Assignment 6: GLMs (Linear Regressios, ANOVA, & t-tests)

Yilin Zhong

Spring 2023

OVERVIEW

This exercise accompanies the lessons in Environmental Data Analytics on generalized linear models.

Directions

1. Rename this file `<FirstLast>_A06_GLMs.Rmd` (replacing `<FirstLast>` with your first and last name).
2. Change "Student Name" on line 3 (above) with your name.
3. Work through the steps, **creating code and output** that fulfill each instruction.
4. Be sure to **answer the questions** in this assignment document.
5. When you have completed the assignment, **Knit** the text and code into a single PDF file.

Set up your session

1. Set up your session. Check your working directory. Load the tidyverse, agricolae and other needed packages. Import the *raw* NTL-LTER raw data file for chemistry/physics (`NTL-LTER_Lake_ChemistryPhysics_Raw.csv`). Set date columns to date objects.

2. Build a ggplot theme and set it as your default theme.

```
#1
getwd()
```

```
## [1] "C:/Users/victo/Desktop/Spring 2023/EDA/EDA-Spring2023"
```

```
library(tidyverse)
```

```
## -- Attaching packages --------------------------------------- tidyverse 1.3.2 --
## v ggplot2 3.3.6      v purrr   0.3.4
## v tibble  3.1.8      v dplyr   1.0.10
## v tidyr   1.2.0      v stringr 1.4.1
## v readr   2.1.2      v forcats 0.5.2
## -- Conflicts ------------------------------------------ tidyverse_conflicts() --
## x dplyr::filter() masks stats::filter()
## x dplyr::lag()    masks stats::lag()
```

```
library(agricolae)
library(here)
```

```
## here() starts at C:/Users/victo/Desktop/Spring 2023/EDA/EDA-Spring2023
```

```
library(lubridate)
```

```
##
## Attaching package: 'lubridate'
##
## The following objects are masked from 'package:base':
##
##     date, intersect, setdiff, union
```

```
library(ggthemes)

NTL_chem<-read.csv("./Data/Raw/NTL-LTER_Lake_ChemistryPhysics_Raw.csv",
                        stringsAsFactors = T)
NTL_chem$sampledate <- as.Date(NTL_chem$sampledate , format = "%m/%d/%y")
class(NTL_chem$sampledate)
```

```
## [1] "Date"
```

```
#2
my_theme<-theme_base()+
  theme(
     legend.background = element_rect(
      color='grey',
      fill = 'white'),
    plot.background = element_rect(
      color = 'white'),
     plot.title = element_text(
      color = 'red'),
    legend.title = element_text(
      color = 'orange')
  )

theme_set(my_theme)
```

Simple regression

Our first research question is: Does mean lake temperature recorded during July change with depth across all lakes?

3. State the null and alternative hypotheses for this question: > Answer: H0: The mean of lake temperature recorded during July is equal with change to depth across all lakes. Ha: The mean of lake temperature recorded during July is not equal with change to depth across all lakes.

4. Wrangle your NTL-LTER dataset with a pipe function so that the records meet the following criteria:

- Only dates in July.
- Only the columns: `lakename`, `year4`, `daynum`, `depth`, `temperature_C`
- Only complete cases (i.e., remove NAs)

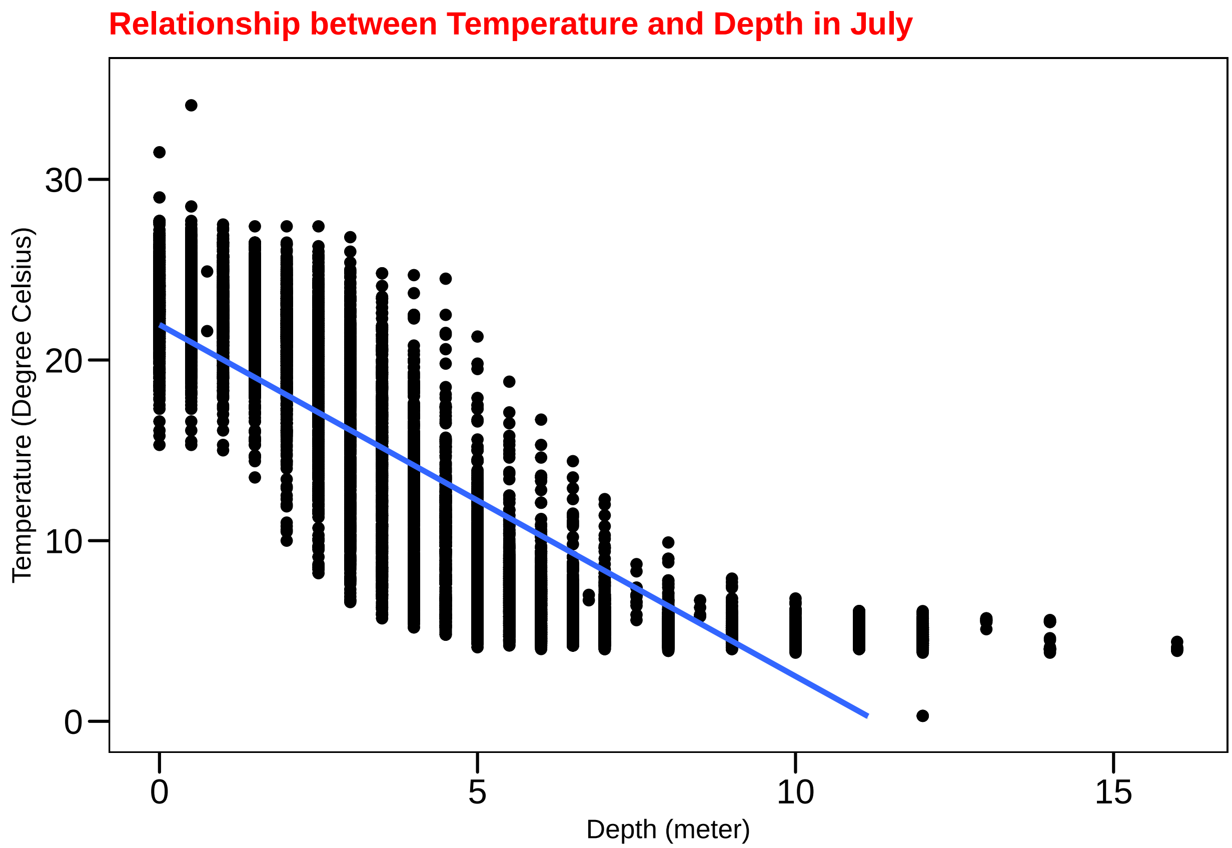
5. Visualize the relationship among the two continuous variables with a scatter plot of temperature by depth. Add a smoothed line showing the linear model, and limit temperature values from 0 to 35 °C. Make this plot look pretty and easy to read.

```
#4
NTL_chem_wrangle<-NTL_chem %>%
  mutate(month = month(sampledate)) %>%
  filter(month == 7) %>%
  select(lakename:daynum, depth:temperature_C) %>%
  na.omit()

#5
ggplot(NTL_chem_wrangle, aes(x=depth, y=temperature_C))+
  geom_point()+
  ylim(0,35)+
  labs(x= "Depth (meter)",
       y="Temperature (Degree Celsius)",
       title = "Relationship between Temperature and Depth in July")+
  theme(title = element_text(size = 10))+
  geom_smooth(method = lm)
```

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

```
## Warning: Removed 24 rows containing missing values (geom_smooth).
```



6. Interpret the figure. What does it suggest with regards to the response of temperature to depth? Do the distribution of points suggest about anything about the linearity of this trend?

   Answer: According to the plot, as depth increases, temperature decreases. By looking at the distribution points, it suggests that the trend is not really linear. It is more like an exponential decrease of temperature as depth increases. For instance, from depth 0 to around 7, the temperature decreases dramtically. After that, the temperature remain quite steady with no significant changes.

7. Perform a linear regression to test the relationship and display the results

```
#7
temp.vs.dep<-lm(data=NTL_chem_wrangle, depth ~ temperature_C)
summary(temp.vs.dep)
```

```
##
## Call:
## lm(formula = depth ~ temperature_C, data = NTL_chem_wrangle)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -4.0685 -1.1065 -0.2334  0.9668  8.0964
##
## Coefficients:
```

```
##                Estimate Std. Error t value Pr(>|t|)
## (Intercept)    9.573728   0.033803   283.2   <2e-16 ***
## temperature_C -0.379578   0.002289  -165.8   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 1.694 on 9726 degrees of freedom
## Multiple R-squared:  0.7387, Adjusted R-squared:  0.7387
## F-statistic: 2.75e+04 on 1 and 9726 DF,  p-value: < 2.2e-16
```

8. Interpret your model results in words. Include how much of the variability in temperature is explained by changes in depth, the degrees of freedom on which this finding is based, and the statistical significance of the result. Also mention how much temperature is predicted to change for every 1m change in depth.

   Answer:73.97% of variability in temperature is explained by changes in depth. This finding is based on 9726 degrees of freedom. The result is statistically significant as the p-value is much less than 0.05, with a p-vaulue of <0.001. Every 1m increase in depth results in decreases of 0.38 degrees Celsius in temperature.

Multiple regression

Let's tackle a similar question from a different approach. Here, we want to explore what might the best set of predictors for lake temperature in July across the monitoring period at the North Temperate Lakes LTER.

9. Run an AIC to determine what set of explanatory variables (year4, daynum, depth) is best suited to predict temperature.

10. Run a multiple regression on the recommended set of variables.

```r
#9
NTL_lm.aic<-lm(data=NTL_chem_wrangle,temperature_C ~ year4 + daynum + depth)
step(NTL_lm.aic)
```

```
## Start:  AIC=26065.53
## temperature_C ~ year4 + daynum + depth
##
##          Df Sum of Sq    RSS   AIC
## <none>                141687 26066
## - year4   1       101 141788 26070
## - daynum  1      1237 142924 26148
## - depth   1    404475 546161 39189

##
## Call:
## lm(formula = temperature_C ~ year4 + daynum + depth, data = NTL_chem_wrangle)
##
## Coefficients:
## (Intercept)        year4       daynum        depth
##    -8.57556      0.01134      0.03978     -1.94644
```

```r
#10
aicmodel<-lm(data=NTL_chem_wrangle,temperature_C ~ year4 + daynum + depth)
summary(aicmodel)
```

```
##
## Call:
## lm(formula = temperature_C ~ year4 + daynum + depth, data = NTL_chem_wrangle)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -9.6536 -3.0000  0.0902  2.9658 13.6123
##
## Coefficients:
##              Estimate Std. Error  t value Pr(>|t|)
## (Intercept) -8.575564   8.630715   -0.994  0.32044
## year4        0.011345   0.004299    2.639  0.00833 **
## daynum       0.039780   0.004317    9.215  < 2e-16 ***
## depth       -1.946437   0.011683 -166.611  < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 3.817 on 9724 degrees of freedom
## Multiple R-squared:  0.7412, Adjusted R-squared:  0.7411
## F-statistic:  9283 on 3 and 9724 DF,  p-value: < 2.2e-16
```

11. What is the final set of explanatory variables that the AIC method suggests we use to predict temperature in our multiple regression? How much of the observed variance does this model explain? Is this an improvement over the model using only depth as the explanatory variable?

    Answer: The final set of explanatory variables that the AIC method suggests us to use to predict temperature in our multiple regression are year4, daynum, and depth. This model explain 74.12% of the observed variance. This is an improvement over the model using only depth as the explanatory variable because the adjusted R squared in here is higher than the adjusted r-squared value in the previous model.

Analysis of Variance

12. Now we want to see whether the different lakes have, on average, different temperatures in the month of July. Run an ANOVA test to complete this analysis. (No need to test assumptions of normality or similar variances.) Create two sets of models: one expressed as an ANOVA models and another expressed as a linear model (as done in our lessons).

```r
#12
lake.vs.temp.ano<-aov(data = NTL_chem_wrangle,temperature_C~ lakename)
summary(lake.vs.temp.ano)
```

```
##               Df Sum Sq Mean Sq F value Pr(>F)
## lakename       8  21642  2705.2      50 <2e-16 ***
## Residuals   9719 525813    54.1
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```r
lake.vs.temp.ano2<-lm(data = NTL_chem_wrangle,temperature_C~ lakename)
summary(lake.vs.temp.ano2)
```

```
##
## Call:
## lm(formula = temperature_C ~ lakename, data = NTL_chem_wrangle)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -10.769  -6.614  -2.679   7.684  23.832
##
## Coefficients:
##                          Estimate Std. Error t value Pr(>|t|)
## (Intercept)               17.6664     0.6501  27.174  < 2e-16 ***
## lakenameCrampton Lake     -2.3145     0.7699  -3.006 0.002653 **
## lakenameEast Long Lake    -7.3987     0.6918 -10.695  < 2e-16 ***
## lakenameHummingbird Lake  -6.8931     0.9429  -7.311 2.87e-13 ***
## lakenamePaul Lake         -3.8522     0.6656  -5.788 7.36e-09 ***
## lakenamePeter Lake        -4.3501     0.6645  -6.547 6.17e-11 ***
## lakenameTuesday Lake      -6.5972     0.6769  -9.746  < 2e-16 ***
## lakenameWard Lake         -3.2078     0.9429  -3.402 0.000672 ***
## lakenameWest Long Lake    -6.0878     0.6895  -8.829  < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 7.355 on 9719 degrees of freedom
## Multiple R-squared:  0.03953,    Adjusted R-squared:  0.03874
## F-statistic:    50 on 8 and 9719 DF,  p-value: < 2.2e-16
```

13. Is there a significant difference in mean temperature among the lakes? Report your findings.

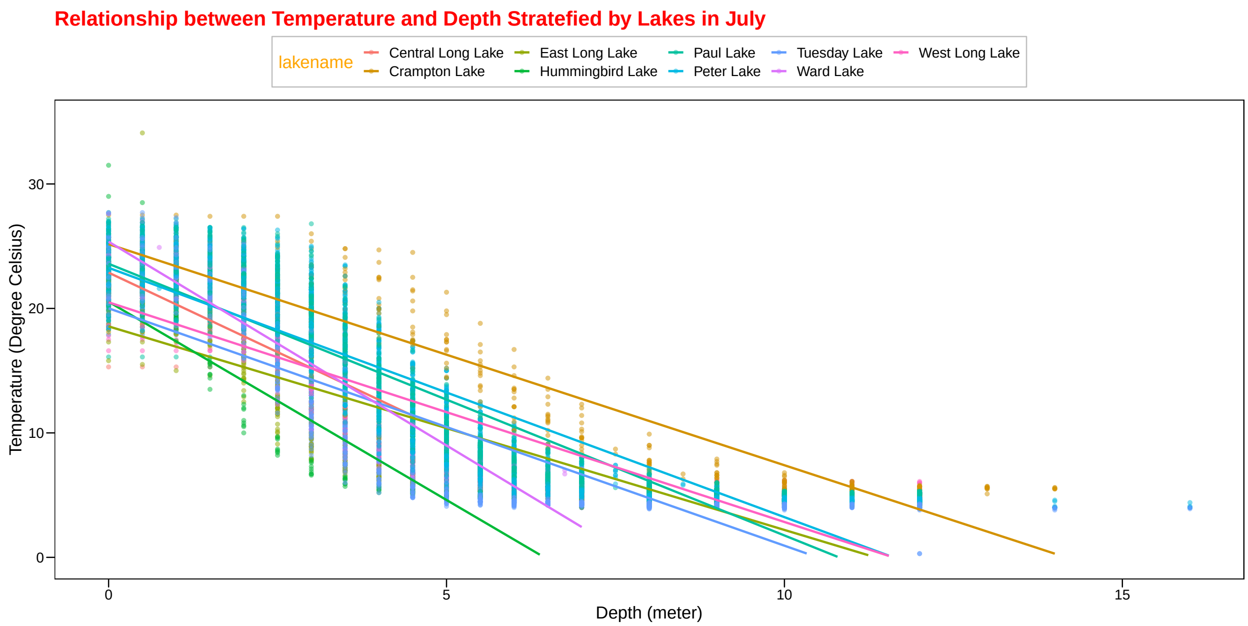
    Answer: Given the result of the anova model and lm model, there is a significant difference in mean temperature among the lakes. For instance, in the anova model, the p-value if way less than 0.05, with a p-value of <0.001. This rejects the Null hypothesis, and stating that difference between a pair of group means is statistically significant. This is the same for the lm model, which the p-value for this lm model is <0.001 that rejects the null hypothesis, and states that all coefficient in the model is not equal to 0. This states that the mean are not the same across the lakes.

14. Create a graph that depicts temperature by depth, with a separate color for each lake. Add a geom_smooth (method = "lm", se = FALSE) for each lake. Make your points 50 % transparent. Adjust your y axis limits to go from 0 to 35 degrees. Clean up your graph to make it pretty.

```r
#14.
ggplot(NTL_chem_wrangle, aes(x=depth, y=temperature_C, color=lakename))+
  geom_point(alpha = 0.5)+
  ylim(0,35)+
  labs(x= "Depth (meter)",
       y="Temperature (Degree Celsius)",
       title = "Relationship between Temperature and Depth Stratefied by Lakes in July")+
  theme(legend.position = "top")+
  geom_smooth(method = lm, se= FALSE)
```

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

## Warning: Removed 73 rows containing missing values (geom_smooth).
```



15. Use the Tukey's HSD test to determine which lakes have different means.

```
#15
TukeyHSD(lake.vs.temp.ano)
```

```
##   Tukey multiple comparisons of means
##     95% family-wise confidence level
##
## Fit: aov(formula = temperature_C ~ lakename, data = NTL_chem_wrangle)
##
## $lakename
##                                          diff        lwr        upr     p adj
## Crampton Lake-Central Long Lake    -2.3145195 -4.7031913  0.0741524 0.0661566
## East Long Lake-Central Long Lake   -7.3987410 -9.5449411 -5.2525408 0.0000000
## Hummingbird Lake-Central Long Lake -6.8931304 -9.8184178 -3.9678430 0.0000000
## Paul Lake-Central Long Lake        -3.8521506 -5.9170942 -1.7872070 0.0000003
## Peter Lake-Central Long Lake       -4.3501458 -6.4115874 -2.2887042 0.0000000
## Tuesday Lake-Central Long Lake     -6.5971805 -8.6971605 -4.4972005 0.0000000
## Ward Lake-Central Long Lake        -3.2077856 -6.1330730 -0.2824982 0.0193405
## West Long Lake-Central Long Lake   -6.0877513 -8.2268550 -3.9486475 0.0000000
## East Long Lake-Crampton Lake       -5.0842215 -6.5591700 -3.6092730 0.0000000
## Hummingbird Lake-Crampton Lake     -4.5786109 -7.0538088 -2.1034131 0.0000004
## Paul Lake-Crampton Lake            -1.5376312 -2.8916215 -0.1836408 0.0127491
## Peter Lake-Crampton Lake           -2.0356263 -3.3842699 -0.6869828 0.0000999
## Tuesday Lake-Crampton Lake         -4.2826611 -5.6895065 -2.8758157 0.0000000
## Ward Lake-Crampton Lake            -0.8932661 -3.3684639  1.5819317 0.9714459
## West Long Lake-Crampton Lake       -3.7732318 -5.2378351 -2.3086285 0.0000000
## Hummingbird Lake-East Long Lake     0.5056106 -1.7364925  2.7477137 0.9988050
```

```
## Paul Lake-East Long Lake            3.5465903  2.6900206  4.4031601 0.0000000
## Peter Lake-East Long Lake           3.0485952  2.2005025  3.8966879 0.0000000
## Tuesday Lake-East Long Lake         0.8015604 -0.1363286  1.7394495 0.1657485
## Ward Lake-East Long Lake            4.1909554  1.9488523  6.4330585 0.0000002
## West Long Lake-East Long Lake       1.3109897  0.2885003  2.3334791 0.0022805
## Paul Lake-Hummingbird Lake          3.0409798  0.8765299  5.2054296 0.0004495
## Peter Lake-Hummingbird Lake         2.5429846  0.3818755  4.7040937 0.0080666
## Tuesday Lake-Hummingbird Lake       0.2959499 -1.9019508  2.4938505 0.9999752
## Ward Lake-Hummingbird Lake          3.6853448  0.6889874  6.6817022 0.0043297
## West Long Lake-Hummingbird Lake     0.8053791 -1.4299320  3.0406903 0.9717297
## Peter Lake-Paul Lake               -0.4979952 -1.1120620  0.1160717 0.2241586
## Tuesday Lake-Paul Lake             -2.7450299 -3.4781416 -2.0119182 0.0000000
## Ward Lake-Paul Lake                 0.6443651 -1.5200848  2.8088149 0.9916978
## West Long Lake-Paul Lake           -2.2356007 -3.0742314 -1.3969699 0.0000000
## Tuesday Lake-Peter Lake            -2.2470347 -2.9702236 -1.5238458 0.0000000
## Ward Lake-Peter Lake                1.1423602 -1.0187489  3.3034693 0.7827037
## West Long Lake-Peter Lake          -1.7376055 -2.5675759 -0.9076350 0.0000000
## Ward Lake-Tuesday Lake              3.3893950  1.1914943  5.5872956 0.0000609
## West Long Lake-Tuesday Lake         0.5094292 -0.4121051  1.4309636 0.7374387
## West Long Lake-Ward Lake           -2.8799657 -5.1152769 -0.6446546 0.0021080
```

```r
lakevstemp.hsd<-HSD.test(lake.vs.temp.ano, "lakename", group = TRUE)
lakevstemp.hsd
```

```
## $statistics
##   MSerror   Df     Mean       CV
##   54.1016 9719 12.72087 57.82135
##
## $parameters
##    test   name.t ntr StudentizedRange alpha
##   Tukey lakename   9         4.387504  0.05
##
## $means
##                   temperature_C      std    r Min  Max    Q25   Q50    Q75
## Central Long Lake      17.66641 4.196292  128 8.9 26.8 14.400 18.40 21.000
## Crampton Lake          15.35189 7.244773  318 5.0 27.5  7.525 16.90 22.300
## East Long Lake         10.26767 6.766804  968 4.2 34.1  4.975  6.50 15.925
## Hummingbird Lake       10.77328 7.017845  116 4.0 31.5  5.200  7.00 15.625
## Paul Lake              13.81426 7.296928 2660 4.7 27.7  6.500 12.40 21.400
## Peter Lake             13.31626 7.669758 2872 4.0 27.0  5.600 11.40 21.500
## Tuesday Lake           11.06923 7.698687 1524 0.3 27.7  4.400  6.80 19.400
## Ward Lake              14.45862 7.409079  116 5.7 27.6  7.200 12.55 23.200
## West Long Lake         11.57865 6.980789 1026 4.0 25.7  5.400  8.00 18.800
##
## $comparison
## NULL
##
## $groups
##                   temperature_C groups
## Central Long Lake      17.66641      a
## Crampton Lake          15.35189     ab
## Ward Lake              14.45862     bc
## Paul Lake              13.81426      c
## Peter Lake             13.31626      c
```

```
## West Long Lake         11.57865      d
## Tuesday Lake           11.06923     de
## Hummingbird Lake       10.77328     de
## East Long Lake         10.26767      e
##
## attr(,"class")
## [1] "group"
```

16.From the findings above, which lakes have the same mean temperature, statistically speaking, as Peter Lake? Does any lake have a mean temperature that is statistically distinct from all the other lakes?

> Answer:From the findings above, statistically speaking, Paul and Ward lakes have the same mean temperature with Peter lake.There is no lake that have a mean temperature that is statistically distinct from all the other lakes because all of the lakes are at least have one other lake that the mean temperature are the same with each other. All of the lakes have at least one other lake that they belong to the same group, which means same mean temperature.

17. If we were just looking at Peter Lake and Paul Lake. What's another test we might explore to see whether they have distinct mean temperatures?

> Answer: Another test we might explore to see whether they have distinct mean temperatures is two-sample t-test. Two sample T-test compares the means between two groups.

18. Wrangle the July data to include only records for Crampton Lake and Ward Lake. Run the two-sample T-test on these data to determine whether their July temperature are same or different. What does the test say? Are the mean temperatures for the lakes equal? Does that match you answer for part 16?

```
cramp.ward<-NTL_chem_wrangle %>%
filter(lakename == "Ward Lake"| lakename == "Crampton Lake")

t.test(cramp.ward$temperature_C ~ cramp.ward$lakename)
```

```
##
##  Welch Two Sample t-test
##
## data:  cramp.ward$temperature_C by cramp.ward$lakename
## t = 1.1181, df = 200.37, p-value = 0.2649
## alternative hypothesis: true difference in means between group Crampton Lake and group Ward Lake is n
## 95 percent confidence interval:
##  -0.6821129  2.4686451
## sample estimates:
## mean in group Crampton Lake     mean in group Ward Lake
##                    15.35189                    14.45862
```

> Answer: The test shown a p-value of 0.2649, which is greater than 0.05. This means it does not have enough evidence to reject the null hypothesis and stating that the mean temperature for the lakes are equal. This matches the answer from part 16 because the post-hoc test in part 16 shows that the two lakes belong to the same group, which means they have the same mean temperature.