Group 10 Horsetooth Final Report

Samantha Nauman, Drew Miller, Sophia Rye

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Introduction

Horsetooth Reservoir is located west of Fort Collins, Colorado, and began construction in 1946 as part of the Colorado-Big Thompson Project. According to Coyote Gulch (2022), the Colorado-Big Thompson project consists of 12 reservoirs, 35 miles of tunnels, and 95 miles of canals, with the 13.1-mile-long Alva B. Adams Tunnel beneath the Continental Divide serving as the key to the entire project. Between 1946 and 1949, four dams were built to help store water in what is now Horsetooth Reservoir: Horsetooth, Soldier Canyon, Dixon Canyon, and Spring Canyon (City of Fort Collins Utilities, 2014). In 1951, the reservoir began holding water, primarily supplied through the Hansen Feeder Canal from the western slope of the Continental Divide, to store and provide water to the front range. The entire watershed that Horsetooth Reservoir spans contains watersheds west and east of the Continental Divide, along with a local watershed including many streams that supply water to the reservoir. After rainfall and during snowmelt, streams such as Well Gulch, Arthur's Rock Gulch, and Soldier Canyon transport the water into Horsetooth Reservoir. With around 500,000 annual visitors, factors such as wildfires from recreational activities have been found to impact the reservoir's water quality (City of Fort Collins Utilities, 2014). Challenges arising in water quality have been managed over the years to maintain water treatment processes, such as low dissolved oxygen levels in the epilimnion, rising temperatures, and rising total organic carbon. This reservoir is iconic to the area and famous for its beauty, recreation ability, fishing, etc., and provides Fort Collins drinking water, irrigation, and agricultural use. Our in-field sampling for the limnological analysis was taken at Horsetooth and our group, group 10 spent the following months after September analyzing the data.

Methods

Sampling for this project took place in mid-September at Horsetooth Reservoir. We went to Inlet Bay on the southeast side of the reservoir (Figure 1). A map/image is inserted below. During the sampling, we took measurements such as Secchi Depth, Algae, Zooplankton, Water Chemistry, and Chlorophyll A measurements. This is all of the samples except the depth and salinity profile which we ran out of time for during the trip. The first measurement taken was the Secchi depth, in simple terms this was to look at the clarity within the lake by taking a disc and measuring how deep you could see it. However, the real reason to look at Secchi depth is to understand the productivity and nutrient load of the reservoir. The differences in depth represent how much algae is blooming from increased nutrients in the system. The second sample taken was to look at the algae and zooplankton within the lake, for this measurement we took a dip net placing it within the top two meters of water to get the most productive algae and zooplankton, and then preserved the specimens to look under the microscopes in the lab. This measurement again was to look at the dominant algae and zooplankton to help us determine nutrients and influxes in the system. The differences in different times of year are very stark and can lead to the whole reservoir reacting differently to types of conditions in the environment. Another measurement taken was to find the water chemistry and look at specific elements such as dissolved carbon, phosphorus, and nitrogen. To find each of these values we filtered water from the epilimnion and hypolimnion and looked at the water used in the lab later. We did this to see the aquatic health, possible contaminants, and overall ecosystem health. Finally, we measured Chlorophyll A by looking at the filters used for the amount left behind. We did this

measurement for similar reasons as the rest, such as viewing primary producers, looking for dangerous algae blooms, and looking at the overall health of the lake. This is Fort Collins drinking water so each measurement is taken to determine the health of the ecosystem and safety of water to drink and use.

```
map <- image_read('HorsetoothMap.png')
print(map)
```

```
## # A tibble: 1 × 7
##   format width height colorspace matte filesize density
##   <chr>  <int>  <int> <chr>      <lgl>    <int> <chr>
## 1 PNG      954    956 sRGB       TRUE   1145230 57x57
```

Figure 1. Map of Horsetooth Reservoir with a mark of the destination where sampling took place: Inlet Bay

Results (figures and calculations)

```
Group_10<-read_csv("Group03_09062024_profiledata.csv")
```

```
## Rows: 9 Columns: 9
## ── Column specification ────────────────────────────────────────────────────────
## Delimiter: ","
## chr (1): group
## dbl (6): z_m, temp_c, ph, cond, do_percent, do_mgL
## lgl (2): sal, chla_ugL
##
## ℹ Use `spec()` to retrieve the full column specification for this data.
## ℹ Specify the column types or set `show_col_types = FALSE` to quiet this message.
```

```
head(Group_10)
```

```
## # A tibble: 6 × 9
##   group     z_m temp_c    ph   cond sal   do_percent do_mgL chla_ugL
##   <chr>   <dbl>  <dbl> <dbl>  <dbl> <lgl>      <dbl>  <dbl> <lgl>
## 1 Group_3     2   21.0  7.42 0.0706 NA          99     7.39 NA
## 2 Group_3     4   20.8  7.54 0.071  NA          98.2   7.35 NA
## 3 Group_3     6   20.8  7.7  0.071  NA          98.1   7.33 NA
## 4 Group_3     8   20.7  7.05 0.0705 NA          95.5   7.13 NA
## 5 Group_3    10   18.7  6.82 0.066  NA          90.6   6.9  NA
## 6 Group_3    14   18.4  6.65 0.0635 NA          66.5   5.21 NA
```

```
Group_10<-Group_10 %>%
  mutate(group=ifelse(group=="Group_3","Group_10",group))
```

1. Oxygen Profile, DO (Percent) and DO (mg/L) Series:

```
Group_10_long <- Group_10 %>%
  pivot_longer(cols = c(do_percent, do_mgL),names_to = "Variable",
               values_to = "Value")

    ggplot(Group_10_long, aes(x = Value, y = z_m, color = Variable)) +
      geom_line(size = 1) +
      geom_point(size = 3) +
      scale_y_reverse() +
      labs(
        x = "Dissolved Oxygen",
        y = "Depth (m)",
        color = "DO Type",
        title = "Oxygen Profile: DO % and DO mg/L",
        caption = "Figure 2. DO in milligrams per liter and as a percentage by depth"
      ) +
      theme_classic() +
      theme(
        text = element_text(size = 14),
        plot.title = element_text(hjust = 0.5)
      )
```

```
## Warning: Using `size` aesthetic for lines was deprecated in ggplot2 3.4.0.
## ℹ Please use `linewidth` instead.
## This warning is displayed once every 8 hours.
## Call `lifecycle::last_lifecycle_warnings()` to see where this warning was
## generated.
```

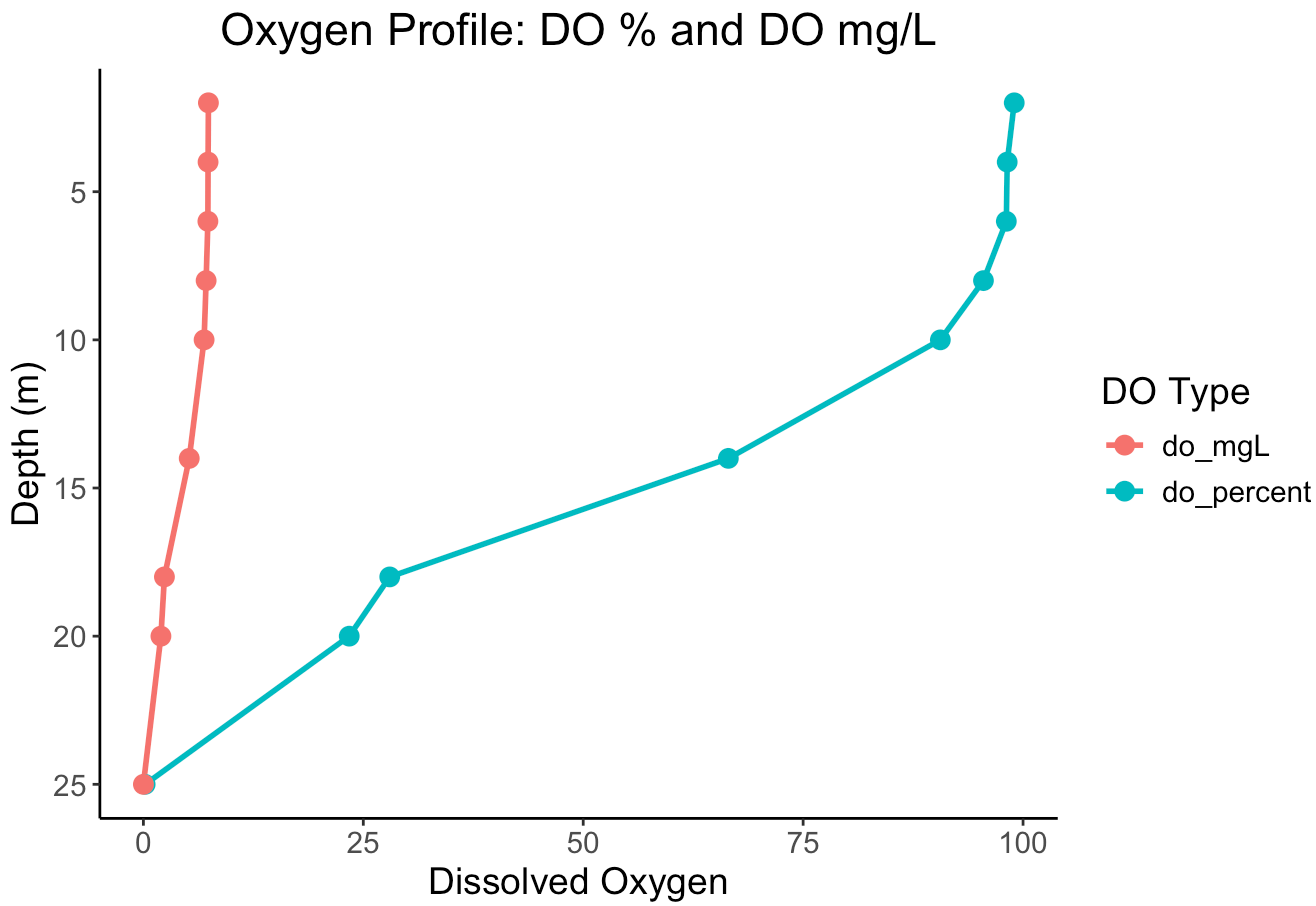


Figure 2. DO in milligrams per liter and as a percentage by depth

2. Temperature Profile:

```
temp_c_prof <- ggplot(data=Group_10,aes(x=temp_c,y=z_m, color=group, shape= group)) +
geom_point(size=3, color="deeppink", show.legend = TRUE)+
theme_bw() +
labs(title="Temperature (C) Profile",x='Temperature (C)', y='Depth (m)',caption="Figure
3. Group 10 Temerature (C) Profile at Horsetooth Reservoir")+
scale_y_reverse(expand = c(0.015,0))+
theme(text = element_text(size = 10))
temp_c_prof
```

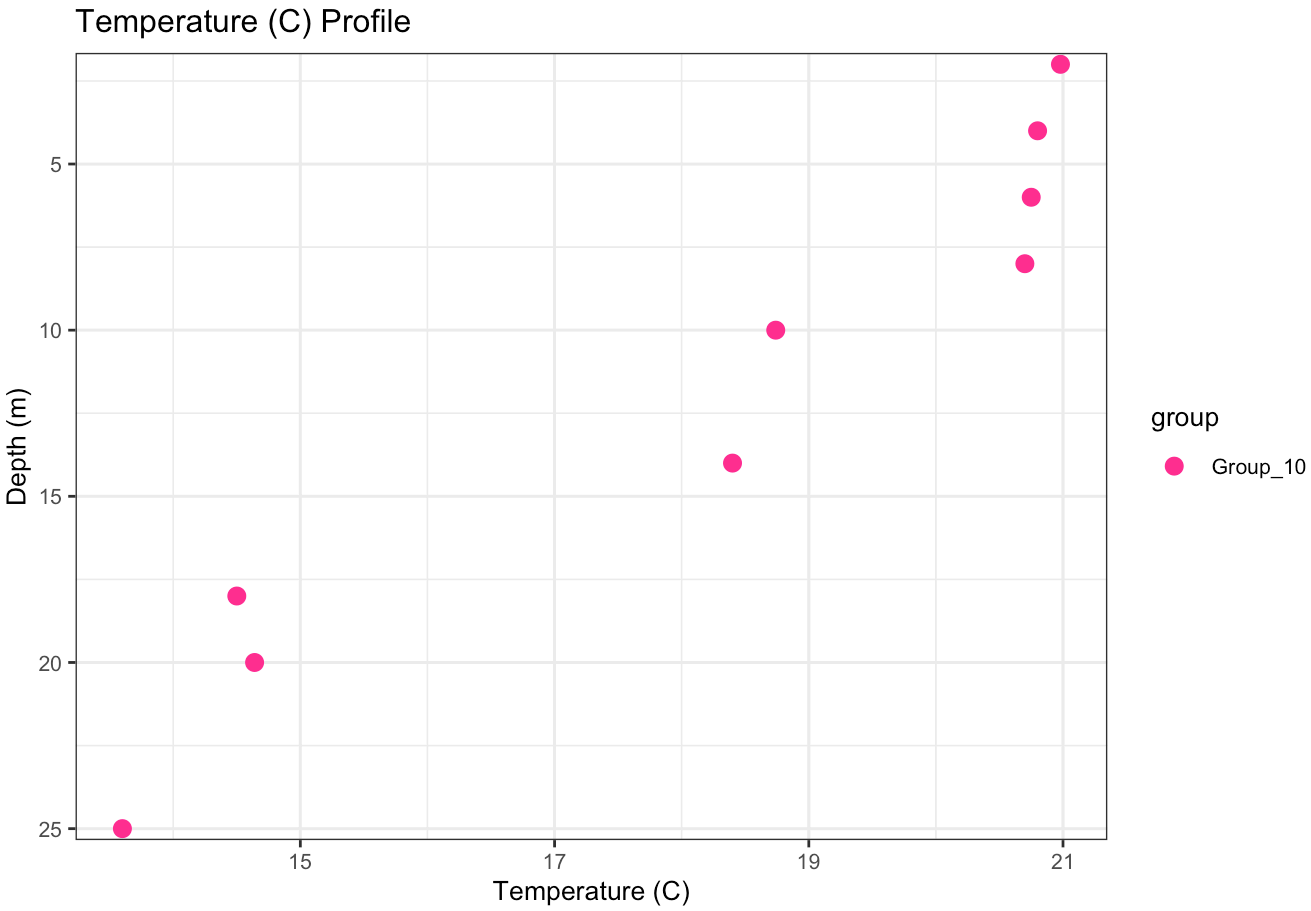


Figure 3. Group 10 Temerature (C) Profile at Horsetooth Reservoir

3. A pH Profile

```
pH_prof <- ggplot(data=Group_10,aes(x=ph,y=z_m, color=group, shape= group)) +
geom_point(size=3, color="aquamarine4",show.legend = TRUE)+
theme_few() +
labs(title="pH Profile",x='pH', y= 'Depth (m)',caption="Figure 4. Group 10 pH Profile at
Horsetooth Reservoir")+
scale_y_reverse(expand = c(0.015,0))+
theme(text = element_text(size = 10))
pH_prof
```

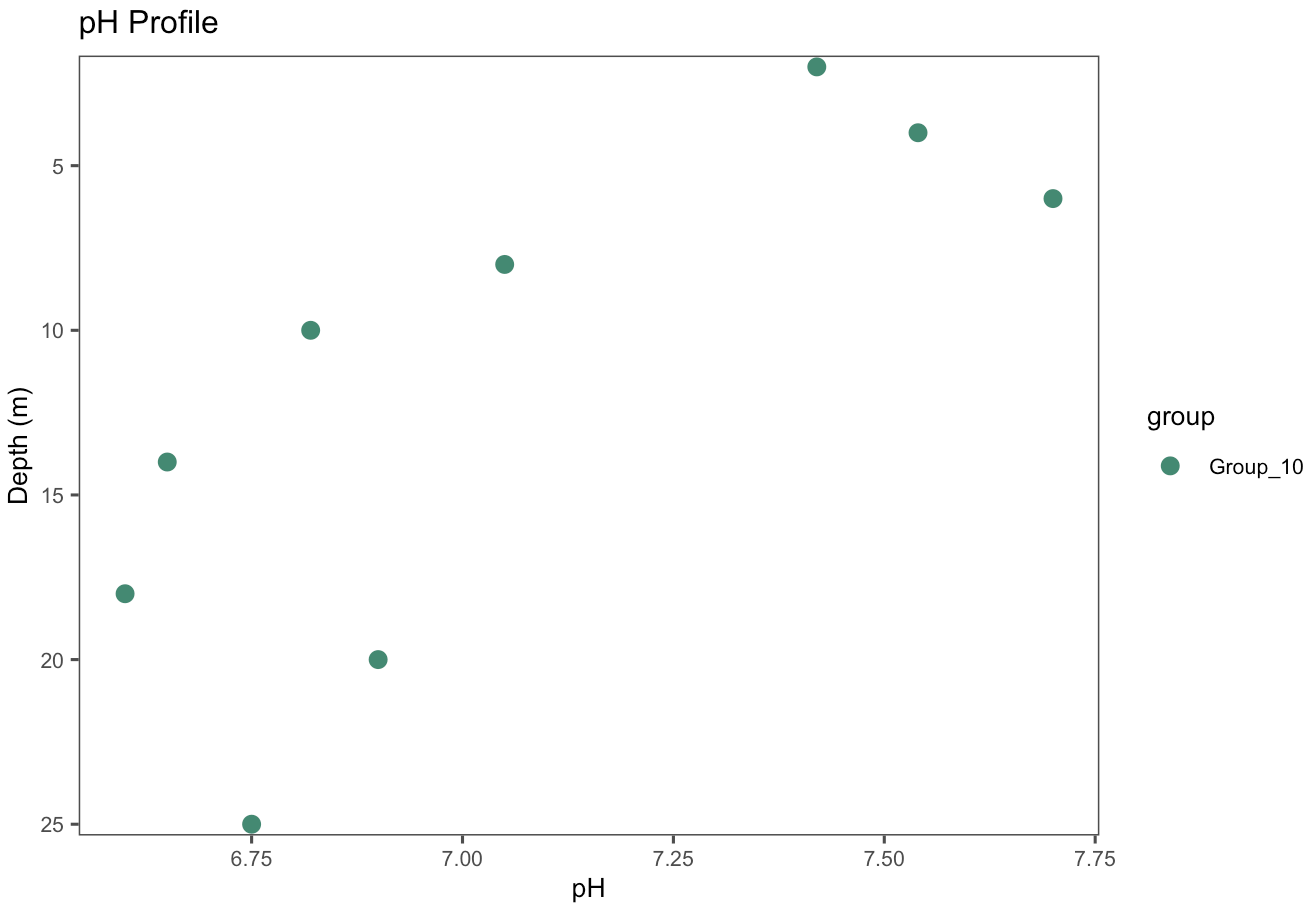


Figure 4. Group 10 pH Profile at Horsetooth Reservoir

4. Standard Curve for Total Nitrogen

```
STDCurve<-read_csv("ESS474Fall2024stdcurvedata.csv")
```

```
## Rows: 26 Columns: 2
## ── Column specification ────────────────────────────────────────────────────────
## Delimiter: ","
## dbl (2): mg_L_TN, Area
##
## ℹ Use `spec()` to retrieve the full column specification for this data.
## ℹ Specify the column types or set `show_col_types = FALSE` to quiet this message.
```

```
# add Group 10 data
SCurveG10 <- data.frame(
  mg_L_TN=c(0.3162,0.3077,0.2942,0.2981,0.2624,0.2647),
  Area=c(8.164,7.948,7.606,7.705,6.801,6.861)
)
STDCurve<-rbind(STDCurve,SCurveG10)

# x is the area, y is the TN
model<-lm(mg_L_TN~Area, data=STDCurve)
  formula<-paste0("y=",round(coef(model)[2],4),"x+",round(coef(model)[1],4))
  r_squared<-paste0("R^2=",round(summary(model)$r.squared,4))

STD_Curve <- ggplot(data=STDCurve,aes(x=Area,y=mg_L_TN))+
  geom_point(color="purple", size=3)+
  geom_smooth(method="lm",se=FALSE, color="black", linetype="dashed")+
  labs(title="Total Nitrogen (mg/L) by Area",x="Area",y="Total Nitrogen (mg/L)", caption
="Figure 5. Standard Curve for total dissolved nitrogen by area, inlcuding Group 10 dat
a")+
  theme_bw()+
  annotate("text",x=100,y=8,label=formula,color="black",size=5,hjust=0)+
  annotate("text",x=100,y=7,label=r_squared,color="black",size=5,hjust=0)
STD_Curve
```

```
## `geom_smooth()` using formula = 'y ~ x'
```

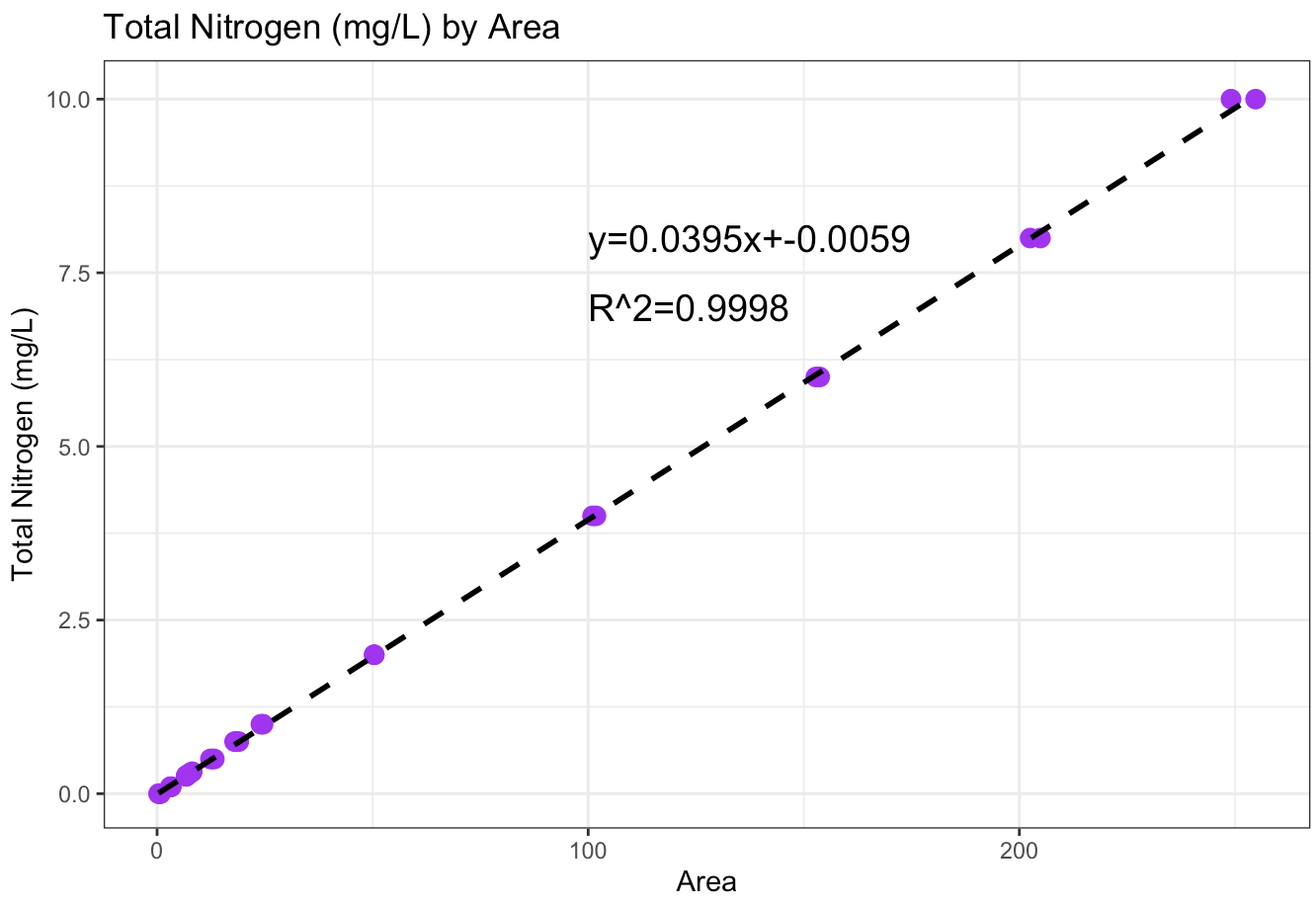


Figure 5. Standard Curve for total dissolved nitrogen by area, inlcuding Group 10 data

5. Comparison of Total Nitrogen Between the Epilimnion and Hypolimnion Depths: All Groups:

```
groupTN <- read.csv("ESS474_Standard_Curve.csv")
meanE_TN<-mean(groupTN$TN_mgL[c(16:19,24:28,34:38,45:49,54:57,64:68,74:80)], na.rm=TRUE)
print(paste("Group TN Epilimnion Mean=",meanE_TN, "mg/L"))
```

```
## [1] "Group TN Epilimnion Mean= 0.259557142857143 mg/L"
```

```
meanH_TN<-mean(groupTN$TN_mgL[c(10:15,20:23,29:33,39:44,50:53,59:63,69:73)], na.rm=TRUE)
print(paste("Group TN Hypolimnion Mean=",meanH_TN, "mg/L"))
```

```
## [1] "Group TN Hypolimnion Mean= 0.263607142857143 mg/L"
```

Note: Due to lack of labeling, lack of samples, and/or unusual values of diluted samples for Groups 1, 9 and 10, with judgement calculations for those group's data was excluded when comparing total nitrogen between the epilimnion and hypolimnion depths. The difficulties with those groups data are because of the closeness of the average value of the hypo and epi samples (making it difficult to know how to classify the unlabelled samples).

Comparison of Total Nitrogen between Epilimnion and Hypolimnion for Group 10: Due to error of lack of labeling, unusual values of diluted samples for Group 10 was ruled out of the group data. This is because the closeness of the average value of the hypolimnion and epilimnion samples made it difficult to classify the unlabelled samples.

6. Comparison of Chlorophyll a Values Between the Epilimnion and Hypolimnion Depths

```
Chla_Data <- read_csv("Horsetooth_Chla_Data_2024.csv")
```

```
## Rows: 15 Columns: 4
## ── Column specification ────────────────────────────────────────────────────────
## Delimiter: ","
## chr (3): Group_Number, Sample_Label, Was filter folded in half?
## dbl (1): Chla_ug_per_Liter
##
## ℹ Use `spec()` to retrieve the full column specification for this data.
## ℹ Specify the column types or set `show_col_types = FALSE` to quiet this message.
```

```
mean_chla<-mean(Chla_Data$Chla_ug_per_Liter, na.rm=TRUE)
print(paste(mean_chla, "ug/L"))
```

```
## [1] "0.221285714285714 ug/L"
```

```
mean_G10chla<-mean(Chla_Data$Chla_ug_per_Liter[11:12], na.rm=TRUE)
print(paste(mean_G10chla,"ug/L"))
```

```
## [1] "0.2515 ug/L"
```

```
ggplot(data=Chla_Data,aes(x=Chla_ug_per_Liter))+
    geom_histogram(linewidth=1,color="black",alpha=0.7)+
    geom_vline(aes(xintercept=mean_chla),color="red",linetype="dashed",size=1)+
    labs(title="Distribution of Epilimnion Chlorophyll-a Values",x="Chlorophyll a (ug/
L)",y="Frequency",caption="Figure 6. Distribution of epilimnion chlorphyll a values take
n across all groups, including the mean")+
      theme_bw()
```

```
## `stat_bin()` using `bins = 30`. Pick better value with `binwidth`.
```

```
## Warning: Removed 1 row containing non-finite outside the scale range
## (`stat_bin()`).
```

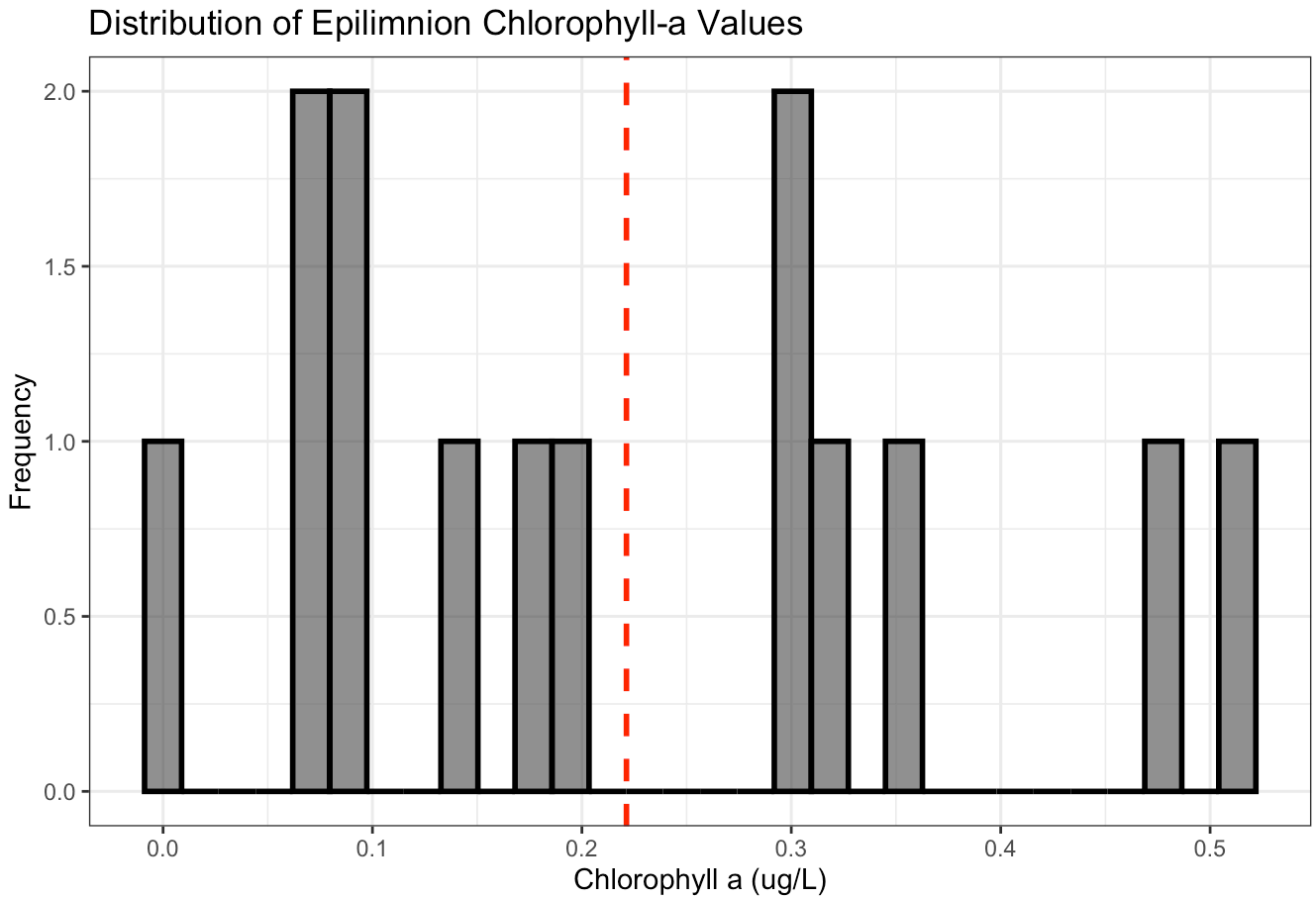


Figure 6. Distribution of epilimnion chlorphyll a values taken across all groups, including the mean

7. Dissolved Organic Carbon Values Between the Epilimnion and Hypolimnion Depths

```
DOC <- read_csv("ESS474_HorsetoothReservoir_DOC_2024.csv")
```

```
## Rows: 33 Columns: 3
## ── Column specification ────────────────────────────────────────────────────────
## Delimiter: ","
## chr (2): Sample_Name, Unit
## dbl (1): Result_DissolvedOrganicCarbon
##
## ℹ Use `spec()` to retrieve the full column specification for this data.
## ℹ Specify the column types or set `show_col_types = FALSE` to quiet this message.
```

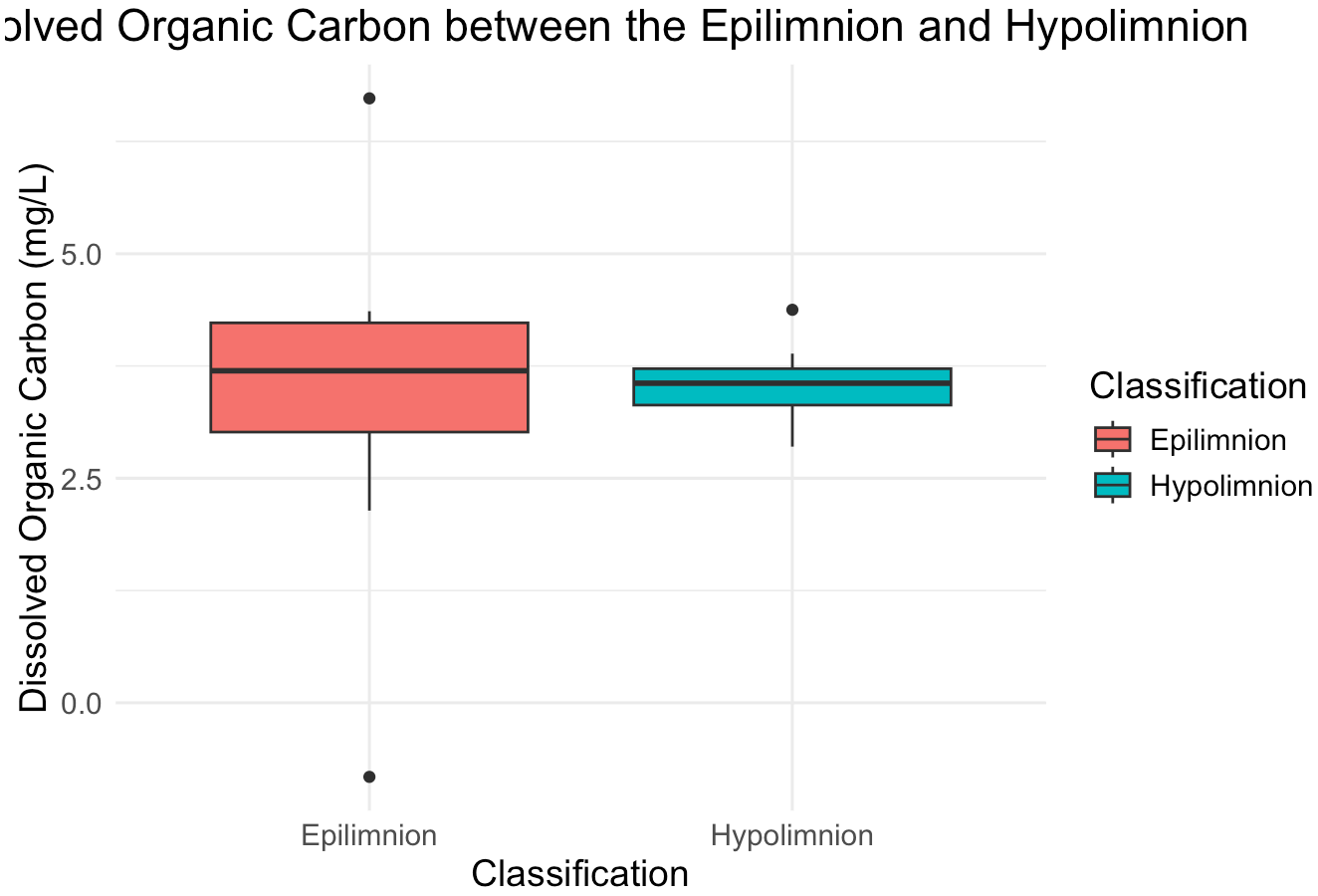
```
DOC <- DOC %>%
  mutate(Classification = ifelse(row_number() <= 16, "Epilimnion", "Hypolimnion"))
meanDOC_E <-mean(DOC$Result_DissolvedOrganicCarbon[1:16], na.rm=TRUE)
print(paste("Epilimnion DOC=",meanDOC_E,"mg/L"))
```

```
## [1] "Epilimnion DOC= 3.51409375 mg/L"
```

```
meanDOC_H<-mean(DOC$Result_DissolvedOrganicCarbon[17:33], na.rm=TRUE)
print(paste("Hypolimnion DOC=",meanDOC_H, "mg/L"))
```

```
## [1] "Hypolimnion DOC= 3.55447058823529 mg/L"
```

```
ggplot(DOC, aes(x=Classification,y=Result_DissolvedOrganicCarbon,fill=Classification)) +
  geom_boxplot() +
  labs(
    title = "Dissolved Organic Carbon between the Epilimnion and Hypolimnion",
    x = "Classification",
    y = "Dissolved Organic Carbon (mg/L)",
    caption = "Figure 7. Comparison of Dissolved Organic Carbon (mg/L) values between Ep
ilimnion and Hypolimnion depths."
  ) +
  theme_minimal() +
  theme(
    text = element_text(size = 14),
    plot.title = element_text(hjust = 0.5))
```



ed Organic Carbon (mg/L) values between Epilimnion and Hypolimnion depths.

Note: Due to lack of labeling, finding a mean between the epilimnion and hypolimnion may result in incorrect values that correlate with the group mean comparison. Therefore, finding means for Group 10 may be inaccurate and were excluded from the results.

8. Estimate of Group 10 Phytoplankton Diversity (no figure)

    Diatoms: 1 Cyanobacteria: 1 Euglenoids: 9 Dinoflagellates: 6 Unidentified Phytoplankton: 17

```
library(vegan)
```

```
## Loading required package: permute
```

```
## Loading required package: lattice
```

```
## This is vegan 2.6-8
```

```
library(readr)

name <- c("Diatoms", "Cyanobacteria", "Euglenoids", "Dinoflagellates", "Unidentified Phy
toplankton")
count <- c(1, 1, 9, 6, 17)

shannon_index <- diversity(count, index = "shannon")
print(paste("Shannon Index:",shannon_index))
```

```
## [1] "Shannon Index: 1.21194273460587"
```

```
simpson_index <- diversity(count, index = "simpson")
print(paste("Simpson Index:",simpson_index))
```

```
## [1] "Simpson Index: 0.647058823529412"
```

9. Distribution of Secchi Depths (and mean)

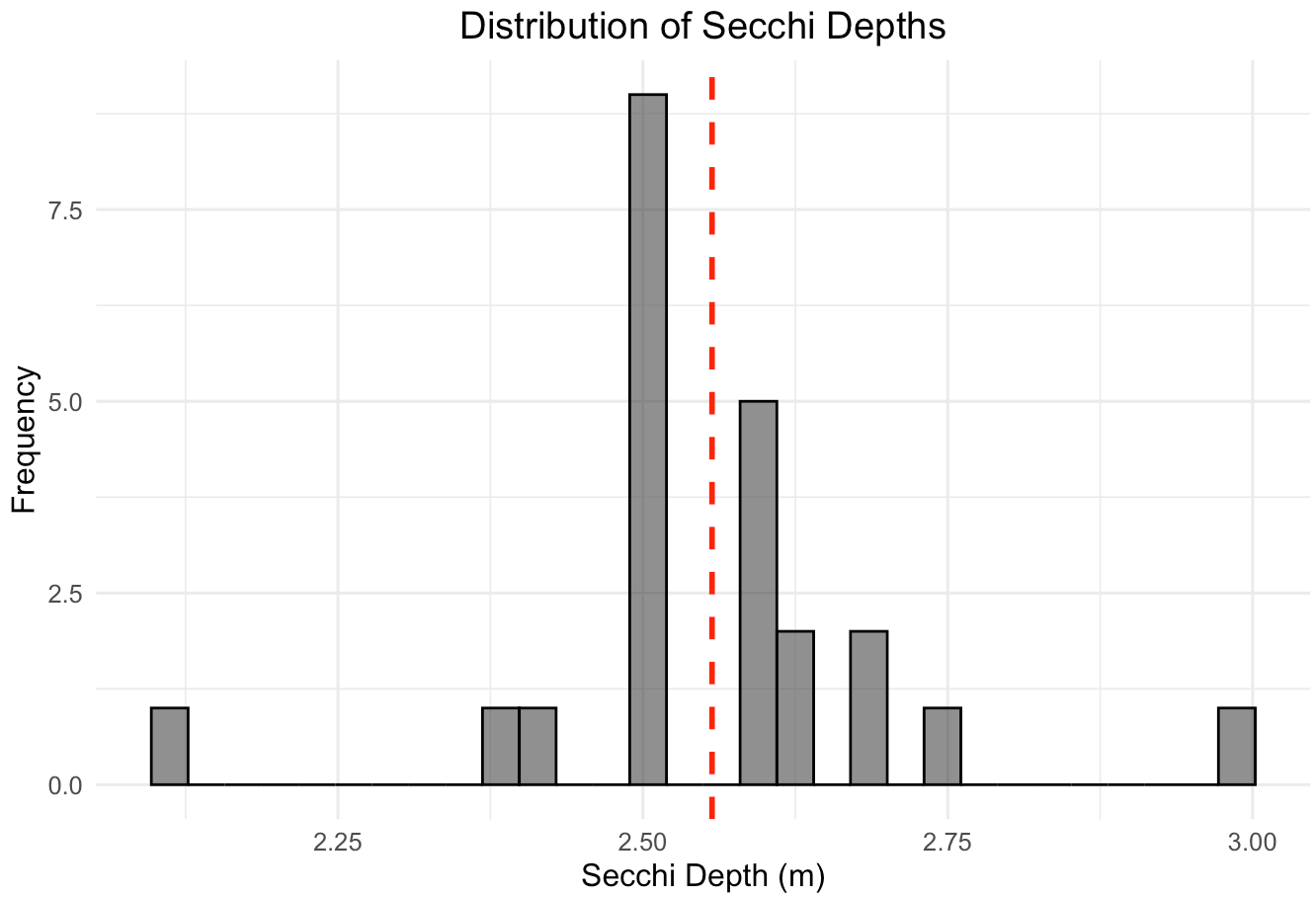
```
Secchi<-read.csv("HorsetoothSampling_SecchiDepth_2024.csv")

mean_secchi<-mean(Secchi$depth_m)
print(paste("Secchi Depth",mean_secchi,"m"))
```

```
## [1] "Secchi Depth 2.55673913043478 m"
```

```
ggplot(Secchi, aes(x = depth_m)) +
  geom_histogram(color = "black", alpha = 0.7) +
  geom_vline(aes(xintercept = mean_secchi), color = "red", linetype = "dashed", size =
1) +
  labs(
    title = "Distribution of Secchi Depths",
    x = "Secchi Depth (m)",
    y = "Frequency",
    caption = paste("Figure 8. Distribution of Secchi depths taken across all groups in
meters, including the mean value as the dashed line", round(mean_secchi, 2), "m")
  ) +
  theme_minimal() +
  theme(
    text = element_text(size = 12),
    plot.title = element_text(hjust = 0.5)
  )
```

```
## `stat_bin()` using `bins = 30`. Pick better value with `binwidth`.
```



3. Distribution of Secchi depths taken across all groups in meters, including the mean value as the dashed line 2.56 m

Results (interpretation)

1. Figures:

   Figure 1: This figure is simply a map of where we surveyed the Reservoir. This point was by one of the southern dams and not much within the lake would have changed where we took samples other than slightly higher readings of nutrients or algae if near an influx or higher or lower temps. It was important to be by a dam to get true readings when looking at the entire reservoir because we wanted to get deep to see the differences.

Figure 2: This figure is the oxygen profile of the Horsetooth Reservoir in September showing both the true dissolved oxygen in milligrams per liter and dissolved oxygen percent while going down in the reservoir. There is a clear trend for both lines and the simple trend is that there is much more oxygen towards the top of the reservoir compared to the bottom. This result from what we learned is correct as the main source of oxygen is from the atmosphere, and on the graph the top has almost 100 percent oxygen. The next trend to see is the steep drop in oxygen percent, this having to do with the mixing layer of the lake. With the strong separation of layers due to the heat of the atmosphere, the mixing layer stays at about 100 percent oxygen and the steep dropoff is due to the separation in the thermocline. The oxygen becomes much more valuable deeper and is used by either metal oxidizing or by algae low in the photic zone, and as seen in both lines goes to near zero. Figure 3: This figure is much simpler to explain and also shows the trend of dropping temperature the deeper the probe went into the lake. At almost the same spot oxygen in Figure 2 dropped off, and so did the temperature seen in this graph. This similarity can again be explained within the layers. The main source of heat for the lake is the sun contacting the water within the top layer until no more light can be passed through. This heated water is mixed within the top layer, the epilimnion, and stays almost the same temperature for the first ten meters. Then as oxygen drops off so

does the temperature this is a characteristic of the thermocline as light and mixing of the top layer stops here, leaving the constant temperature in the hypolimnion. Now although the temperature drops like oxygen it does not go below a certain degree of Celsius like oxygen went to zero. This is due to the simple principle of pressure and water can freeze from the bottom leaving the bottom of the reservoir near fourteen degrees Celsius in September.

Figure 4: The pH graph of Figure 4 is much more sporadic compared to the other two figures explained, following a much different pattern but overall having a lower range as well between 6.5 and 7.75 pH. The upper ten meters is the highest pH of the entire graph and our interpretation of this is due to the increase of photosynthesis in these upper layers of the lake. The algae and primary producers are most prevalent near the top making the shift away from more carbonic acid as carbon dioxide is used in this process. This would make the lake more basic towards the top. Then we see a similar shift in the thermocline, where in all profile graphs we would expect a shift. Towards the bottom, it becomes slightly more basic compared to the top and this is for the inverse effect as stated above, there is less photosynthesis and more carbonic acid. The bottom also has two more reasons it is more acidic and that is due to the decomposition of organic matter and temperature holding more dissolved carbon dioxide. Both these things create more acidic byproducts than towards the top layers. But this being said we can not explain the sudden increase and decrease of pH around 20 meters. For this small blip, I would say there is an incorrect reading but it could be a small flux of algae or something dropping pH.

Figure 5: This graph shows the total dissolved nitrogen as a standard curve, supplying our group with an equation to find the total nitrogen in milligrams per liter, and then comparing that over a much larger area. The points used are in a linear line giving us a graph to show the nitrogen amount grows, following the more area included. Another important thing to include with this graph is the R^2 number when this number is closer to 1 the more accurate the numbers are for the standard curve. Our group's R^2 is 0.998 showing a very accurate equation to find total dissolved nitrogen, and this is partly due in thanks to Alan excluding the bad values seen while measuring. The standard curve is very important to look at as nitrogen is an important element limiting growth for the primary producers within a system.

Figure 6: This figure shows the distribution of Chlorophyll A measurements throughout the entire class. This graph is one of the more spread out data ones, as the mean no group got exactly on, but the readings were all either above or below. This large range was due to different sampling errors as many groups did not keep filters closed or some measured from hypolimnion, to name a few issues with this graph. So based on our data we were on the higher side, due to filtering more water on our samples, but regardless I think the group average turned out okay, giving a decent average. The chlorophyll A helps see the productivity of the lake and life in the epilimnom.

Figure 7: This next figure compares the differences in dissolved organic carbon within two layers of the lake, the Epilimniom and the Hypolimmniom. The two averages as seen on the graph were very close together and this corresponds with the rest of the graphs seen from the sampling project as there is only a slight difference in most measurements. The Epilimnioms DOC was consistently higher than the lower layers and this is due to the top mixing seen in the summer for reservoirs. Most of the DOC is from carbon dioxide being mainly introduced from the atmosphere making the upper levels have a higher mean than the lower. But I wanted to comment on the interesting trend of dissolved organic carbon being only slightly lower and this is due to the temperature and organic decomposition towards the bottom of the system. The colder temperatures allow carbon to stay unused by organic matter although not receiving the constant new supply from the atmosphere. But the organic matter that then dies and sinks to the bottom when decomposing releases carbon keeping the means almost the same but still slightly less than the upper layers of the atmosphere.

Figure 8: This is the most simple graph as it is just viewing the distribution of Secchi depth measurements of the groups. The was about 2.6 meters and the entire class was very consistent in the measurement, as it needed no fancy equipment. Our secchi depths fell into the range of difference of the class mean, guaranteeing the accuracy of the measurement, and this was a large success for us as a class because most samples had much more variability.

2. Phytoplankton Diversity:

Shannon Index: 1.21 Simpson Index: 0.65 When calculating phytoplankton diversity, a Shannon Index indicates richness, and a Simpson Index indicates evenness. With calculating a Shannon Index, a value of 1.21 is considered very low, which means there is low richness and diversity within the microscopic community. This suggests that there is a low biodiversity of phytoplankton present in Horsetooth Reservoir. The Simpson Index was 0.65, closer to 1 than zero, which means there is some evenness/balance across the species within the microscopic community. However, some species are more dominant than others, such as the unidentified phytoplankton. Together, the phytoplankton diversity found contains low diversity with a slight balance in distribution, aside from one dominating species.

Discussion

a. Dissolved organic carbon concentrations often vary as depth increases in lakes, due to processes like water column stratification, production/phytoplankton abundance, organic processes and factors such as allochthonous inputs. In surface waters, DOC levels are influenced by the input of organic material from primary production (e.g., phytoplankton) and terrestrial runoff (or high nutrient loading) from agriculture, human use and industry etc. Deeper waters, particularly in oxygen poor zones, may have less DOC from the decomposition of organic matter, as productivity is reduced in low oxygen environments. In stratified lakes, DOC concentrations are often lower in the hypolimnion compared to the epilimnion.

When looking at the data in Figure 2, we notice that the DOC levels/ percentages significantly change with increasing depth. When we sample, mid-september the water was stratified as the autumn mixing had not yet taken place. This results in a very stark difference in the biogeochemistry of the lake when comparing the hypolimnion and epilimnion.

In Figure 2, we notice that the DOC % and DOC mg/L is higher in concentration when at shallower levels. At depths of around 20m-25m, we notice almost no dissolved oxygen in the system. This is because of the presence of the aphotic zone, no light can penetrate to that depth. Productivity is low and therefore no oxygen is being created at the deeper depths of a stratified lake. Decomposition and anoxic (oxygenless) reactions take place at greater depths. Any processes that require oxygen take place closer to the epilimnion. All the oxygen in the system gets used up by the time it reaches those depths. In addition, with little wind mixing taking place we can explain the contrast in oxygen levels at the surface compared to the benthos.

b. The total nitrogen like the organic carbon is different between the depths in the Horsetooth reservoir due to a few factors of the nitrogen cycle. The Nitrogen cycle includes the exchange of forms of different types of nitrogen, some usable and some unusable but all types are included. But before we get into the nitrogen cycle first we have to talk about the layers formed within the reservoir when studying, at that time in September the weather was hot and the lake layer as seen in figures two, three, and four had a strong epilimnion up to around eight to ten meters with a steep thermocline and then hypolimnion at about fifteen meters and below. This may seem irrelevant but due to the mixing and separation this made the total nitrogen reading different within these three distinct layers. The top layer had the atmospheric nitrogen as well as the excess runoff from human waste and fertilizers. These two influxes we originally thought were supposed to have more nitrogen. But as we said plants use nitrate, a useable type of nitrogen plants can uptake, and with the use of this nitrogen done where the algae is there is less nitrogen at the top of the reservoir in the mixed layer compared to the bottom. At the bottom of the reservoir there is a ton of nutrient cycling from the decomposition of organic matter releasing ammonium. Since there is very little water movement at the bottom of the system the nitrogen is able to freely accumulate. There is also a natural source of nitrogen in the sediment in the hypoxic environment at the bottom of the reservoir the nitrogen is able to fixate and become either ammonium and NH3. Another action at the bottom when there is no

useable oxygen the nitrogen becomes an N2 gas and that is unusable making it just nitrogen not used within the system. This nitrogen from the soil and the atosphere gets spun around in the nitrogen cycle like said and keeps higher levels of nitrogen on the bottom compared to the top.

c. Horsetooth is a reservoir and does not hold all the given characteristics of a lake. As a reservoir, the inputs and outputs into the body of water are unnatural and/or damned. Horsetooth may not be entirely allochthonous meaning that the organic matter may be coming from within the lake and cycling each season. Allochthonous lakes are primarily tributary-fed and have naturally flowing rivers in and out of the body of water. This reservoir is different from most lakes and will thus function differently. Comparing Horsetooth to other reservoirs we notice that Horsetooth is much more variable in its chemistry within the body of water itself and when comparing it to other reservoirs in northern Colorado, (3). This is because of the many tributaries and water bodies that contribute to horsetooth. The Big Thompson and Poudre watershed contribute to Horsetooth and depending on the rainfall and discharge of certain streams/watershed the chemistry of the water will vary. Reservoirs farther away from the base of the mountains/headwaters have more time to homogenize in chemistry allowing for more stable chemistry and composition. For example, this variety in water quality can be seen during black or brown water events when the burnt streams of Cameron Peak deposit sediment into the water and result in high turbidity. This will dramatically alter the chemistry of the water and these events are often unpredictable. Due to Horsetooths' location, at the base of the range, there is little time for the water to homogenize in contrast to other reservoirs in northern Colorado.

When comparing chemicals and toxins, Horseooth has little to no Sulfate, Chlorine, Fluoride, and Nitrate and high amounts of bicarbonate when compared to the Adams and Olympus tunnel (in which some water gets to Horsetooth). Additionally, Horsetooth has little to no Sulfate plus Chloride (when present together can indicate pollution) and Sodium plus Potassium (used to measure soil health in agriculture, a measure of salinity). Horsetooth does however possess slightly higher levels of Magnesium plus Calcium. This heightened level of Magnesium plus Calcium can indicate that the water was eroding rock or came from agriculture. Due to the location and transportation of the water in Horsetooth, it makes sense that these levels are higher. When comparing Horsetooth chemistry to other reservoirs we notice more indication of rock erosion in the water due to the transportation process as compared to agricultural and human-caused pollution in lakes such as Union Reservoir, Windsor Reservoir, DeWeese Reservoir, Cherry Creek Reservoir, etc. These reservoirs are located central to the city and experience many harmful algal blooms and intense terrestrial input because of their location. Horsetooth is tucked into the mountains at a higher elevation and therefore is not as susceptible to the runoff from thousands of acres of farmland or human waste or chemicals from the city. This results in cleaner, more reliable water for the front range.

The similarities in all the reservoirs are that they hold water for multiple uses and are heavily managed or controlled. At Horsetooth, water intake gets shut off when turbidity is too high in the poudre. For reservoirs in the plains, the water taken in is processed and monitored. This ensures the safety of all that use and recreate on the water bodies across the front range.

d. All reservoirs share some basic limnological characteristics because they are man-made and have controlled inflows and no natural outflows. As a result, the water is often still and leads to stratification before seasonal mixing in the fall and spring. Because of the similarity in structure and function, there can be noticeably similar patterns in water chemistry.

However, the main differences between Horsetooth and other reservoirs stem from its location and the sources of water. Horsetooth is situated at a higher elevation in the foothills of the Rocky Mountains, where it gets water from mountain streams that are often clearer and carry more minerals, like calcium and magnesium. Other reservoirs, especially those on the plains receive more water from agricultural runoff and urban areas, which brings in higher

levels of nutrients like Nitrogen and Phosphorus. Along the lines of structure, horsetooth is long and thin which creates a unique seiche/mixing layer within Horsetooth. Most lakes are circular in shape and have a longer, more “normal” seiche/mixing pattern due to wind.

Another difference is the variability in Horsetooth’s water quality. Because it gets water from several tributaries, its water chemistry can change more often, depending on rainfall or even wildfire runoff, like after the Cameron Peak Fire (black/brown water events). This makes its water quality more unpredictable. In contrast, other reservoirs farther from the mountains tend to have more stable water quality, but they can be more affected by pollution from nearby cities and farms.

While Horsetooth shares some basic features with other reservoirs, its higher elevation, proximity to mountain tributaries, and the variability of its tributaries give it cleaner, more mineral-rich water compared to reservoirs located in more urbanized or agricultural areas.

e. Possible errors throughout collecting at Horsetooth Reservoir limited our accuracy to make conclusions on some portions of our data. For example, when collecting Total Dissolved Nitrogen we either did not label or did not take enough samples. Therefore, it was ruled out of the data because of the closeness between the samples, making it difficult to know how to classify the unlabelled samples. In addition, the Dissolved Organic Carbon lacked labels in the differences between our samples from the epilimnion compared to the hypolimnion, also making it difficult to classify the difference between the two. Another study limitation for our group specifically was the time as many of our different samples blended due to limited time. This affected the Chylorphyll A measurements and water chemistry for sure as we had to reuse water and filters making our measurements definitely a little off. We as a group were slightly unprepared and as stated, we with not one hundred percent accuracy were able to get the true measurements. But from all these slight downfalls they would be easily fixed with some practice and more preparation. The nitrogen and carbon labeling issue could have been fixed by preparing our workstation better as well as reading ahead and having a game plan. Another simple fix is practice if we would do the same samples on different occasions we could quickly and much more smoothly take away the large ranges as a class, making the data for all more unstable.

Conclusion

Horsetooth Reservoir is not only a place to swim and boat but it has a much bigger impact on Northern Colorado’s drinking water and for the entire ecosystem around it. Horsetooth, made as a storage system of clean drinking water, acts as an important part of Fort Collins, because of this the viewing and study of this body of water takes the utmost importance. From the countless measurements done on the day of viewing each has an important purpose of keeping the water pristine. The reservoir overall functions as anyone would expect, having certain algae and zooplankton, to the amount of nitrogen and phosphorus that can be found within the water. PH and temperature reflect what most reservoirs around the area see during this time, making our group draw the conclusion the water is taken care of by nature and the people who are paid to look after it. Water is one of our most scarce resources and the test we took confirming the health of water and safety of the ecosystem shows just how valuable this water is to all around.
In this course, we learned about the limnology of lakes globally and completed a case study of the Horsetooth reservoir. In this study, we were able to complete multiple types of chemical and physical analysis in order to understand the limnological characteristics that contribute to horsetooth biogeochemical processes. Horsetooth is a key part of life in Fort Collins, CO as it supplies resources and recreational opportunities for the front range. In-depth learning of horsetooth supported a better overall understanding of limnological processes globally. ## References

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Contribution Roles

Sophia: Investivation, Project Administration, Writing, Visualization, Formal Analysis

Samantha: Investigation, Project Administration, Writing, Data Curation, Formal Analysis, Software

Drew: Investigation, Project Administration, Writing, Visualization, Formal Analysis