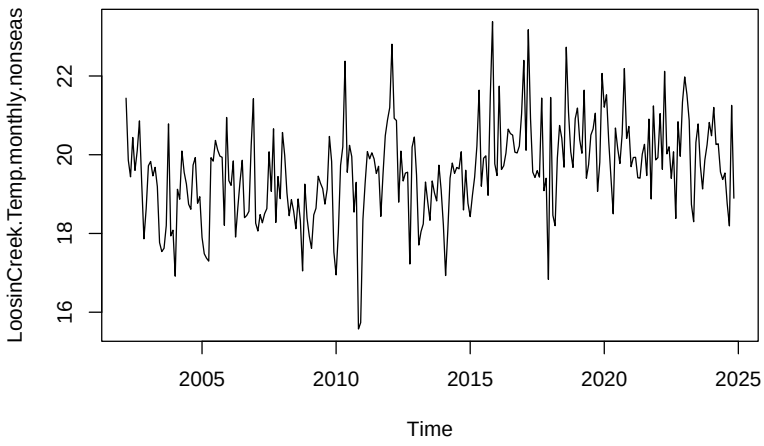


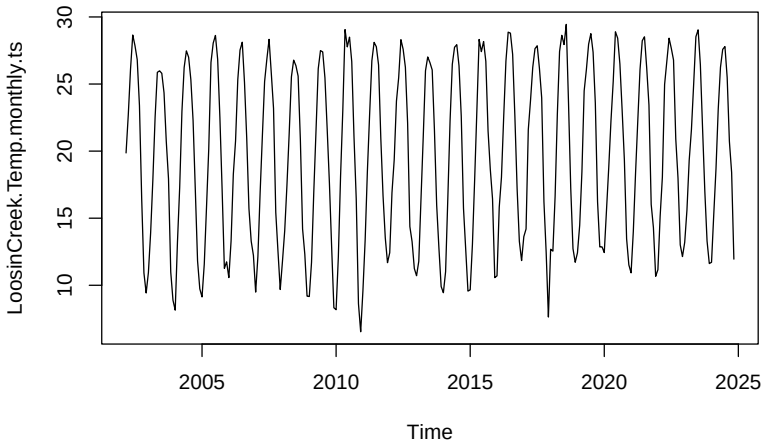

```
##
##  Mann-Kendall trend test
##
## data:  LoosinCreek.NO3.monthly.nonseas
## z = 1.3159, n = 273, p-value = 0.1882
## alternative hypothesis: true S is not equal to 0
## sample estimates:
##            S         varS          tau
## 1.985000e+03 2.273056e+06 5.346585e-02
```

Seaonsal trend is significantly decreasing ?




```
## Score =  784 , Var(Score) = 16676
## denominator =  2970
## tau = 0.264, 2-sided pvalue =1.2701e-09
```



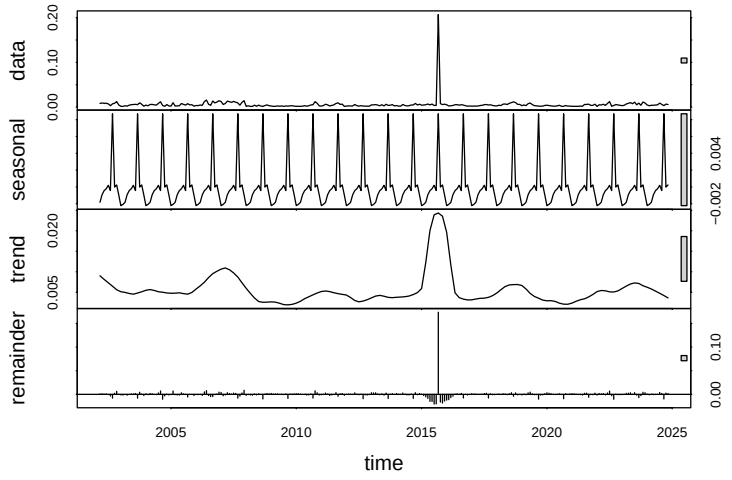



```
##
##  Mann-Kendall trend test
##
## data:  LoosinCreek.Temp.monthly.nonseas
## z = 6.2819, n = 273, p-value = 3.345e-10
## alternative hypothesis: true S is not equal to 0
## sample estimates:
##            S         varS          tau
## 9.472000e+03 2.273059e+06 2.551174e-01
```

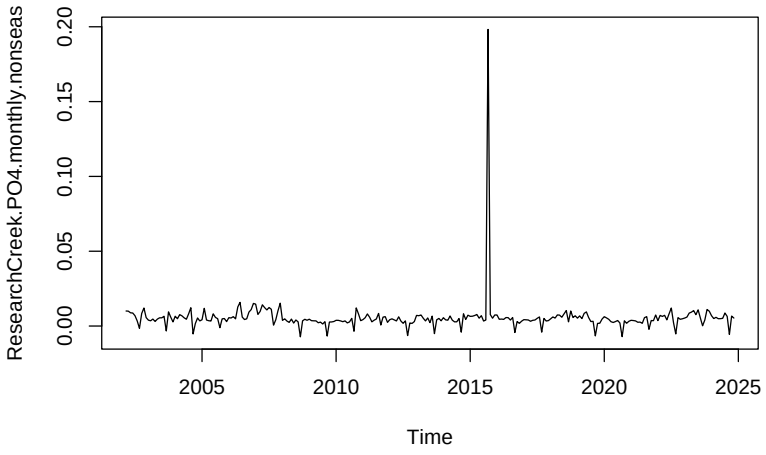
Significantly increasing.

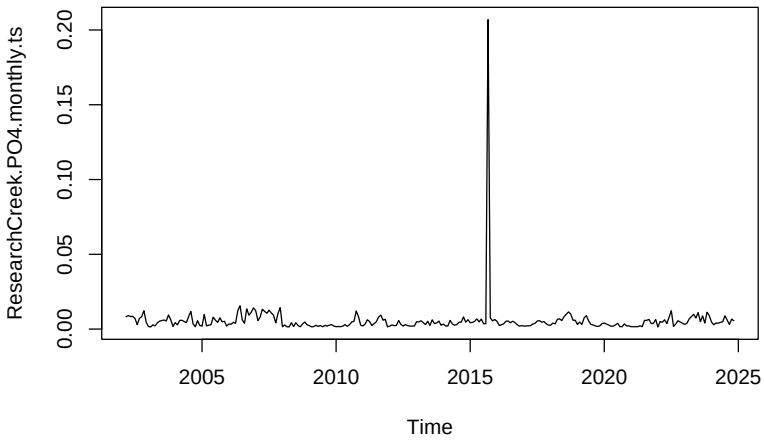
For Loosin's Creek, NH4 showed a significant downward trend and temperature showed a significant upward trend.

Next, let's do **Research Creek**.



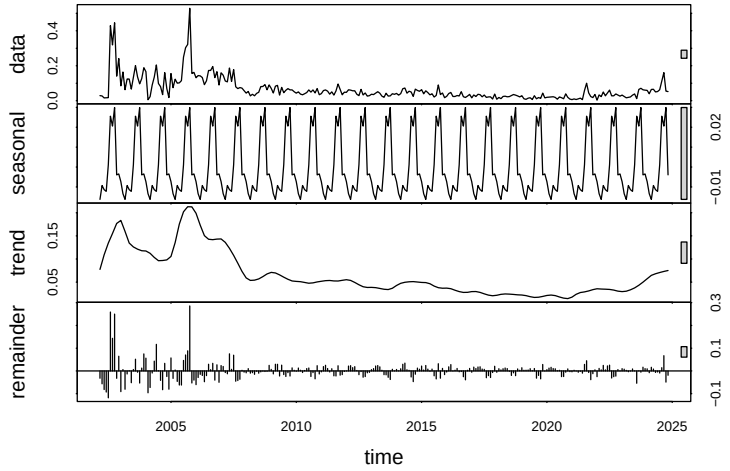

```
## Score =  -36 , Var(Score) = 16674
## denominator =  2968.999
## tau = -0.0121, 2-sided pvalue =0.7804
```



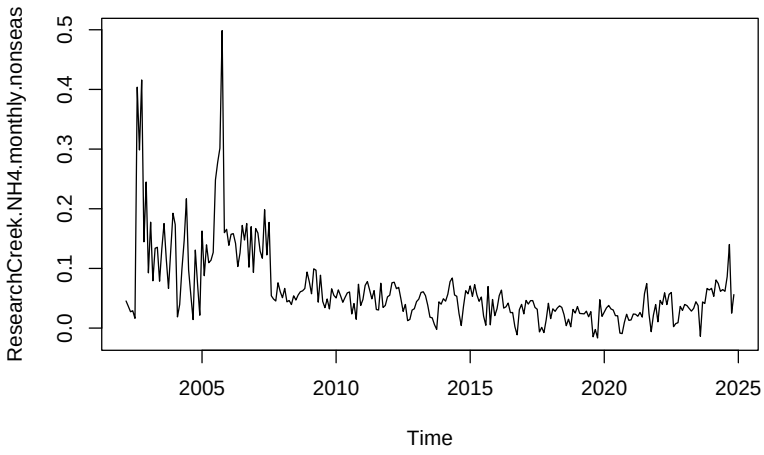


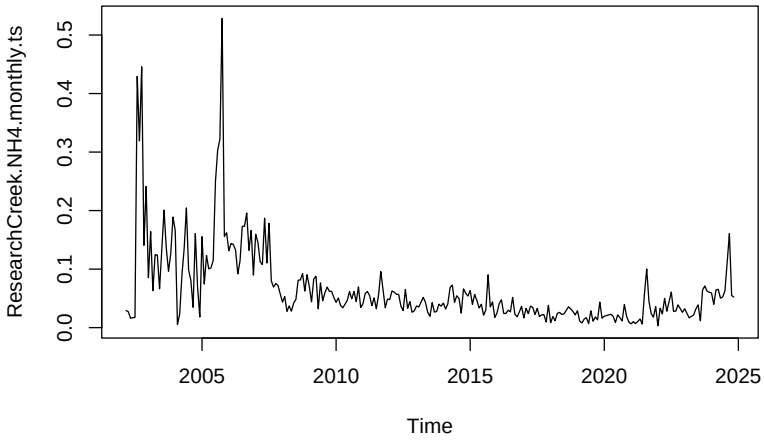

```
##
##  Mann-Kendall trend test
##
## data:  ResearchCreek.PO4.monthly.nonseas
## z = -0.58302, n = 273, p-value = 0.5599
## alternative hypothesis: true S is not equal to 0
## sample estimates:
##             S          varS           tau
## -8.800000e+02  2.273057e+06 -2.370243e-02
```

Insignificant trend.



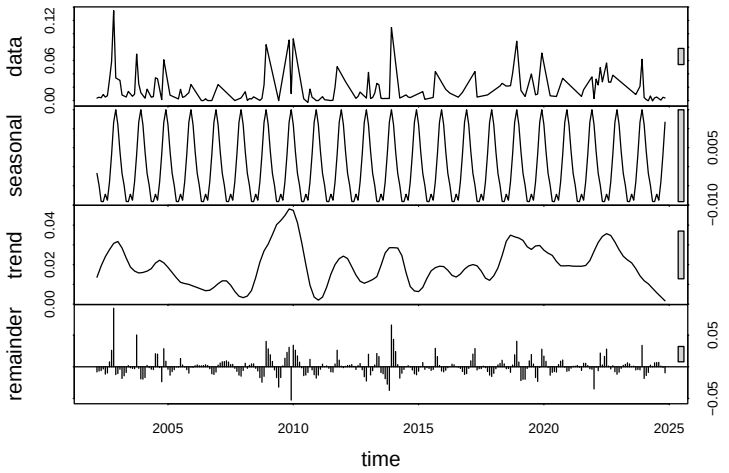

```
## Score =  -1368 , Var(Score) = 16676
## denominator =  2970
## tau = -0.461, 2-sided pvalue =< 2.22e-16
```



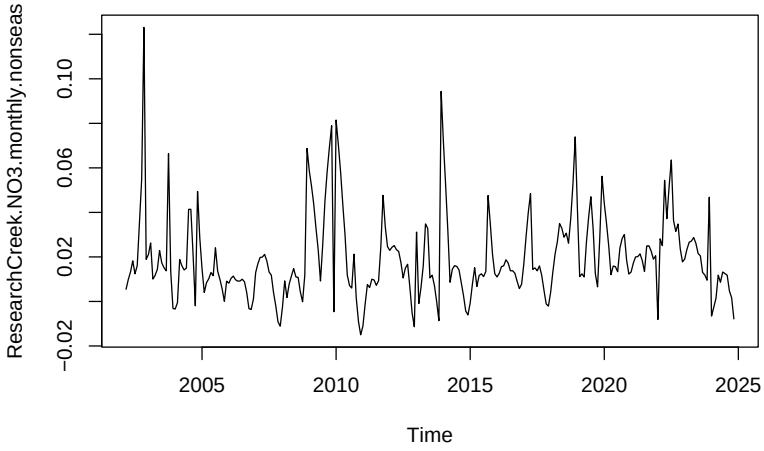


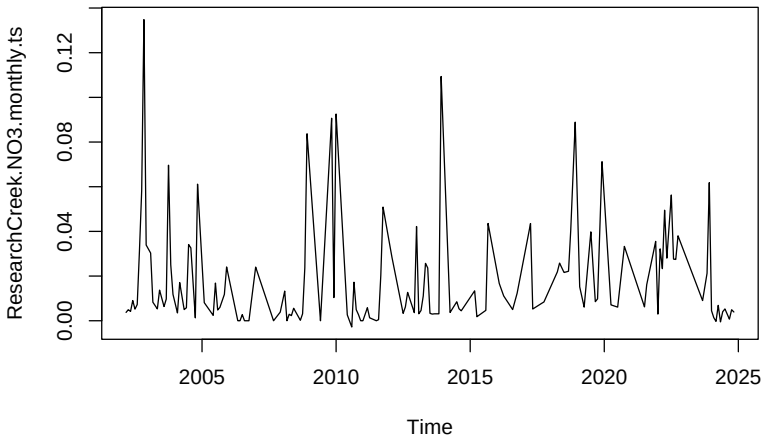

```
##
##  Mann-Kendall trend test
##
## data:  ResearchCreek.NH4.monthly.nonseas
## z = -10.08, n = 273, p-value < 2.2e-16
## alternative hypothesis: true S is not equal to 0
## sample estimates:
##             S          varS           tau
## -1.519800e+04  2.273059e+06 -4.093407e-01
```

Significant downward trend.



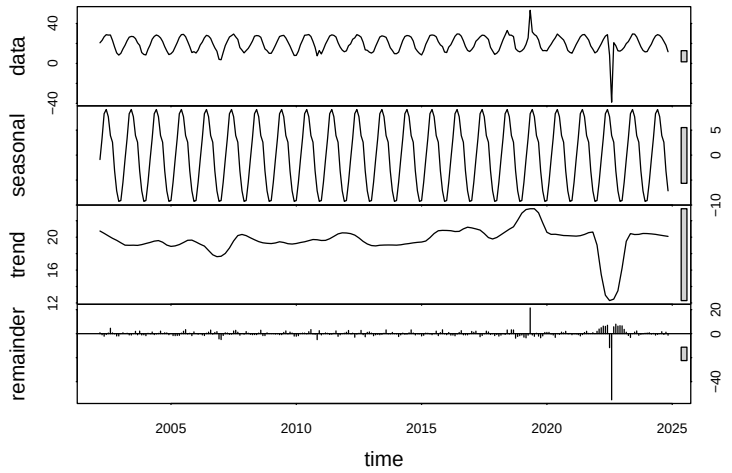

```
## Score =  426 , Var(Score) = 16670
## denominator =  2966.997
## tau = 0.144, 2-sided pvalue =0.00096874
```



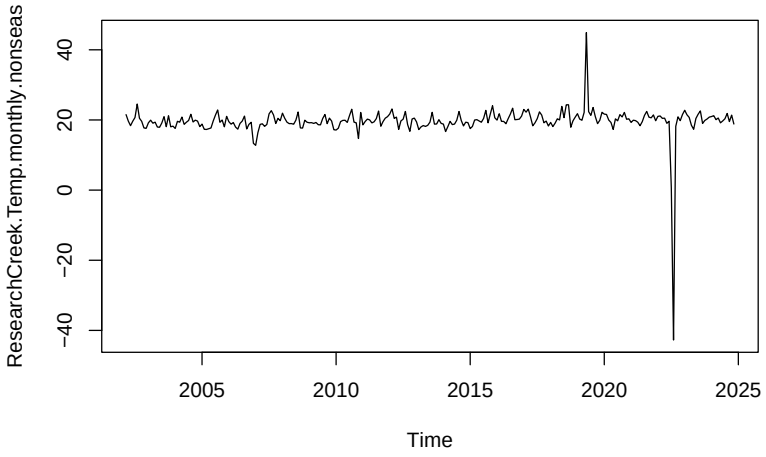


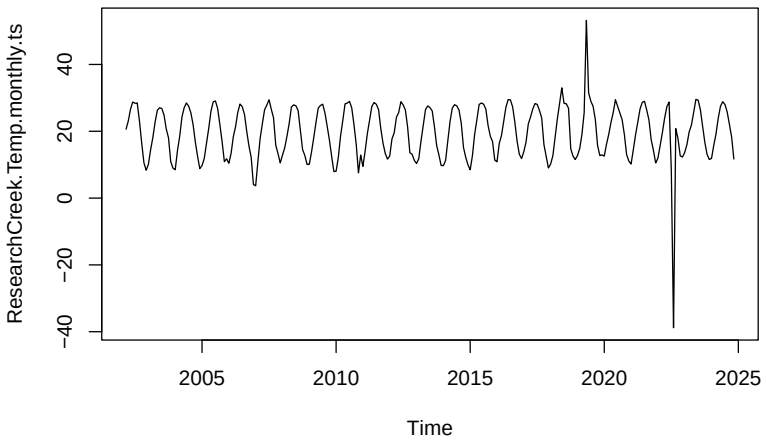

```
##
##  Mann-Kendall trend test
##
## data:  ResearchCreek.NO3.monthly.nonseas
## z = 2.4933, n = 273, p-value = 0.01266
## alternative hypothesis: true S is not equal to 0
## sample estimates:
##            S         varS          tau
## 3.760000e+03 2.273053e+06 1.012795e-01
```

Significant postive trend ?




```
## Score =  700 , Var(Score) = 16676
## denominator =  2970
## tau = 0.236, 2-sided pvalue =5.938e-08
```



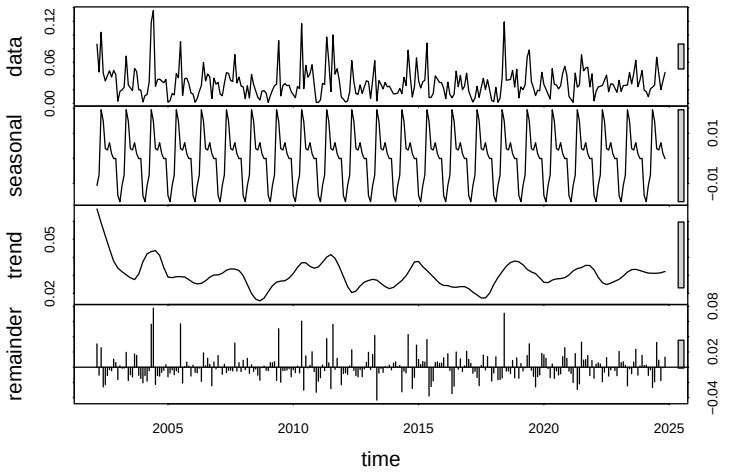



```
##
##  Mann-Kendall trend test
##
## data:  ResearchCreek.Temp.monthly.nonseas
## z = 4.8612, n = 273, p-value = 1.167e-06
## alternative hypothesis: true S is not equal to 0
## sample estimates:
##            S         varS          tau
## 7.330000e+03 2.273059e+06 1.974251e-01
```

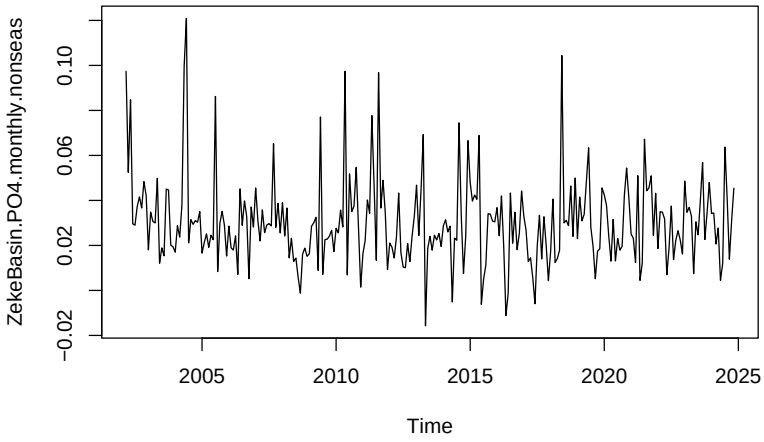
Seems like there is an outlier in the temperature data (most likley some kind of error).

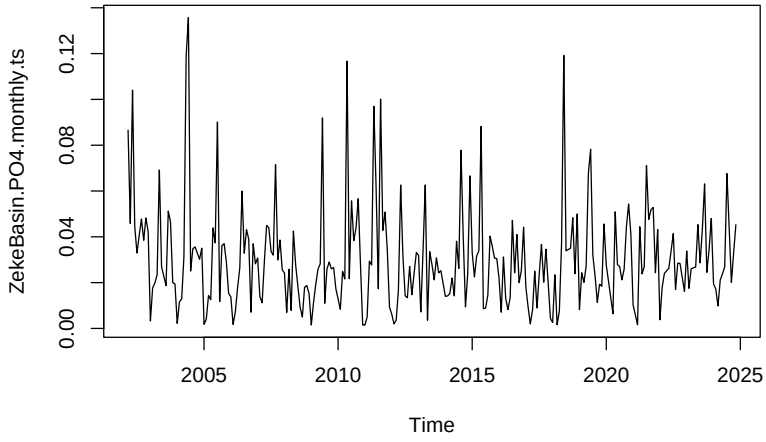
For Research Creek, NH4 had a significant downward trend and NO3 had a significant postive trend ?

Lastly, we will do **Zeke's Basin**.



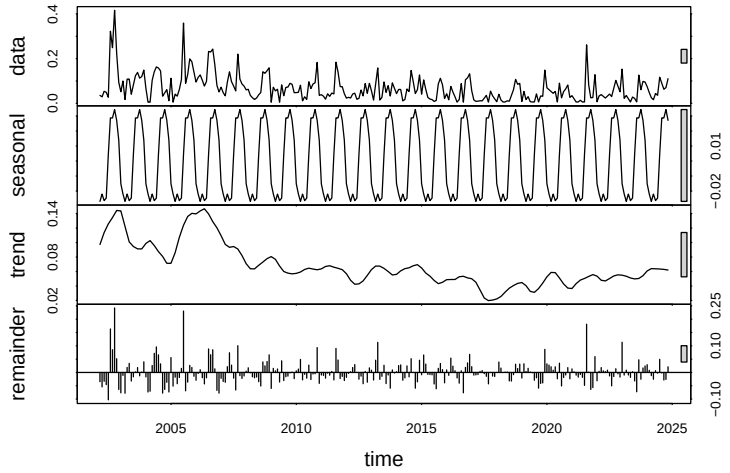

```
## Score =  -44 , Var(Score) = 16668
## denominator =  2965.995
## tau = -0.0148, 2-sided pvalue =0.73325
```



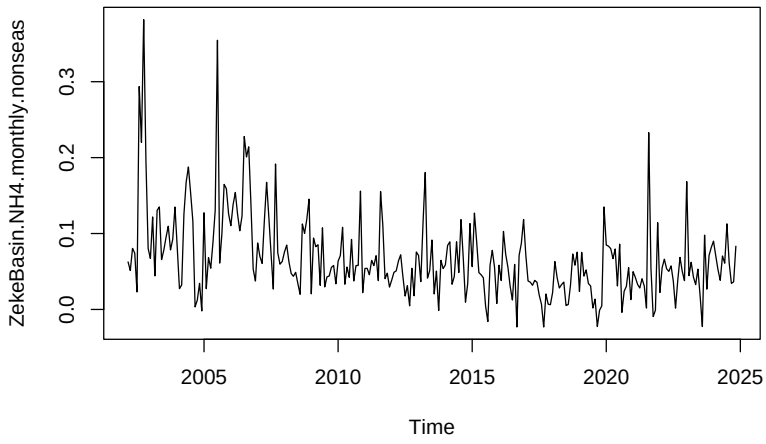


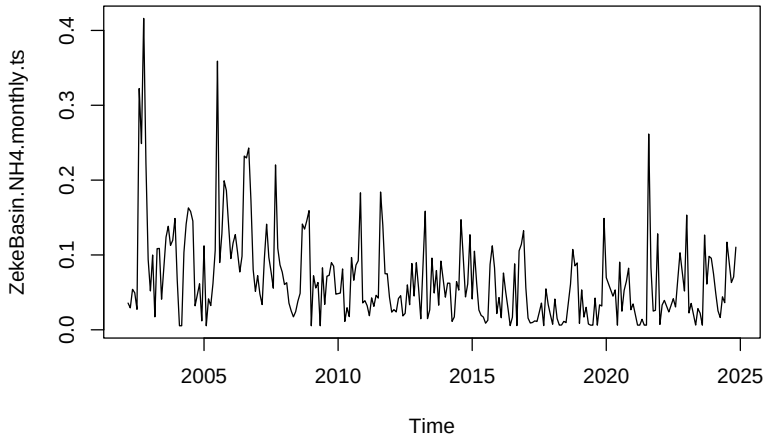

```
##
##  Mann-Kendall trend test
##
## data:  ZekeBasin.PO4.monthly.nonseas
## z = -0.51935, n = 273, p-value = 0.6035
## alternative hypothesis: true S is not equal to 0
## sample estimates:
##             S          varS           tau
## -7.840000e+02  2.273051e+06 -2.111841e-02
```

Insignificant trend.



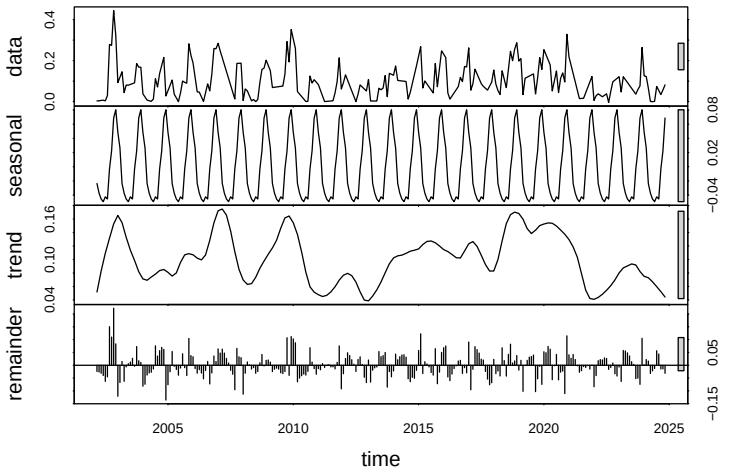

```
## Score =  -857 , Var(Score) = 16666.33
## denominator =  2965.491
## tau = -0.289, 2-sided pvalue =3.1719e-11
```



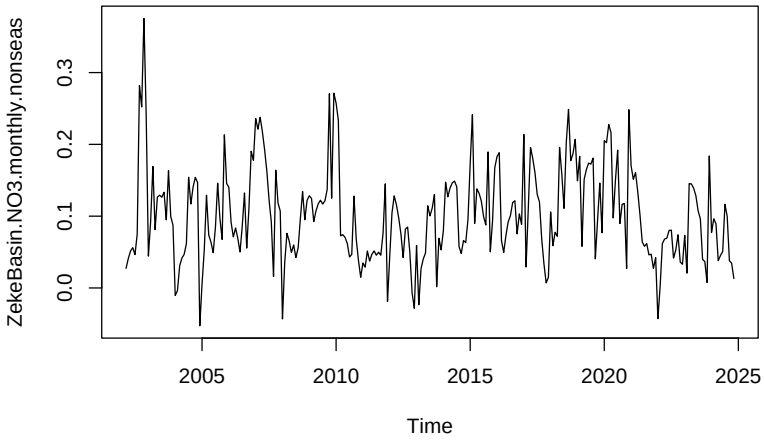


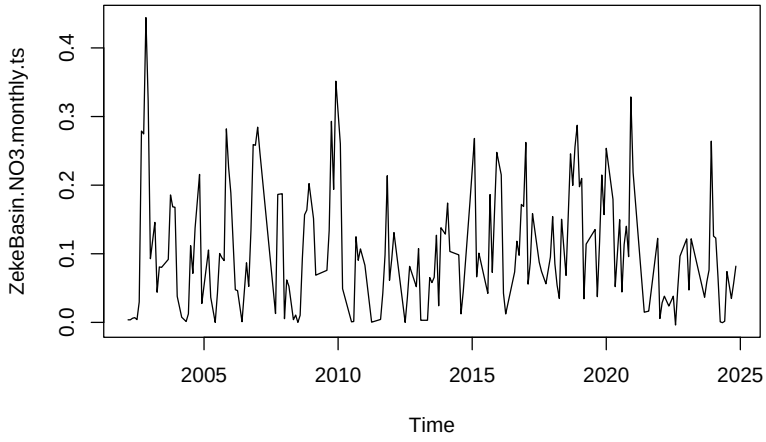

```
##
##  Mann-Kendall trend test
##
## data:  ZekeBasin.NH4.monthly.nonseas
## z = -6.4643, n = 273, p-value = 1.018e-10
## alternative hypothesis: true S is not equal to 0
## sample estimates:
##             S          varS           tau
## -9.747000e+03  2.273049e+06 -2.625561e-01
```

Significant downward trend.



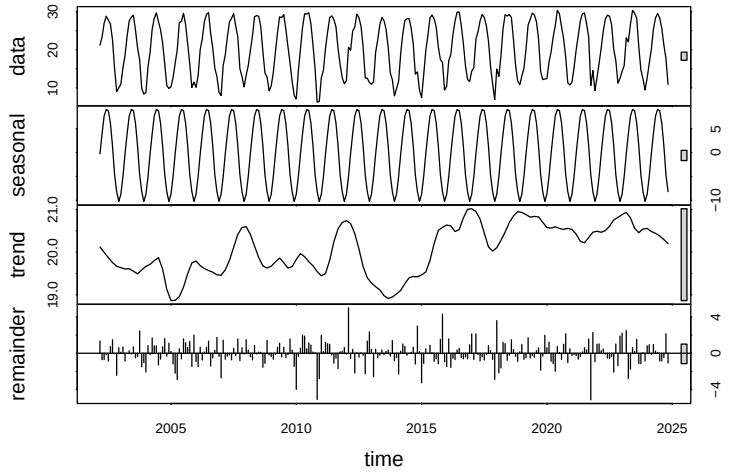

```
## Score =  -48 , Var(Score) = 16674
## denominator =  2968.999
## tau = -0.0162, 2-sided pvalue =0.7101
```



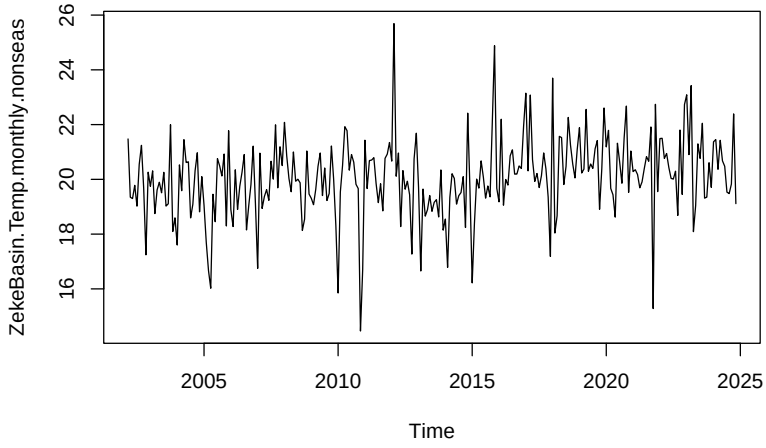


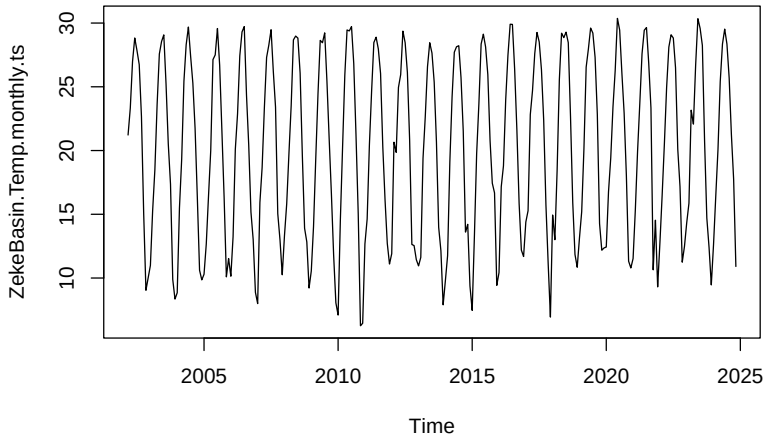

```
##
##  Mann-Kendall trend test
##
## data:  ZekeBasin.NO3.monthly.nonseas
## z = -0.48486, n = 273, p-value = 0.6278
## alternative hypothesis: true S is not equal to 0
## sample estimates:
##             S          varS           tau
## -7.320000e+02  2.273057e+06 -1.971611e-02
```

Insignificant trend.




```
## Score =  546 , Var(Score) = 16676
## denominator =  2970
## tau = 0.184, 2-sided pvalue =2.3566e-05
```






```
##
##  Mann-Kendall trend test
##
## data:  ZekeBasin.Temp.monthly.nonseas
## z = 4.434, n = 273, p-value = 9.25e-06
## alternative hypothesis: true S is not equal to 0
## sample estimates:
##            S         varS          tau
## 6.686000e+03 2.273059e+06 1.800797e-01
```

Significant upward trend.

For **Zeke's Basin**, NH4 had a significant downward trend and temperature had a significant upward trend.

7. Summary and Conclusion

8. References

NOAA National Estuarine Research Reserve System (NERRS). System-wide Monitoring Program. Data accessed from the NOAA NERRS Centralized Data Management Office website: http://www.nerrsdata.org; accessed 12 October 2025. doi:10.25921/vw8a-8031.