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 setting up my session
getwd()
```

```
## [1] "/Users/kariis/Documents/EDA2"
```

```
library(tidyverse)
```

```
## -- Attaching packages --------------------------------------- tidyverse 1.3.2 --
## v ggplot2 3.4.0     v purrr   1.0.1
## v tibble  3.1.8     v dplyr   1.1.0
## v tidyr   1.3.0     v stringr 1.5.0
## v readr   2.1.3     v forcats 1.0.0
## -- Conflicts ------------------------------------------ tidyverse_conflicts() --
## x dplyr::filter() masks stats::filter()
## x dplyr::lag()    masks stats::lag()
```

```r
library(agricolae)
library(ggplot2)
library(corrplot)
```

```
## corrplot 0.92 loaded
```

```r
library(here)
```

```
## here() starts at /Users/kariis/Documents/EDA2
```

```r
library(formatR)
library(lubridate)
```

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

```r
#reading in raw data
LakeChemRaw <-
  read.csv(here("./Data/Raw/NTL-LTER_Lake_ChemistryPhysics_Raw.csv"),
           stringsAsFactors = TRUE)
#fixing date column to be read as an object, not a factor
class(LakeChemRaw$sampledate)
```

```
## [1] "factor"
```

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

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

```r
#2 building a ggplot theme!
ThemeBuilder <- theme_classic(base_size = 14) +
  theme(axis.text = element_text(color = "blue"),
        legend.position = "top")

theme_set(ThemeBuilder)
```

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: Mean lake temperature recorded during July does not change with depth across the lakes. Ha: Mean lake temperature recorded during July does change with depth across the 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
#wrangling the data
#omitting NAs

LakeChemGroups <- LakeChemRaw %>%
  group_by(lakename, sampledate, year4, daynum, depth, temperature_C) %>%
  summarise() %>%
  na.omit(temperature_C)
```

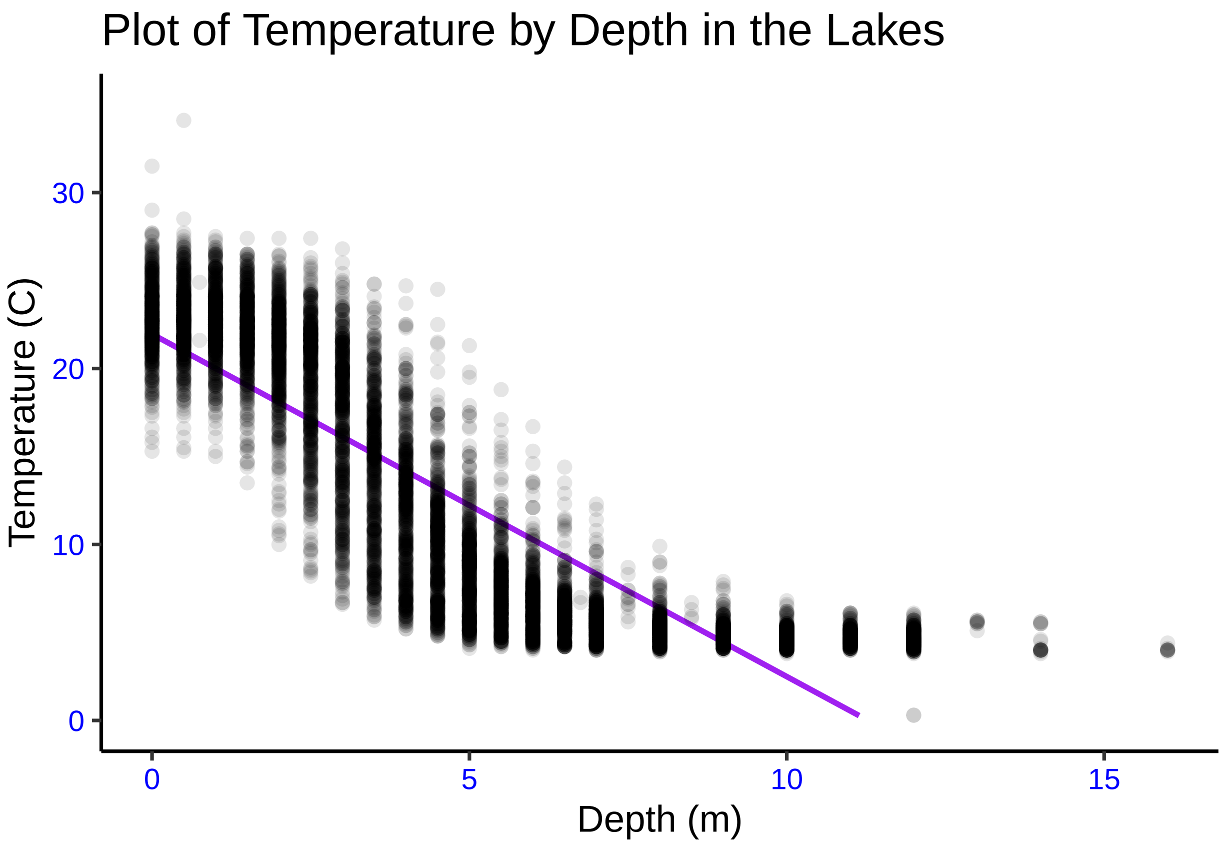
```
## `summarise()` has grouped output by 'lakename', 'sampledate', 'year4',
## 'daynum', 'depth'. You can override using the `.groups` argument.
```

```
LakeChemMonthCol <- mutate(LakeChemGroups, month= month(sampledate)) %>%
  filter(month %in% c(7))


#5 linear regression scatter plot
Laketempbydepth <-
  ggplot(LakeChemMonthCol, aes(x = depth, y = temperature_C)) +
  labs(title = "Plot of Temperature by Depth in the Lakes", x = "Depth (m)", y = "Temperature (C)") +
  geom_smooth(method = "lm", se = FALSE, color = "purple") +
  ylim (0, 35) +
  geom_point(alpha = 1/10, size = 2)
print(Laketempbydepth)
```

```
## `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: The greater the depth, the lower the temperature.

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

```
#7 performing a correlation test to reject or accept null hypothesis
cor.test(LakeChemMonthCol$depth, LakeChemMonthCol$temperature_C)
```

```
##
##  Pearson's product-moment correlation
##
## data:  LakeChemMonthCol$depth and LakeChemMonthCol$temperature_C
## t = -165.83, df = 9726, p-value < 2.2e-16
## alternative hypothesis: true correlation is not equal to 0
## 95 percent confidence interval:
##  -0.8646036 -0.8542169
## sample estimates:
##        cor
## -0.8594989
```

```
lakeregression <- lm(data = LakeChemMonthCol, temperature_C ~ depth)
summary(lakeregression)
```

```
##
## Call:
## lm(formula = temperature_C ~ depth, data = LakeChemMonthCol)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -9.5173 -3.0192  0.0633  2.9365 13.5834
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept) 21.95597    0.06792   323.3   <2e-16 ***
## depth       -1.94621    0.01174  -165.8   <2e-16 ***
## ---
## Signif. codes:  0 ’***’ 0.001 ’**’ 0.01 ’*’ 0.05 ’.’ 0.1 ’ ’ 1
##
## Residual standard error: 3.835 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: There is a significant negative correlation between temperature and depth (greater depths = lower temperature) and this model shows about 73% of the total vairance in temperature. There is a strong correlation between the two varibales at 0.85. With a p-value of less than 0, we can reject the null hypothesis and accept that there is a direct correlation between the variables. Y-intercept: 21.9559 + depth: -1.9462 = a change in 1 meter in depth will bring about a -1.9462 temp change.

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
LakeAIC <- lm(data = LakeChemMonthCol, temperature_C ~ daynum + year4 + depth)

step(LakeAIC)
```

```
## Start:  AIC=26065.53
## temperature_C ~ daynum + year4 + 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 ~ daynum + year4 + depth, data = LakeChemMonthCol)
##
## Coefficients:
## (Intercept)       daynum        year4        depth
##    -8.57556      0.03978      0.01134     -1.94644
```

```
#10
AicModel <- lm(data = LakeChemMonthCol, temperature_C ~ daynum + year4 + depth)
summary(AicModel)
```

```
##
## Call:
## lm(formula = temperature_C ~ daynum + year4 + depth, data = LakeChemMonthCol)
##
## 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
## daynum       0.039780   0.004317    9.215  < 2e-16 ***
## year4        0.011345   0.004299    2.639  0.00833 **
## 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 AIC method suggested we remove no data to predict temperature the best.

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 averaging of diff temps by lakename
Difftemps <- LakeChemMonthCol %>%
  group_by(sampledate, lakename) %>%
  summarise()
```

```
## ‘summarise()‘ has grouped output by ’sampledate’. You can override using the
## ‘.groups‘ argument.
```

```
summary(Difftemps)
```

```
##    sampledate                     lakename
##  Min.   :1984-07-01   Paul Lake      :150
##  1st Qu.:1991-07-24   Peter Lake     :150
##  Median :1997-07-25   Tuesday Lake   : 86
##  Mean   :1999-02-16   West Long Lake: 52
##  3rd Qu.:2006-07-03   East Long Lake: 49
##  Max.   :2016-07-27   Crampton Lake : 15
##                       (Other)       : 31
```

```
#running anova test 1
TempsAnova <- aov(data = LakeChemMonthCol, temperature_C ~ lakename)
summary(TempsAnova)
```

```
##               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
```

```
#running anova test 2 with lm
TempsAnova2 <- lm(data = LakeChemMonthCol, temperature_C ~ lakename)
summary(TempsAnova2)
```

```
##
## Call:
## lm(formula = temperature_C ~ lakename, data = LakeChemMonthCol)
##
## 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.

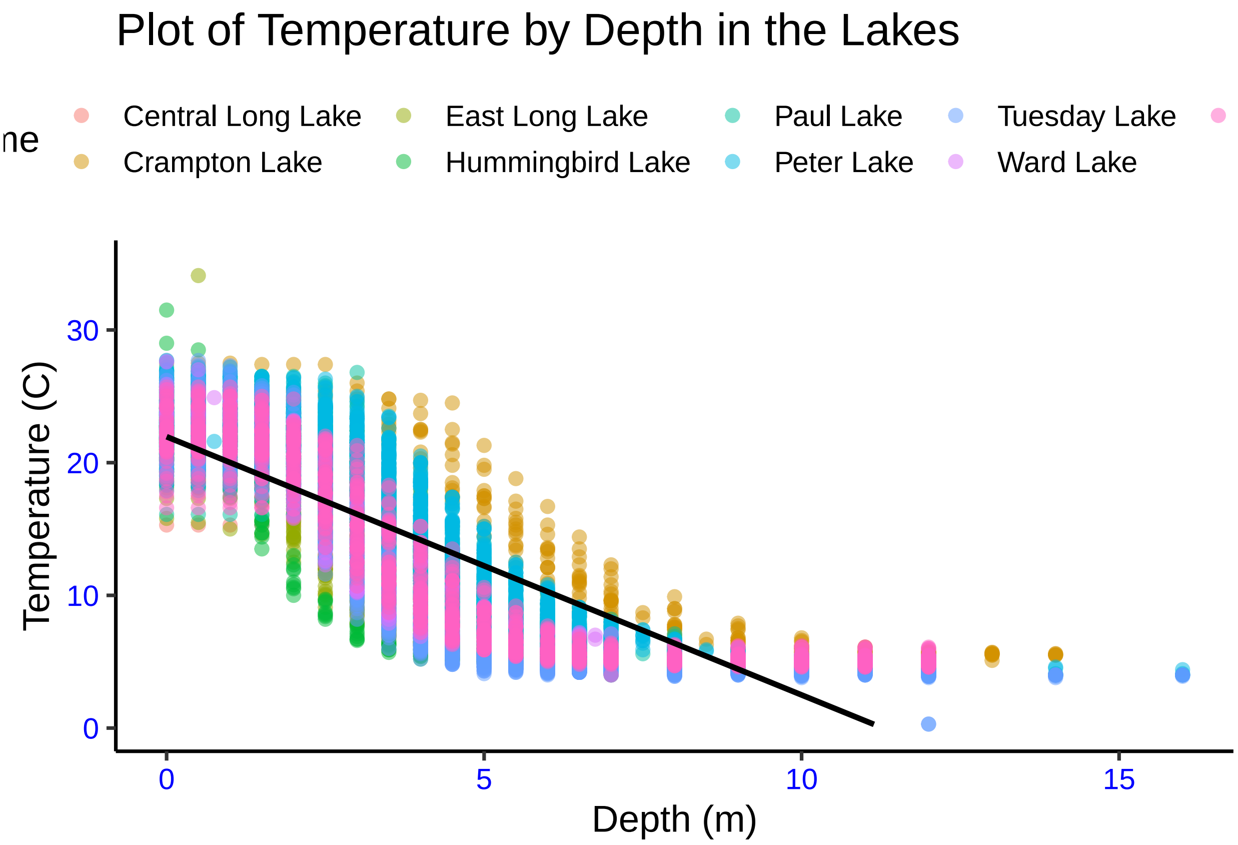
    Answer: No, there are no significant differences in the mean temperature among the lakes with all p-values remaining below 0.05.

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.

```
#14.# plotting temp by depth with separate color points for each lake, 50% transparent using the alpha
 DepthPlot <-
  ggplot(LakeChemMonthCol, aes(x = depth, y = temperature_C, col = lakename)) +
  labs(title = "Plot of Temperature by Depth in the Lakes", x = "Depth (m)", y = "Temperature (C)") +
  geom_point(size= 2, alpha = 0.5) +
  geom_smooth(method = "lm", se = FALSE, color = "black") +
  ylim (0, 35)
print(DepthPlot)
```

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

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

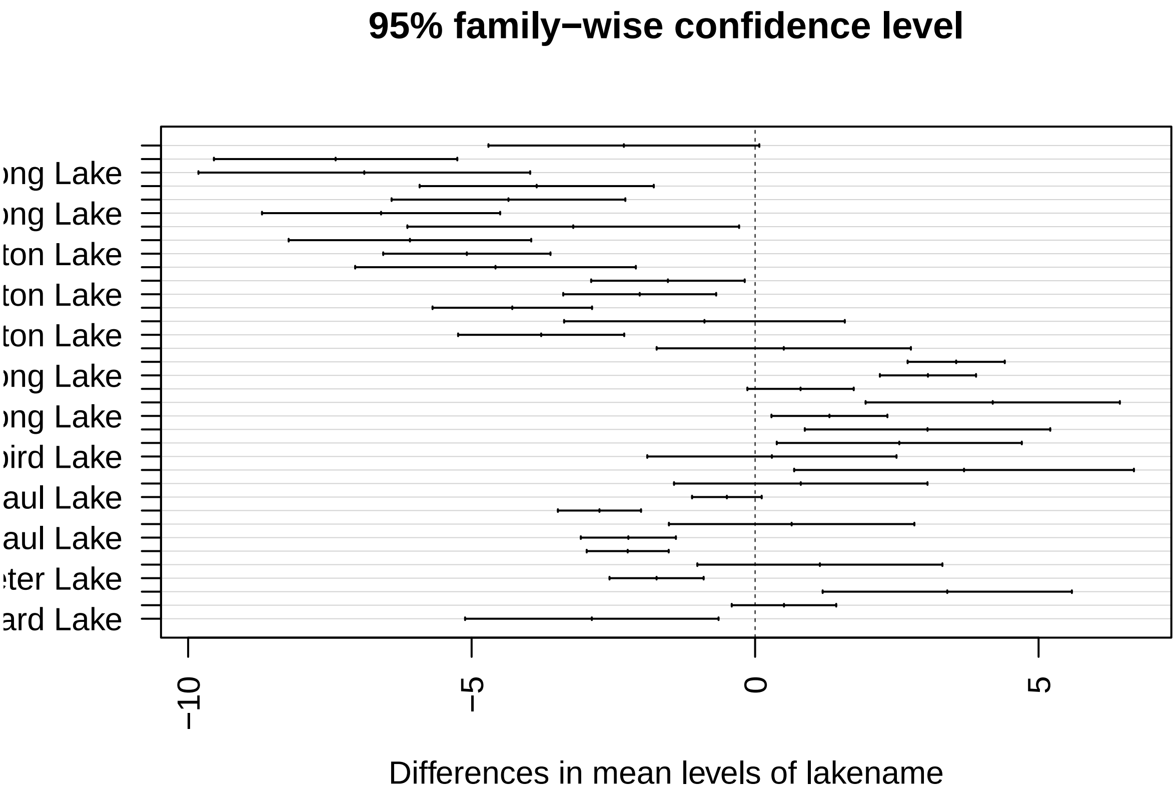


15. Use the Tukey's HSD test to determine which lakes have different means.

```
#15 using the Tukey test to determine means
TukeyHSD(TempsAnova)
```

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

```
plot(TukeyHSD(TempsAnova, conf.level = .95), las = 2)
```



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: Both Peter and Ward Lakes have no statistically significant difference in means. Tuesday Lake and Hummingbird Lake share quite a large p-value almost nearing 1!

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: A t-test! T-tests can compare the average values of two datasets.

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?

```r
#wrangling july data to filter Crampton and Ward lakes
CramptonWard <- LakeChemMonthCol %>%
  filter(lakename == "Crampton Lake"| lakename == "Ward Lake")
#running t-test
CW.twosample <- t.test(CramptonWard$temperature_C ~ CramptonWard$lakename)
CW.twosample2 <- lm(CramptonWard$temperature_C ~ CramptonWard$lakename)
summary(CW.twosample2)
```

```
##
## Call:
## lm(formula = CramptonWard$temperature_C ~ CramptonWard$lakename)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -10.3519  -7.5286   0.1947   7.0481  13.1414
##
## Coefficients:
##                                Estimate Std. Error t value Pr(>|t|)
## (Intercept)                     15.3519     0.4087   37.56   <2e-16 ***
## CramptonWard$lakenameWard Lake  -0.8933     0.7906   -1.13    0.259
## ---
## Signif. codes:  0 ’***’ 0.001 ’**’ 0.01 ’*’ 0.05 ’.’ 0.1 ’ ’ 1
##
## Residual standard error: 7.289 on 432 degrees of freedom
## Multiple R-squared:  0.002946,   Adjusted R-squared:  0.0006383
## F-statistic: 1.277 on 1 and 432 DF,  p-value: 0.2592
```

> Answer: The mean temperatures for the lakes are not equal with Crampton and Ward sharing very different p-values (<2e-16 and 0.259) and stil, under 0.05.