Assignment 5: Water Quality in Lakes

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OVERVIEW

This exercise accompanies the lessons in Hydrologic Data Analysis on water quality in lakes

Directions

1. Change "Student Name" on line 3 (above) with your name.
2. Work through the steps, **creating code and output** that fulfill each instruction.
3. Be sure to **answer the questions** in this assignment document.
4. When you have completed the assignment, **Knit** the text and code into a single HTML file.
5. After Knitting, submit the completed exercise (HTML file) to the dropbox in Sakai. Add your last name into the file name (e.g., "A05_Salk.html") prior to submission.

The completed exercise is due on 2 October 2019 at 9:00 am.

Setup

1. Verify your working directory is set to the R project file,
2. Load the tidyverse, lubridate, and LAGOSNE packages.
3. Set your ggplot theme (can be theme_classic or something else)
4. Load the LAGOSdata database and the trophic state index csv file we created on 2019/09/27.

```
getwd()
```

```
## [1] "Z:/Hydrologic_Data_Analysis2/Assignments"
```

```
library(tidyverse)
library(lubridate)
library(LAGOSNE)

theme_set(theme_classic())
options(scipen = 100)

#lagosne_get(dest_folder = LAGOSNE:::lagos_path(), overwrite = TRUE)
LAGOSdata <- lagosne_load()
```

Trophic State Index

5. Similar to the trophic.class column we created in class (determined from TSI.chl values), create two additional columns in the data frame that determine trophic class from TSI.secchi and TSI.tp (call these trophic.class.secchi and trophic.class.tp).

```
LAGOSlocus <- LAGOSdata$locus
LAGOSstate <- LAGOSdata$state
LAGOSnutrient <- LAGOSdata$epi_nutr

LAGOSlocus$lagoslakeid <- as.factor(LAGOSlocus$lagoslakeid)
LAGOSnutrient$lagoslakeid <- as.factor(LAGOSnutrient$lagoslakeid)

LAGOSlocations <- left_join(LAGOSlocus, LAGOSstate, by = "state_zoneid")
```

```
LAGOSlocations <-
  within(LAGOSlocations,
         state <- factor(state, levels = names(sort(table(state), decreasing=TRUE))))
LAGOStrophic <-
  left_join(LAGOSnutrient, LAGOSlocations, by = "lagoslakeid") %>%
  select(lagoslakeid, sampledate, chla, tp, secchi,
         gnis_name, lake_area_ha, state, state_name) %>%
  mutate(sampleyear = year(sampledate),
         samplemonth = month(sampledate),
         season = as.factor(quarter(sampledate, fiscal_start = 12))) %>%
  drop_na(chla:secchi)

levels(LAGOStrophic$season) <- c("Winter", "Spring", "Summer", "Fall")

LAGOStrophic <-
  mutate(LAGOStrophic,
         TSI.chl = round(10*(6 - (2.04 - 0.68*log(chla)/log(2)))),
         TSI.secchi = round(10*(6 - (log(secchi)/log(2)))),   #In R, log is the natural log.
         TSI.tp = round(10*(6 - (log(48/tp)/log(2)))),
         trophic.class =
            ifelse(TSI.chl < 40, "Oligotrophic",
                   ifelse(TSI.chl < 50, "Mesotrophic",
                          ifelse(TSI.chl < 70, "Eutrophic", "Hypereutrophic"))),
         trophic.class.secchi =
            ifelse(TSI.secchi < 40, "Oligotrophic",
                   ifelse(TSI.secchi < 50, "Mesotrophic",
                          ifelse(TSI.secchi < 70, "Eutrophic", "Hypereutrophic"))),
         trophic.class.tp =
            ifelse(TSI.tp < 40, "Oligotrophic",
                   ifelse(TSI.tp < 50, "Mesotrophic",
                          ifelse(TSI.tp < 70, "Eutrophic", "Hypereutrophic"))))
```

6. How many observations fall into the four trophic state categories for the three metrics (trophic.class, trophic.class.secchi, trophic.class.tp)? Hint: `count` function.

```
chlcount <-
  LAGOStrophic %>%
  count(trophic.class)
print(chlcount)
```

```
## # A tibble: 4 x 2
##   trophic.class      n
##   <chr>          <int>
## 1 Eutrophic      41861
## 2 Hypereutrophic 14379
## 3 Mesotrophic    15413
## 4 Oligotrophic    3298
```

```
secchicount <-
  LAGOStrophic %>%
  count(trophic.class.secchi)
print(secchicount)
```

```
## # A tibble: 4 x 2
##   trophic.class.secchi     n
```

```
##   <chr>                <int>
## 1 Eutrophic            28659
## 2 Hypereutrophic        5099
## 3 Mesotrophic          25083
## 4 Oligotrophic         16110
```

```
tpcount <-
  LAGOStrophic %>%
  count(trophic.class.tp)
print(tpcount)
```

```
## # A tibble: 4 x 2
##   trophic.class.tp     n
##   <chr>            <int>
## 1 Eutrophic        24839
## 2 Hypereutrophic    7228
## 3 Mesotrophic      23023
## 4 Oligotrophic     19861
```

7. What proportion of total observations are considered eutrohic or hypereutrophic according to the three different metrics (trophic.class, trophic.class.secchi, trophic.class.tp)?

```
chl.proportion <-
  sum(LAGOStrophic$trophic.class == 'Eutrophic' | LAGOStrophic$trophic.class == 'Hypereutrophic') /
  sum(LAGOStrophic$trophic.class == 'Eutrophic' | LAGOStrophic$trophic.class == 'Hypereutrophic' |
      LAGOStrophic$trophic.class == 'Mesotrophic' | LAGOStrophic$trophic.class == 'Oligotrophic')
print(chl.proportion)
```

```
## [1] 0.7503569
```

```
secchi.proportion <-
  sum(LAGOStrophic$trophic.class.secchi == 'Eutrophic' | LAGOStrophic$trophic.class.secchi == 'Hypereuti
  sum(LAGOStrophic$trophic.class.secchi == 'Eutrophic' | LAGOStrophic$trophic.class.secchi == 'Hypereuti
      LAGOStrophic$trophic.class.secchi == 'Mesotrophic' | LAGOStrophic$trophic.class.secchi == 'Oligoti
print(secchi.proportion)
```

```
## [1] 0.4504009
```

```
tp.proportion <-
  sum(LAGOStrophic$trophic.class.tp == 'Eutrophic' | LAGOStrophic$trophic.class.tp == 'Hypereutrophic')
  sum(LAGOStrophic$trophic.class.tp == 'Eutrophic' | LAGOStrophic$trophic.class.tp == 'Hypereutrophic'
      LAGOStrophic$trophic.class.tp == 'Mesotrophic' | LAGOStrophic$trophic.class.tp == 'Oligotrophic')
print(tp.proportion)
```

```
## [1] 0.4278395
```

Which of these metrics is most conservative in its designation of eutrophic conditions? Why might this be?

> Total phosphorus. Using this metric as a proxy for eutrophic conditions assumes that phosphorus is the limiting nutrient. While this is true in summer, this dataset contains yearround observations. For this reason, we would expect total phosphorus to underestimate the true amount of biomass in our lakes and therefore its true trophic state.

Note: To take this further, a researcher might determine which trophic classes are susceptible to being differently categorized by the different metrics and whether certain metrics are prone to categorizing trophic class as more or less eutrophic. This would entail more complex code.

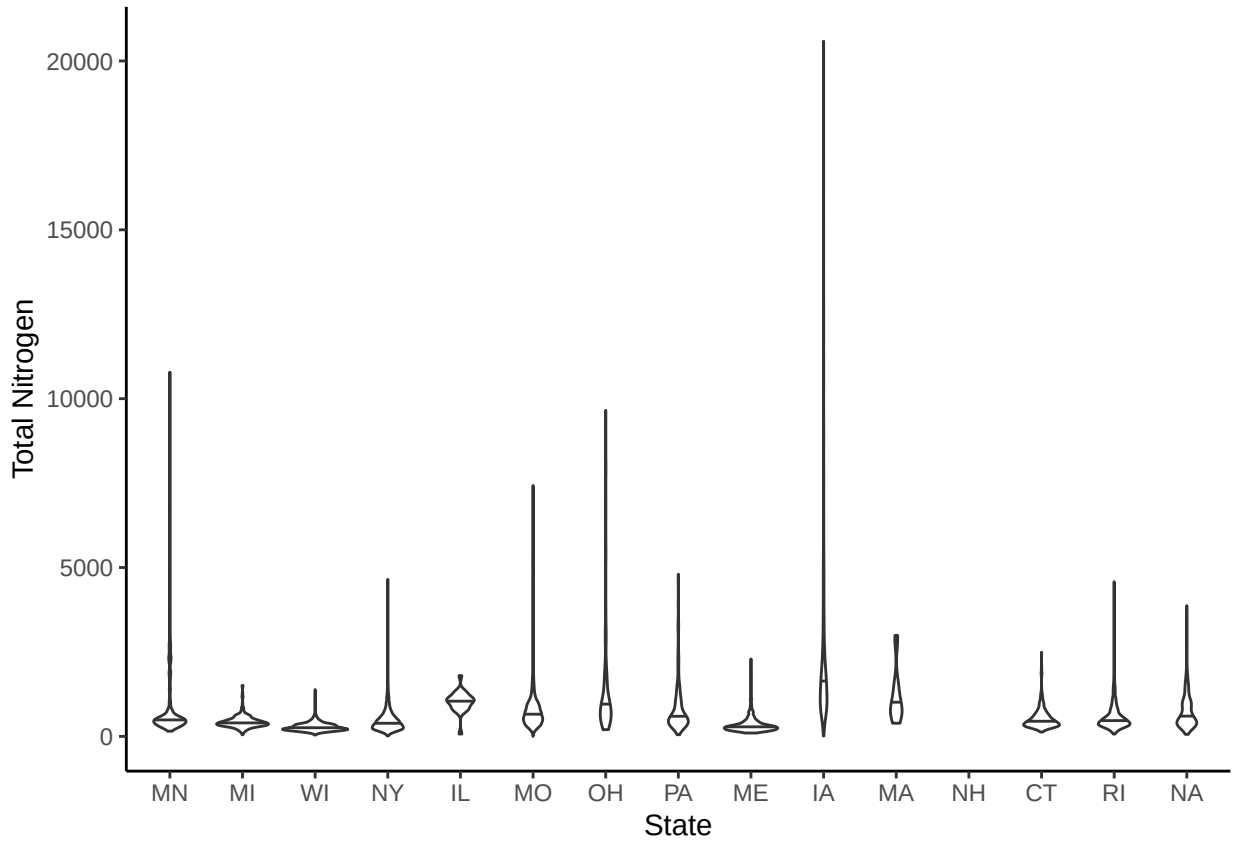
Nutrient Concentrations

8. Create a data frame that includes the columns lagoslakeid, sampledate, tn, tp, state, and state_name. Mutate this data frame to include sampleyear and samplemonth columns as well. Call this data frame LAGOSNandP.

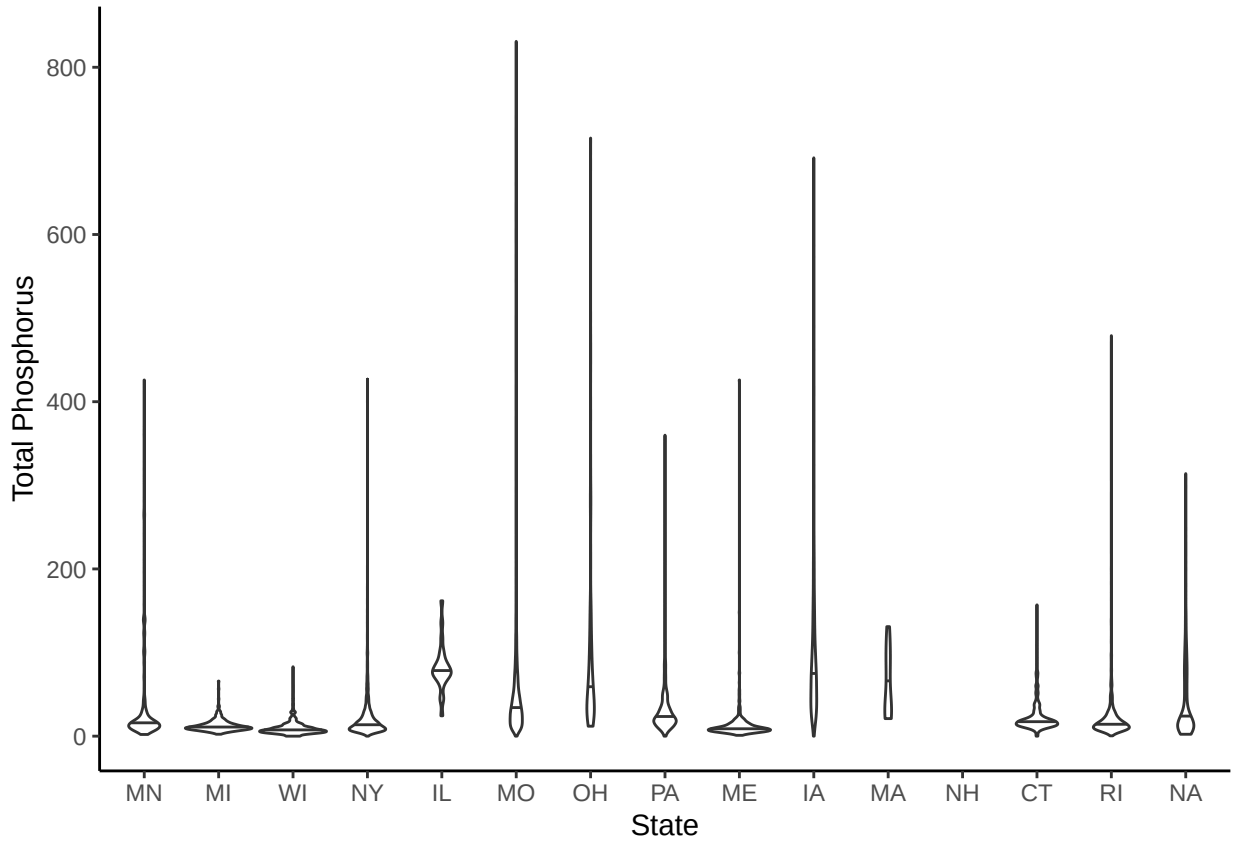
```
LAGOSNandP <-
  left_join(LAGOSnutrient, LAGOSlocations, by = "lagoslakeid") %>%
  select(lagoslakeid, sampledate, chla, tn, tp, secchi,
         gnis_name, lake_area_ha, state, state_name) %>%
  mutate(sampleyear = year(sampledate),
         samplemonth = month(sampledate)) %>%
  drop_na(chla:secchi)
```

9. Create two violin plots comparing TN and TP concentrations across states. Include a 50th percentile line inside the violins.

```
TN_violin <- ggplot(LAGOSNandP, aes(x = state, y = tn)) +
  geom_violin(draw_quantiles = 0.50)+
  labs(x = "State", y = "Total Nitrogen")
print(TN_violin)
```




```
TP_violin <- ggplot(LAGOSNandP, aes(x = state, y = tp)) +
  geom_violin(draw_quantiles = 0.50)+
  labs(x = "State", y = "Total Phosphorus")
print(TP_violin)
```



Which states have the highest and lowest median concentrations?

```
stats <-
  LAGOSNandP %>%
  group_by(state) %>%
  summarise( MedianN = median(tn),
             MedianP = median(tp))

# I can do range with the naked eye, but not median.
```

TN: Highest is Iowa Lowest is Wisconsin

TP: Highest is Illinois Lowest is Wisconsin

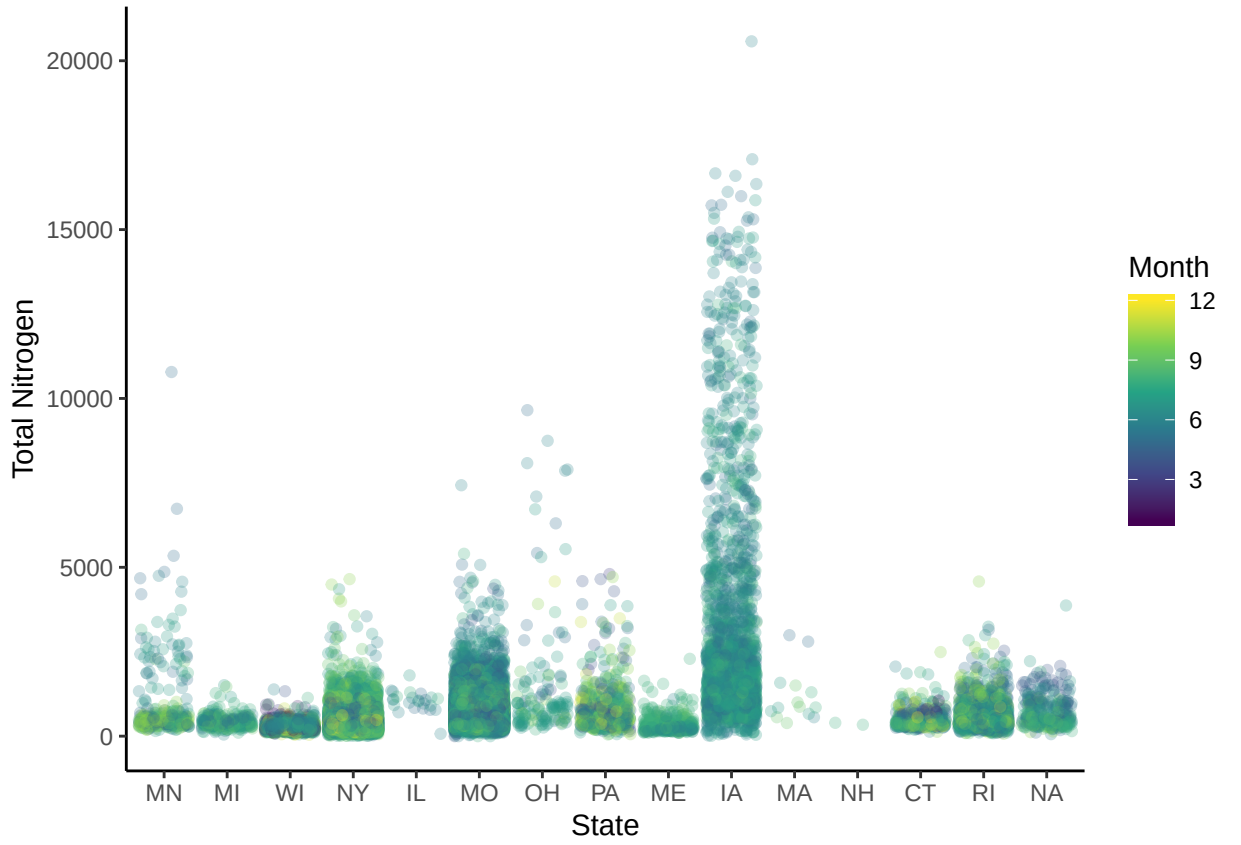
Which states have the highest and lowest concentration ranges?

TN: Highest is Iowa Lowest is Wisconsin

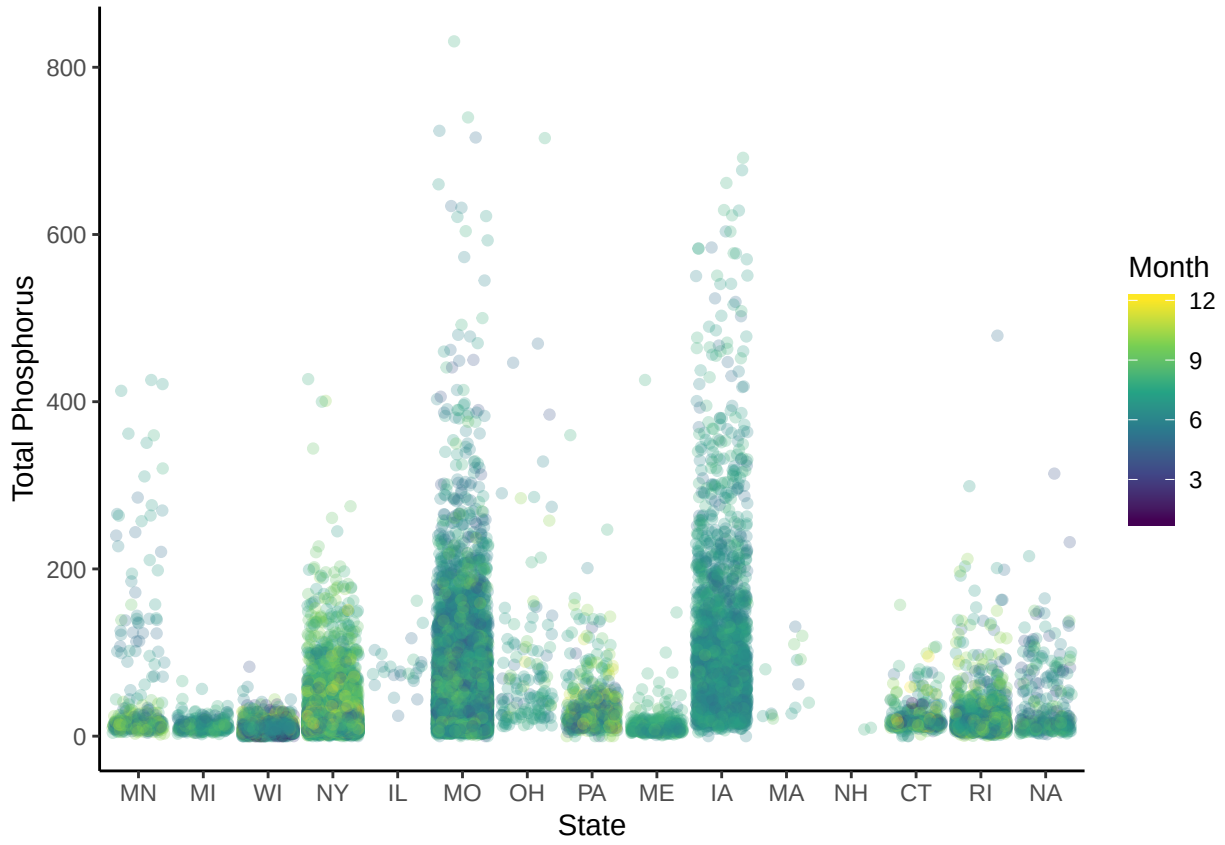
TP: Highest is Missouri Lowest is Michigan

10. Create two jitter plots comparing TN and TP concentrations across states, with samplemonth as the color. Choose a color palette other than the ggplot default.

```
TNjitter <- ggplot(LAGOSNandP, aes(x = state, y = tn, color = samplemonth))+
  geom_jitter(alpha = 0.25)+
  scale_color_viridis_c()+
  labs(x = "State", y = "Total Nitrogen", color = "Month")
print(TNjitter)
```




```
TPjitter <- ggplot(LAGOSNandP, aes(x = state, y = tp, color = samplemonth))+
  geom_jitter(alpha = 0.25)+
  scale_color_viridis_c()+
  labs(x = "State", y = "Total Phosphorus", color = "Month")
print(TPjitter)
```



Which states have the most samples? How might this have impacted total ranges from #9?

```
LAGOSP <-
  left_join(LAGOSnutrient, LAGOSlocations, by = "lagoslakeid") %>%
  select(lagoslakeid, sampledate, chla, tp, secchi,
         gnis_name, lake_area_ha, state, state_name) %>%
  mutate(sampleyear = year(sampledate),
         samplemonth = month(sampledate)) %>%
  drop_na(tp)
#creating a dataframe for P analysis

LAGOSN <-
  left_join(LAGOSnutrient, LAGOSlocations, by = "lagoslakeid") %>%
  select(lagoslakeid, sampledate, chla, tn, secchi,
         gnis_name, lake_area_ha, state, state_name) %>%
  mutate(sampleyear = year(sampledate),
         samplemonth = month(sampledate)) %>%
  drop_na(tn)
#creating a dataframe for N analysis


countbystateTP <-
  LAGOSP %>%
  group_by(state_name) %>%
  tally() %>%
  na.omit()
```

```
countbystateTN <-
  LAGOSN %>%
  group_by(state_name) %>%
  tally() %>%
  na.omit()
```

TN: Missouri TP: Wisconsin States with smaller datasets might not be large enough to capture their own statistical tails, because the extreme ends of their tails don't occur often enough to be captured in a small, random sampling.

Which months are sampled most extensively? Does this differ among states?

```
countbymonthTP <-
  LAGOSP %>%
  group_by(samplemonth) %>%
  tally() %>%
  na.omit()

countbymonthTN <-
  LAGOSN %>%
  group_by(samplemonth) %>%
  tally() %>%
  na.omit()
```

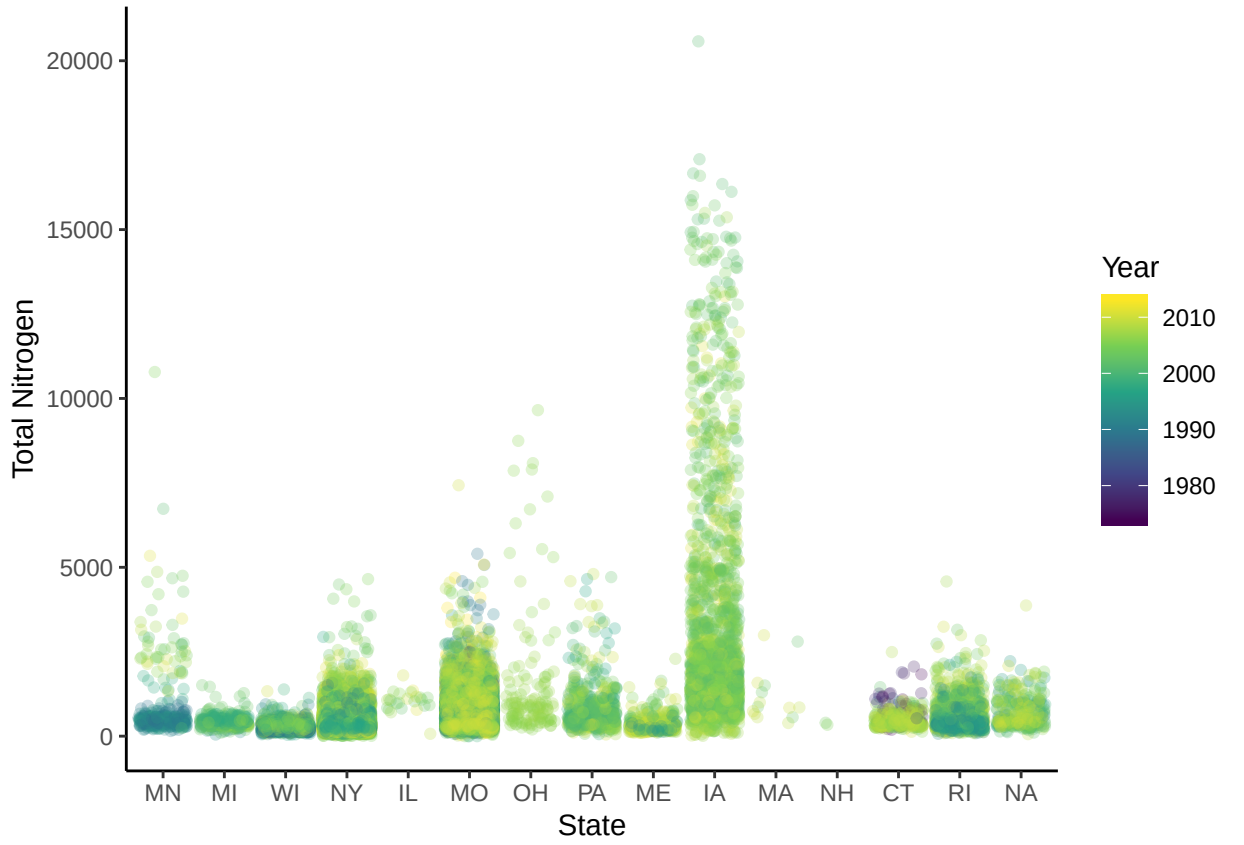
TN: July

TP: August

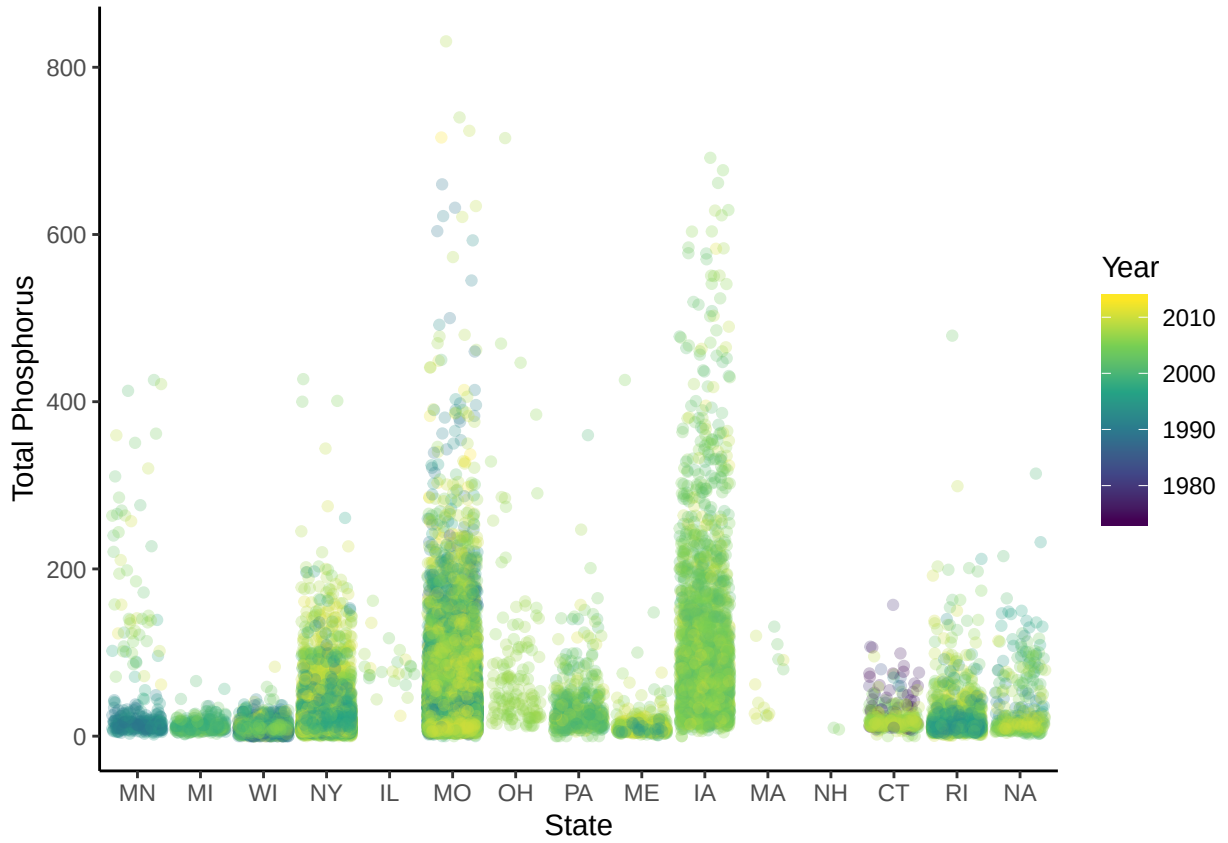
```
countbymonthstateN <-
  LAGOSN %>%
  group_by(state_name, samplemonth) %>%
  tally() %>%
  na.omit()
#Yes, it does for nitrogen.

countbymonthstateP <-
  LAGOSP %>%
  group_by(state_name, samplemonth) %>%
  tally() %>%
  na.omit()
#Yes, it does for phosphorus.
```

11. Create two jitter plots comparing TN and TP concentrations across states, with sampleyear as the color. Choose a color palette other than the ggplot default.

```
TNjitter <- ggplot(LAGOSNandP, aes(x = state, y = tn, color = sampleyear))+
  geom_jitter(alpha = 0.25)+
  scale_color_viridis_c()+
  labs(x = "State", y = "Total Nitrogen", color = "Year")
print(TNjitter)
```




```
TPjitter <- ggplot(LAGOSNandP, aes(x = state, y = tp, color = sampleyear))+
  geom_jitter(alpha = 0.25)+
  scale_color_viridis_c()+
  labs(x = "State", y = "Total Phosphorus", color = "Year")
print(TPjitter)
```



Which years are sampled most extensively? Does this differ among states?

```
countbyyearTP <-
  LAGOSP %>%
  group_by(sampleyear) %>%
  tally() %>%
  na.omit()

countbyyearTN <-
  LAGOSN %>%
  group_by(sampleyear) %>%
  tally() %>%
  na.omit()
```

TN: 2009

TP: 2009

```
countbyyearstateN <-
  LAGOSN %>%
  group_by(state_name, sampleyear) %>%
  tally() %>%
  na.omit()
#Yes, it does for nitrogen.

countbyyearstateP <-
  LAGOSP %>%
  group_by(state_name, sampleyear) %>%
```

```
  tally() %>%
  na.omit()
#Yes, it does for phosphorus.
```

Reflection

12. What are 2-3 conclusions or summary points about lake water quality you learned through your analysis?

    There is extensive variation in data collection temporally and geographically. Different areas have different vairation and different level of nutrients in their lakes.

13. What data, visualizations, and/or models supported your conclusions from 12?

    The first conclusion was driven home by the series of dataframes I made at the end of this assignment. I compared data collection by state, month of year, and year; all by nutrient, and saw large variation in data available. The second conclusion was driven home by the different ranges and medians in the violin plot of nutrient concentration by state.

14. Did hands-on data analysis impact your learning about water quality relative to a theory-based lesson? If so, how?

    I felt like for this lesson, I got bogged down in the process of creating dataframes to show distribution of data collection, and was less focused at times on the water science behind them. When we focused on comparing nutrient levels across states, such as in the violin plot, I felt the hands on learning was very helpful.

15. How did the real-world data compare with your expectations from theory?

    I would have expected that the Land of 10,000 Lakes would have the most data samples. I suppose it is one of the coldest and remote states in the dataframe. I was not surprised to see that July had the most data collection, or that the big agriculture states had the highest nutrient levels.