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

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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] "/home/guest/R/EDA-Fall2022"
```

```
install.packages("formatR")
```

```
## Installing package into '/home/guest/R/x86_64-pc-linux-gnu-library/4.2'
## (as 'lib' is unspecified)
```

```
install.packages("tidyverse")
```

```
## Installing package into '/home/guest/R/x86_64-pc-linux-gnu-library/4.2'
## (as 'lib' is unspecified)
```

```
install.packages("agricolae")
```

```
## Installing package into '/home/guest/R/x86_64-pc-linux-gnu-library/4.2'
## (as 'lib' is unspecified)
```

```r
install.packages("lubridate")
```

```
## Installing package into '/home/guest/R/x86_64-pc-linux-gnu-library/4.2'
## (as 'lib' is unspecified)
```

```r
install.packages("corrplot")
```

```
## Installing package into '/home/guest/R/x86_64-pc-linux-gnu-library/4.2'
## (as 'lib' is unspecified)
```

```r
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()
```

```r
library(agricolae)
library(lubridate)
```

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

```r
library(corrplot)
```

```
## corrplot 0.92 loaded
```

```r
NTL.chem.raw <- read.csv("./Data/Raw/NTL-LTER_Lake_ChemistryPhysics_Raw.csv",
    stringsAsFactors = TRUE)

NTL.chem.raw$sampledate <- as.Date(NTL.chem.raw$sampledate,
    format = "%m/%d/%y")
class(NTL.chem.raw$sampledate)
```

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

```r
# 2
mytheme <- theme_classic(base_size = 14) + theme(axis.text = element_text(color = "black"),
    legend.position = "top")

theme_set(mytheme)  #set theme for all subsequent plots
```

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: Lake temerpature does not change with depth during the month of July Ha: Lake temperature does change with depth during the month of July

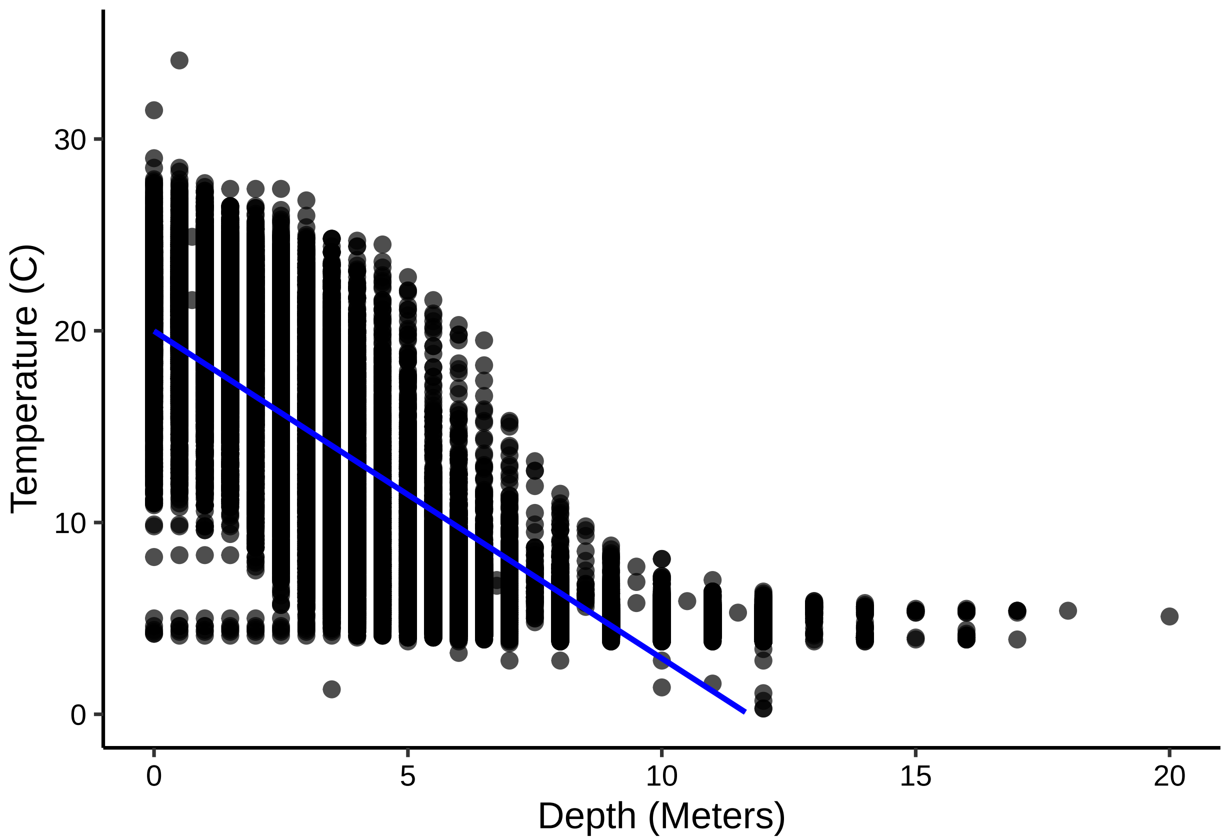
4. Wrangle your NTL-LTER dataset with a pipe function so that the records meet the following criteria:

- 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.wrangled <- NTL.chem.raw %>%
    mutate(Month = month(sampledate)) %>%
    filter(Month == 7) %>%
    select(lakename, year4, daynum, depth, temperature_C) %>%
    na.omit()

# 5

# scatterplot
temp.vs.depth <- ggplot(NTL.chem.raw, aes(x = depth,
    y = temperature_C)) + geom_point(alpha = 0.7, size = 2.5) +
    geom_smooth(method = lm, color = "blue") + ylim(0,
    35) + theme(legend.position = "top") + labs(x = "Depth (Meters)",
    y = "Temperature (C)")
print(temp.vs.depth)
```

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

## Warning: Removed 3858 rows containing non-finite values (stat_smooth).

## Warning: Removed 3858 rows containing missing values (geom_point).

## Warning: Removed 33 rows containing missing values (geom_smooth).
```




```
6. Interpret the figure. What does it suggest with regards to the response of temperature to depth? Do t

> Answer: As depth increases temperature increases. This shows a negative correclation between temperatu
```

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

```r
# 7

# regression information
temp.depth.regression <- lm(NTL.chem.raw$temperature_C ~
    NTL.chem.raw$depth)
summary(temp.depth.regression)
```

```
##
## Call:
## lm(formula = NTL.chem.raw$temperature_C ~ NTL.chem.raw$depth)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -15.7864  -3.1363  -0.1219   3.1815  19.2568
##
## Coefficients:
```

```
##                      Estimate Std. Error t value Pr(>|t|)
## (Intercept)         19.986395   0.037166   537.8   <2e-16 ***
## NTL.chem.raw$depth -1.707162   0.006366  -268.2   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 3.961 on 34754 degrees of freedom
##   (3858 observations deleted due to missingness)
## Multiple R-squared:  0.6742, Adjusted R-squared:  0.6742
## F-statistic: 7.192e+04 on 1 and 34754 DF,  p-value: < 2.2e-16
```

```
# correlation
cor.test(NTL.chem.raw$temperature_C, NTL.chem.raw$depth)
```

```
##
##  Pearson's product-moment correlation
##
## data:  NTL.chem.raw$temperature_C and NTL.chem.raw$depth
## t = -268.17, df = 34754, p-value < 2.2e-16
## alternative hypothesis: true correlation is not equal to 0
## 95 percent confidence interval:
##  -0.8244884 -0.8176373
## sample estimates:
##        cor
## -0.8210924
```

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: The R-squared value is 0.67 percent which means that 67% of the data is repersented by 34754 degrees of freedom. Also you have a negative correlcation of - 0.81 between temperature and depth.

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.

```
# 9

TPAIC <- lm(data = NTL.chem.wrangled, temperature_C ~
    year4 + daynum + depth)
step(TPAIC)
```

```
## 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.wrangled)
##
## Coefficients:
## (Intercept)        year4       daynum        depth
##    -8.57556      0.01134      0.03978     -1.94644
```

```
summary(TPAIC)
```

```
##
## Call:
## lm(formula = temperature_C ~ year4 + daynum + depth, data = NTL.chem.wrangled)
##
## 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
```

```
# NTL.corr <- cor(NTL.chem.wrangled)
# corrplot(NTL.corr, method = 'ellipse')
# corrplot.mixed(NTL.corr, upper = 'ellipse')

# 10
tempregression <- lm(data = NTL.chem.wrangled, temperature_C ~
    year4 + daynum + depth)
summary(tempregression)
```

```
##
## Call:
## lm(formula = temperature_C ~ year4 + daynum + depth, data = NTL.chem.wrangled)
```

```
##
## 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
```

```r
variable.regression <- lm(data = NTL.chem.wrangled,
    temperature_C ~ year4 + daynum)
summary(variable.regression)
```

```
##
## Call:
## lm(formula = temperature_C ~ year4 + daynum, data = NTL.chem.wrangled)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -12.279  -7.158  -2.591   8.072  21.402
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept) -2.827705  16.944033  -0.167    0.867
## year4        0.003779   0.008439   0.448    0.654
## daynum       0.040484   0.008475   4.777 1.81e-06 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 7.494 on 9725 degrees of freedom
## Multiple R-squared:  0.002363,   Adjusted R-squared:  0.002158
## F-statistic: 11.52 on 2 and 9725 DF,  p-value: 1.007e-05
```

```r
variable.regression <- lm(data = NTL.chem.wrangled,
    temperature_C ~ year4 + daynum + depth)
summary(variable.regression)
```

```
##
## Call:
## lm(formula = temperature_C ~ year4 + daynum + depth, data = NTL.chem.wrangled)
##
## 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 R-squared value increased from .67 when just using depth to 0.74 when adding in year4, daynum. A regression run with out depth returns an R squared value of 0.002363. None has the lowest AIC vairable of 26066 so all of the other varialbes will stay in the regression.

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).

```
# 12

# Do not use #
# bartlett.test(NTL.chem.wrangled$lakename
# ~NTL.chem.wrangled$temperature_C)

anova.lakes <- aov(data = NTL.chem.wrangled, temperature_C ~
    lakename)
summary(anova.lakes)
```

```
##                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
```

```
anova.lakes.lm <- lm(data = NTL.chem.wrangled, temperature_C ~
    lakename)
summary(anova.lakes.lm)
```

```
##
## Call:
## lm(formula = temperature_C ~ lakename, data = NTL.chem.wrangled)
##
## 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.

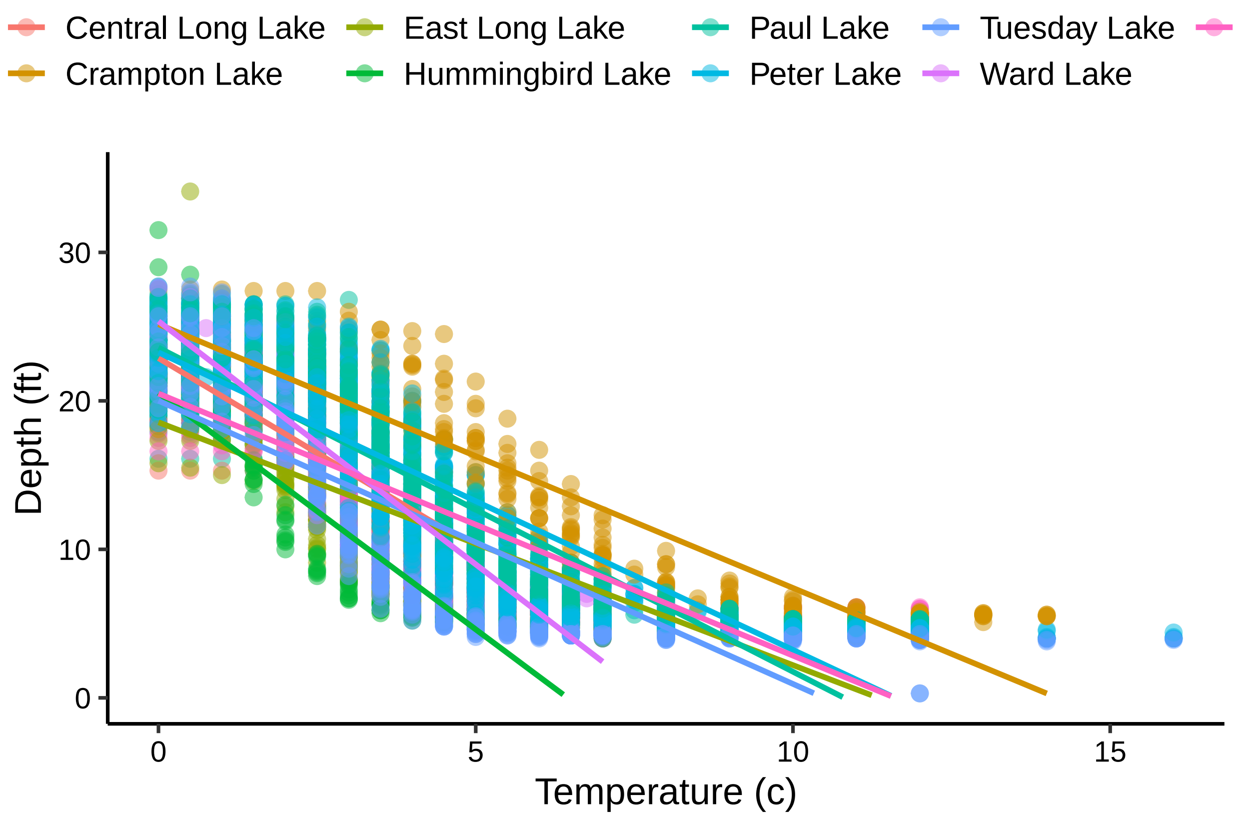
    Answer: The Anova model shows that mean temperature among all the lakes to be statistically signicant. The linear model shows how statistically different every single lake is by providing a their specific p-values. The estimated standard delivation from the intercept is different from intecept temberapture. The standard error value on th linear model is 7.355.

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.
temp.depth.3 <- ggplot(NTL.chem.wrangled, aes(x = depth,
    y = temperature_C, color = lakename)) + geom_point(alpha = 0.5,
    size = 2.5) + geom_smooth(method = lm, se = FALSE) +
    ylim(0, 35) + labs(x = "Temperature (c)", y = "Depth (ft)") +
    theme(legend.position = "top", legend.text = element_text(size = 12),
        legend.title = element_text(size = 12))
print(temp.depth.3)
```

```
## `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(anova.lakes)
```

```
##   Tukey multiple comparisons of means
##     95% family-wise confidence level
##
## Fit: aov(formula = temperature_C ~ lakename, data = NTL.chem.wrangled)
##
## $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
```

```
anova.lakes.hsd <- HSD.test(anova.lakes, "lakename",
    group = TRUE)
anova.lakes.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"
```

```
summary.aov(anova.lakes)
```

```
##               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
```

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: The Anova test does not idenfiy particular differences between paris of means are significant. This Tukey Honest Significant Differerences method determines. Peter and Paul lake both have c grouping and similar means. Peter and paul lake are statistically sginfication with means temp of 13.31 and 13.81 respectively. Ward Lake-Crampton Lake have a difference in mean temperature of 0.8932661

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: We could run a two sample T test on peter and paul lake.

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?

```
# Ho Mu>=50 Ha mu<50

crampton.ward.lake <- NTL.chem.wrangled %>%
    filter(lakename == c("Crampton Lake", "Ward Lake"))

summary(crampton.ward.lake)
```

```
##               lakename       year4          daynum          depth
##  Crampton Lake    :159   Min.   :1999   Min.   :183.0   Min.   : 0.000
##  Ward Lake        : 56   1st Qu.:2004   1st Qu.:188.0   1st Qu.: 2.000
##  Central Long Lake:  0   Median :2005   Median :197.0   Median : 4.500
```

```
##  East Long Lake   :  0   Mean   :2006   Mean   :196.7   Mean   : 4.947
##  Hummingbird Lake :  0   3rd Qu.:2010   3rd Qu.:204.0   3rd Qu.: 6.875
##  Paul Lake        :  0   Max.   :2012   Max.   :211.0   Max.   :14.000
##  (Other)          :  0
##  temperature_C
##  Min.   : 5.00
##  1st Qu.: 7.25
##  Median :15.10
##  Mean   :15.08
##  3rd Qu.:22.30
##  Max.   :27.50
##
```

```
length(crampton.ward.lake)
```

```
## [1] 5
```

```
crampton.ward.ttest <- t.test(crampton.ward.lake$temperature_C,
    mu = 50, alternative = "less")
crampton.ward.ttest
```

```
##
##  One Sample t-test
##
## data:  crampton.ward.lake$temperature_C
## t = -70.513, df = 214, p-value < 2.2e-16
## alternative hypothesis: true mean is less than 50
## 95 percent confidence interval:
##      -Inf 15.89812
## sample estimates:
## mean of x
##     15.08
```

```
ttest2 <- t.test(crampton.ward.lake$temperature_C ~
    crampton.ward.lake$lakename)
ttest2
```

```
##
##  Welch Two Sample t-test
##
## data:  crampton.ward.lake$temperature_C by crampton.ward.lake$lakename
## t = 0.98673, df = 95.77, p-value = 0.3263
## alternative hypothesis: true difference in means between group Crampton Lake and group Ward Lake is n
## 95 percent confidence interval:
##  -1.130614  3.365610
## sample estimates:
## mean in group Crampton Lake     mean in group Ward Lake
##                    15.37107                    14.25357
```

Answer: There are 214 degrees of freedom or obervations. The p value is 0.5 so we are rejecting the null hypothesis and accepting the alternative hypotheis. The means of Crampton lake is 15.37 and the mean of Ward Lake is 14.25.