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

Ruiqing Li

Spring 2023

OVERVIEW

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

Directions

1. Rename this file `<RuiqingLi>_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
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   1.2.1      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(lubridate)
```

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

```
library(here)
```

```
## here() starts at /Users/ruiqingli/Desktop/DataAnalytics/RWORK/EDA-Spring2023
```

```
library(agricolae)
getwd()
```

```
## [1] "/Users/ruiqingli/Desktop/DataAnalytics/RWORK/EDA-Spring2023"
```

```
Raw.NTL.LTER <- read.csv(here("Data/Raw/NTL-LTER_Lake_ChemistryPhysics_Raw.csv"), stringsAsFactors = TRU

Raw.NTL.LTER$sampledate <- as.Date(Raw.NTL.LTER$sampledate, format = "%m/%d/%y")
#2
Mytheme.A6 <- theme_classic(base_size = 14) +
  theme(axis.text = element_text(color = "pink"),
        legend.position = "top")

theme_set(Mytheme.A6)
```

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 lake temperature recorded during July does not change with depth across all lakes. Ha: The mean lake temperature recorded during July does change with 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)

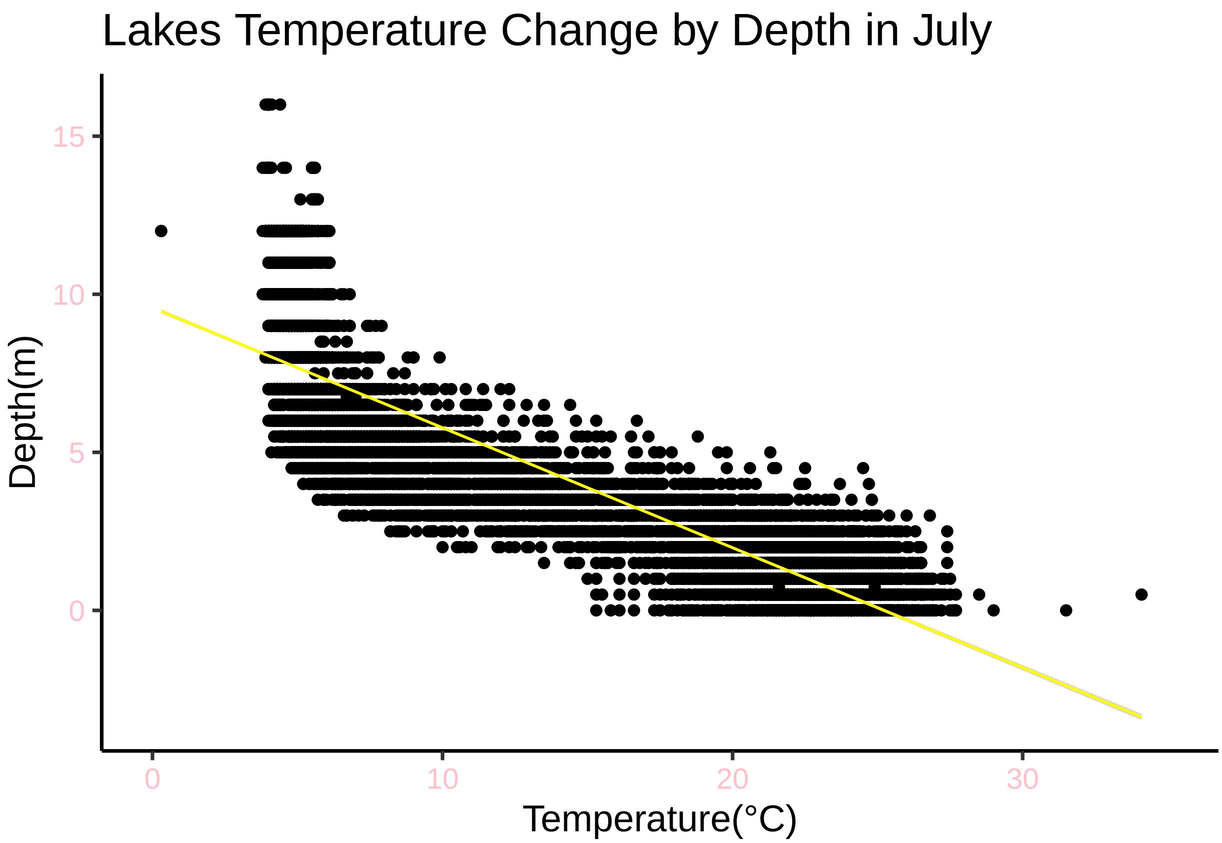
5. Visualize the relationship among the two continuous variables with a scatter plot of temperature by depth. Add a smoothed line showing the linear model, and limit temperature values from 0 to 35 °C. Make this plot look pretty and easy to read.

```
#4
July.NTL.LTER <-
 Raw.NTL.LTER %>%
  select(lakename, year4, daynum, depth, temperature_C) %>%
  filter(month(Raw.NTL.LTER$sampledate) %in% 7)%>%
  na.omit()

#5
TemperatureDepth.NTL.LTER <-
  ggplot(July.NTL.LTER, aes(x = temperature_C, y=depth)) +
  geom_point()+
 xlim(0, 35) +
```

```
  geom_smooth(method=lm,color="yellow",size=0.5)+
                xlab("Temperature(°C)")+
                ylab("Depth(m)")+
  ggtitle("Lakes Temperature Change by Depth in July")
print(TemperatureDepth.NTL.LTER)
```

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



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 temperature increase as the depth decrease. The distrubution of the trend suggests a negative linear relationship between temperature and depth.

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

```
#7
depth.JulyLakes.Regression <- lm(July.NTL.LTER$temperature_C ~ July.NTL.LTER$depth)
summary(depth.JulyLakes.Regression)
```

```
##
## Call:
## lm(formula = July.NTL.LTER$temperature_C ~ July.NTL.LTER$depth)
##
```

```
## 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 ***
## July.NTL.LTER$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 (higher temperature at lower depths), and that this model explains about 73.87 % of the total variance in temperature. The residual standard errror is 3.835 on 9726 degrees of freedom. The F-statistic is 2.75e+04 on 1 and 9726 DF. The temperature is predicted to change 1.95°C every 1m change in 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
depth.year4<-
  lm(July.NTL.LTER$temperature_C ~ July.NTL.LTER$depth + July.NTL.LTER$year4 )
AIC(depth.year4)
```

```
## [1] 53756.97
```

```
summary(depth.year4)
```

```
##
## Call:
## lm(formula = July.NTL.LTER$temperature_C ~ July.NTL.LTER$depth +
```

```
##     July.NTL.LTER$year4)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -9.5543 -3.0227  0.0981  2.9492 13.7469
##
## Coefficients:
##                        Estimate Std. Error  t value Pr(>|t|)
## (Intercept)           -1.104769   8.629545   -0.128  0.89813
## July.NTL.LTER$depth -1.946542   0.011733 -165.906  < 2e-16 ***
## July.NTL.LTER$year4  0.011538   0.004317    2.672  0.00754 **
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 3.834 on 9725 degrees of freedom
## Multiple R-squared:  0.7389, Adjusted R-squared:  0.7389
## F-statistic: 1.376e+04 on 2 and 9725 DF,  p-value: < 2.2e-16
```

```
depth.daynum<-
  lm(July.NTL.LTER$temperature_C ~ July.NTL.LTER$depth + July.NTL.LTER$daynum )
AIC(depth.daynum)
```

```
## [1] 53679.36
```

```
summary(depth.daynum)
```

```
##
## Call:
## lm(formula = July.NTL.LTER$temperature_C ~ July.NTL.LTER$depth +
##     July.NTL.LTER$daynum)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -9.6174 -2.9809  0.0845  2.9681 13.4406
##
## Coefficients:
##                         Estimate Std. Error  t value Pr(>|t|)
## (Intercept)           14.088588   0.855505   16.468   <2e-16 ***
## July.NTL.LTER$depth  -1.946111   0.011685 -166.541   <2e-16 ***
## July.NTL.LTER$daynum  0.039836   0.004318    9.225   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 3.818 on 9725 degrees of freedom
## Multiple R-squared:  0.741,  Adjusted R-squared:  0.741
## F-statistic: 1.391e+04 on 2 and 9725 DF,  p-value: < 2.2e-16
```

```
year4.daynum<-
  lm(July.NTL.LTER$temperature_C ~ July.NTL.LTER$daynum + July.NTL.LTER$year4 )
AIC(year4.daynum)
```

```
## [1] 66798.34
```

```r
summary(year4.daynum)
```

```
##
## Call:
## lm(formula = July.NTL.LTER$temperature_C ~ July.NTL.LTER$daynum +
##     July.NTL.LTER$year4)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -12.279  -7.158  -2.591   8.072  21.402
##
## Coefficients:
##                        Estimate Std. Error t value Pr(>|t|)
## (Intercept)           -2.827705  16.944033  -0.167    0.867
## July.NTL.LTER$daynum   0.040484   0.008475   4.777 1.81e-06 ***
## July.NTL.LTER$year4    0.003779   0.008439   0.448    0.654
## ---
## 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
year4<-
  lm(July.NTL.LTER$temperature_C ~ July.NTL.LTER$year4 )
AIC(year4)
```

```
## [1] 66819.14
```

```r
summary(year4)
```

```
##
## Call:
## lm(formula = July.NTL.LTER$temperature_C ~ July.NTL.LTER$year4)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -12.378  -7.221  -2.579   8.103  21.383
##
## Coefficients:
##                       Estimate Std. Error t value Pr(>|t|)
## (Intercept)           4.775522  16.888014   0.283    0.777
## July.NTL.LTER$year4   0.003975   0.008449   0.470    0.638
##
## Residual standard error: 7.502 on 9726 degrees of freedom
## Multiple R-squared:  2.276e-05,   Adjusted R-squared:  -8.006e-05
## F-statistic: 0.2213 on 1 and 9726 DF,  p-value: 0.638
```

```r
daynum<-
  lm(July.NTL.LTER$temperature_C ~ July.NTL.LTER$daynum )
AIC(daynum)
```

```
## [1] 66796.54
```

```r
summary(daynum)
```

```
##
## Call:
## lm(formula = July.NTL.LTER$temperature_C ~ July.NTL.LTER$daynum)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -12.320  -7.156  -2.594   8.077  21.399
##
## Coefficients:
##                      Estimate Std. Error t value Pr(>|t|)
## (Intercept)          4.722359   1.675347   2.819  0.00483 **
## July.NTL.LTER$daynum 0.040502   0.008475   4.779 1.79e-06 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 7.494 on 9726 degrees of freedom
## Multiple R-squared:  0.002343,   Adjusted R-squared:  0.00224
## F-statistic: 22.84 on 1 and 9726 DF,  p-value: 1.786e-06
```

```r
depth<-
  lm(July.NTL.LTER$temperature_C ~ July.NTL.LTER$depth )
AIC(depth)
```

```
## [1] 53762.12
```

```r
summary(depth)
```

```
##
## Call:
## lm(formula = July.NTL.LTER$temperature_C ~ July.NTL.LTER$depth)
##
## 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 ***
## July.NTL.LTER$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
```

```r
year4.daynum.depth <- lm(data = July.NTL.LTER, July.NTL.LTER$temperature_C ~ July.NTL.LTER$depth + July
AIC(year4.daynum.depth)
```

```
## [1] 53674.39
```

```r
step(year4.daynum.depth)
```

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

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

```r
#10
summary(year4.daynum.depth)
```

```
##
## Call:
## lm(formula = July.NTL.LTER$temperature_C ~ July.NTL.LTER$depth +
##     July.NTL.LTER$year4 + July.NTL.LTER$daynum, data = July.NTL.LTER)
##
## 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
## July.NTL.LTER$depth  -1.946437   0.011683 -166.611  < 2e-16 ***
## July.NTL.LTER$year4   0.011345   0.004299    2.639  0.00833 **
## July.NTL.LTER$daynum  0.039780   0.004317    9.215  < 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: All three explanatory variables (year4, daynum, depth) should be included. According to R-Squared Value, this model explained 74% of the total variance. The previous model using only depth explained about 73.87 % of the total variance in temperature. So, yes, it is an improvement.

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

July.anova <- aov(data = July.NTL.LTER, July.NTL.LTER$temperature_C ~ July.NTL.LTER$lakename)
summary(July.anova)
```

```
##                          Df Sum Sq Mean Sq F value Pr(>F)
## July.NTL.LTER$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(July.anova)
```

```
## Analysis of Variance Table
##
## Response: July.NTL.LTER$temperature_C
##                          Df Sum Sq Mean Sq F value    Pr(>F)
## July.NTL.LTER$lakename    8  21642  2705.2  50.003 < 2.2e-16 ***
## Residuals              9719 525813    54.1
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
July.anova.lm <- lm(data = July.NTL.LTER, July.NTL.LTER$temperature_C ~ July.NTL.LTER$lakename)
summary(July.anova.lm)
```

```
##
## Call:
## lm(formula = July.NTL.LTER$temperature_C ~ July.NTL.LTER$lakename,
##     data = July.NTL.LTER)
##
## 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 ***
## July.NTL.LTER$lakenameCrampton Lake     -2.3145     0.7699  -3.006 0.002653 **
## July.NTL.LTER$lakenameEast Long Lake    -7.3987     0.6918 -10.695  < 2e-16 ***
## July.NTL.LTER$lakenameHummingbird Lake  -6.8931     0.9429  -7.311 2.87e-13 ***
## July.NTL.LTER$lakenamePaul Lake         -3.8522     0.6656  -5.788 7.36e-09 ***
## July.NTL.LTER$lakenamePeter Lake        -4.3501     0.6645  -6.547 6.17e-11 ***
## July.NTL.LTER$lakenameTuesday Lake      -6.5972     0.6769  -9.746  < 2e-16 ***
## July.NTL.LTER$lakenameWard Lake         -3.2078     0.9429  -3.402 0.000672 ***
## July.NTL.LTER$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
```

```
anova(July.anova.lm)
```

```
## Analysis of Variance Table
##
## Response: July.NTL.LTER$temperature_C
##                          Df Sum Sq Mean Sq F value    Pr(>F)
## July.NTL.LTER$lakename    8  21642  2705.2  50.003 < 2.2e-16 ***
## Residuals              9719 525813    54.1
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
TukeyHSD(July.anova)
```

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

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

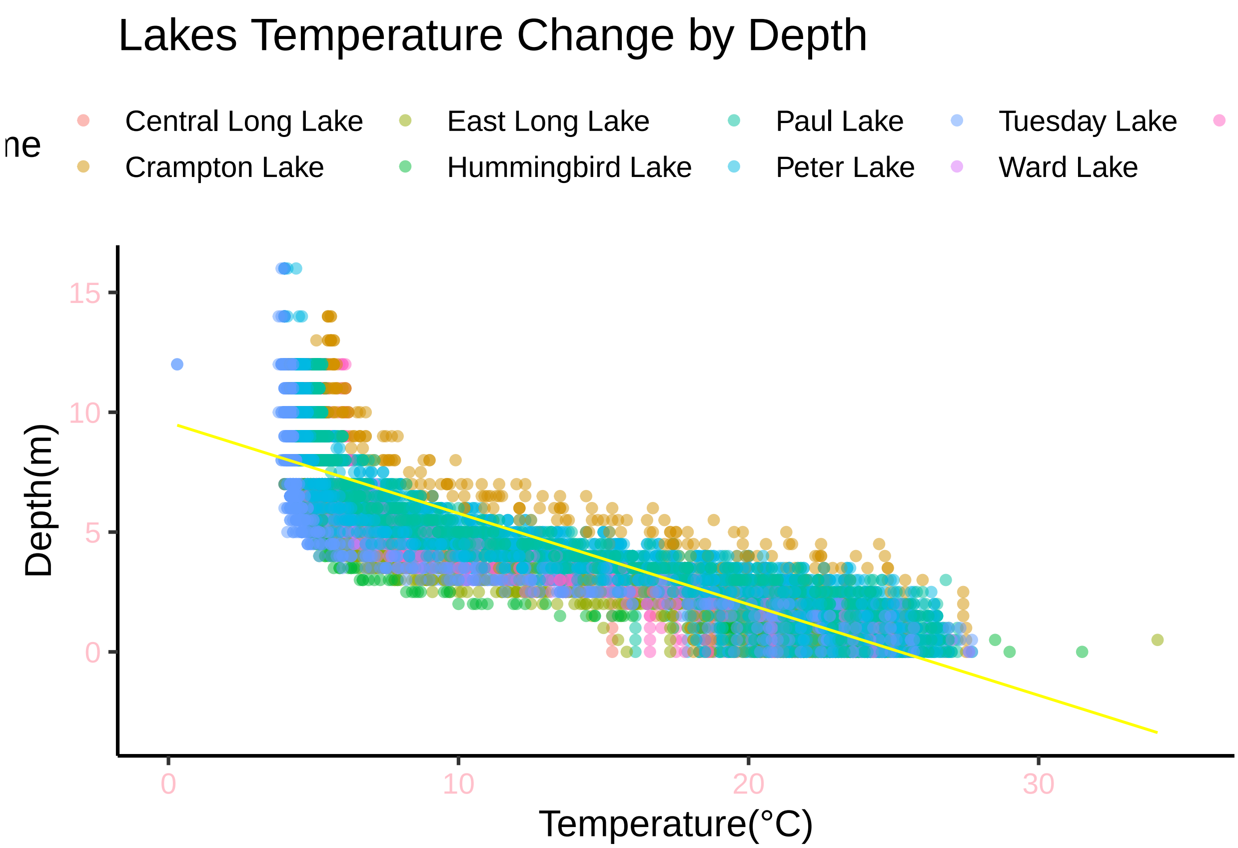
    Answer: Yes, there is.For every meter of difference in lake depth, the temperature among different lakes change between 2.3°C and 6.9°C.

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.

#For July
JulyLakeTemperatureDepth.NTL.LTER <-
  ggplot(July.NTL.LTER, aes(x = temperature_C, y=depth)) +
  geom_point(aes(color=lakename),alpha=0.5)+
 xlim(0, 35) +
  geom_smooth(method = "lm", se = FALSE,color="yellow",size=0.5)+
                xlab("Temperature(°C)")+
                ylab("Depth(m)")+
  ggtitle("Lakes Temperature Change by Depth")
print(JulyLakeTemperatureDepth.NTL.LTER)
```

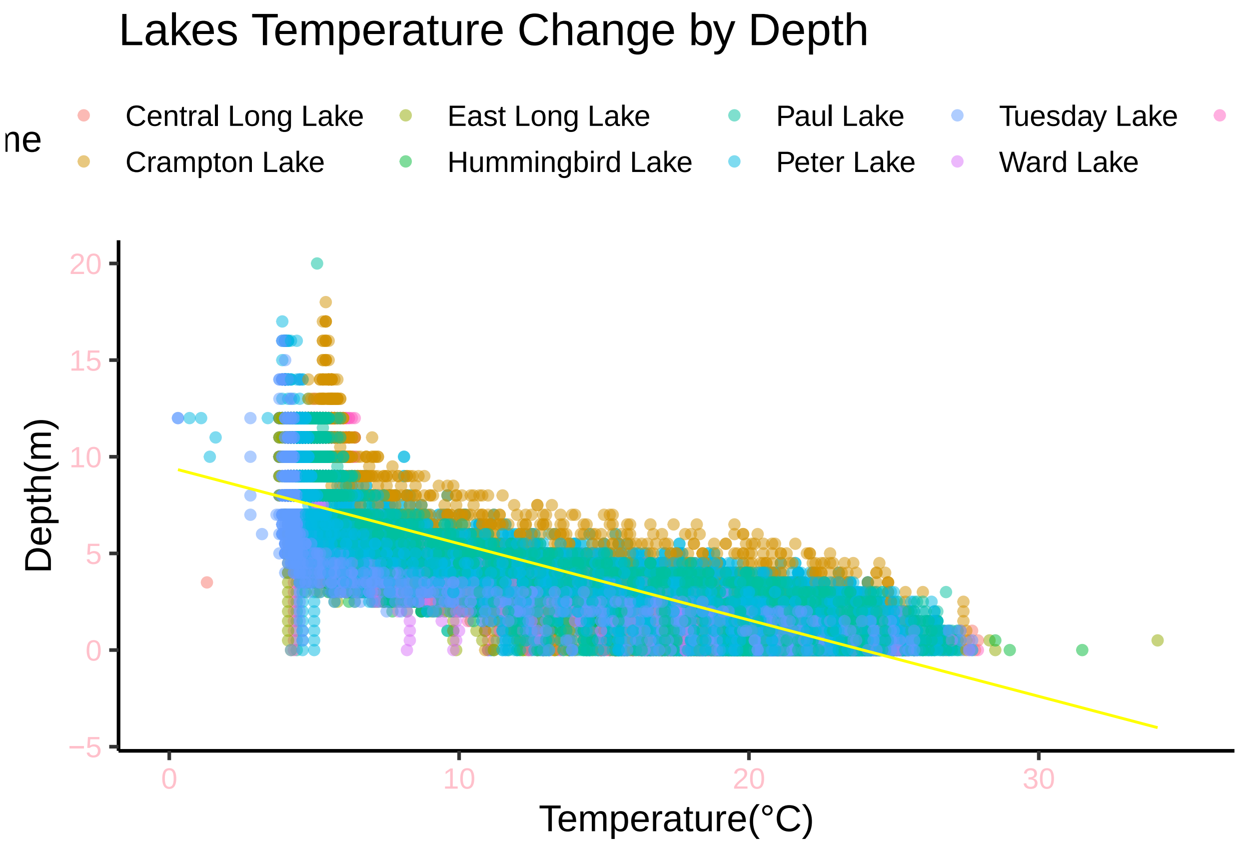
```
## `geom_smooth()` using formula 'y ~ x'
```




```
#For All Months
New.NTL.LTER <-
 Raw.NTL.LTER %>%
  select(lakename, depth, temperature_C) %>%
  na.omit()

AllMonthsLakeTemperatureDepth.NTL.LTER <-
  ggplot(New.NTL.LTER, aes(x = temperature_C, y=depth)) +
  geom_point(aes(color=lakename),alpha=0.5)+
 xlim(0, 35) +
  geom_smooth(method = "lm", se = FALSE,color="yellow",size=0.5)+
                xlab("Temperature(°C)")+
                ylab("Depth(m)")+
  ggtitle("Lakes Temperature Change by Depth")
print(AllMonthsLakeTemperatureDepth.NTL.LTER)
```

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



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

```
#15
#For July
JulyDepth.anova <- aov(data = July.NTL.LTER, July.NTL.LTER$temperature_C ~ July.NTL.LTER$lakename)
summary(JulyDepth.anova)
```

```
##                          Df Sum Sq Mean Sq F value Pr(>F)
## July.NTL.LTER$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(JulyDepth.anova)
```

```
## Analysis of Variance Table
##
## Response: July.NTL.LTER$temperature_C
##                          Df Sum Sq Mean Sq F value    Pr(>F)
## July.NTL.LTER$lakename    8  21642  2705.2  50.003 < 2.2e-16 ***
## Residuals              9719 525813    54.1
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```r
JulyDepth.anova.lm <- lm(data = July.NTL.LTER, July.NTL.LTER$temperature_C ~ July.NTL.LTER$lakename)
summary(JulyDepth.anova.lm)
```

```
##
## Call:
## lm(formula = July.NTL.LTER$temperature_C ~ July.NTL.LTER$lakename,
##     data = July.NTL.LTER)
##
## 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 ***
## July.NTL.LTER$lakenameCrampton Lake     -2.3145     0.7699  -3.006 0.002653 **
## July.NTL.LTER$lakenameEast Long Lake    -7.3987     0.6918 -10.695  < 2e-16 ***
## July.NTL.LTER$lakenameHummingbird Lake  -6.8931     0.9429  -7.311 2.87e-13 ***
## July.NTL.LTER$lakenamePaul Lake         -3.8522     0.6656  -5.788 7.36e-09 ***
## July.NTL.LTER$lakenamePeter Lake        -4.3501     0.6645  -6.547 6.17e-11 ***
## July.NTL.LTER$lakenameTuesday Lake      -6.5972     0.6769  -9.746  < 2e-16 ***
## July.NTL.LTER$lakenameWard Lake         -3.2078     0.9429  -3.402 0.000672 ***
## July.NTL.LTER$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
```

```r
anova(JulyDepth.anova.lm)
```

```
## Analysis of Variance Table
##
## Response: July.NTL.LTER$temperature_C
##                          Df Sum Sq Mean Sq F value    Pr(>F)
## July.NTL.LTER$lakename    8  21642  2705.2  50.003 < 2.2e-16 ***
## Residuals              9719 525813    54.1
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```r
TukeyHSD(JulyDepth.anova)
```

```
##   Tukey multiple comparisons of means
##     95% family-wise confidence level
##
## Fit: aov(formula = July.NTL.LTER$temperature_C ~ July.NTL.LTER$lakename, data = July.NTL.LTER)
##
## $`July.NTL.LTER$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
#For All Months
All.anova <- aov(data = New.NTL.LTER, New.NTL.LTER$temperature_C ~ New.NTL.LTER$lakename)
summary(All.anova)
```

```
##                          Df  Sum Sq Mean Sq F value Pr(>F)
## New.NTL.LTER$lakename     8   57921    7240   155.7 <2e-16 ***
## Residuals             34747 1615571      46
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```r
anova(All.anova)
```

```
## Analysis of Variance Table
##
## Response: New.NTL.LTER$temperature_C
##                          Df  Sum Sq Mean Sq F value    Pr(>F)
## New.NTL.LTER$lakename     8   57921  7240.1  155.72 < 2.2e-16 ***
```

```
## Residuals             34747 1615571    46.5
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
All.anova.lm <- lm(data = New.NTL.LTER, New.NTL.LTER$temperature_C ~ New.NTL.LTER$lakename)
summary(All.anova.lm)
```

```
##
## Call:
## lm(formula = New.NTL.LTER$temperature_C ~ New.NTL.LTER$lakename,
##     data = New.NTL.LTER)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -15.436  -5.959  -2.559   6.549  24.321
##
## Coefficients:
##                                       Estimate Std. Error t value Pr(>|t|)
## (Intercept)                            16.7363     0.3240  51.660  < 2e-16 ***
## New.NTL.LTER$lakenameCrampton Lake     -2.5443     0.3833  -6.638 3.23e-11 ***
## New.NTL.LTER$lakenameEast Long Lake    -6.9570     0.3436 -20.248  < 2e-16 ***
## New.NTL.LTER$lakenameHummingbird Lake  -6.6985     0.4775 -14.030  < 2e-16 ***
## New.NTL.LTER$lakenamePaul Lake         -3.9441     0.3316 -11.893  < 2e-16 ***
## New.NTL.LTER$lakenamePeter Lake        -4.4838     0.3309 -13.549  < 2e-16 ***
## New.NTL.LTER$lakenameTuesday Lake      -6.3896     0.3368 -18.974  < 2e-16 ***
## New.NTL.LTER$lakenameWard Lake         -4.3083     0.4395  -9.802  < 2e-16 ***
## New.NTL.LTER$lakenameWest Long Lake    -5.6778     0.3423 -16.587  < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 6.819 on 34747 degrees of freedom
## Multiple R-squared:  0.03461,    Adjusted R-squared:  0.03439
## F-statistic: 155.7 on 8 and 34747 DF,  p-value: < 2.2e-16
```

```
anova(All.anova.lm)
```

```
## Analysis of Variance Table
##
## Response: New.NTL.LTER$temperature_C
##                          Df  Sum Sq Mean Sq F value    Pr(>F)
## New.NTL.LTER$lakename     8   57921  7240.1  155.72 < 2.2e-16 ***
## Residuals             34747 1615571    46.5
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
TukeyHSD(All.anova)
```

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

```
## $`New.NTL.LTER$lakename`
##                                          diff        lwr        upr     p adj
## Crampton Lake-Central Long Lake    -2.5442854 -3.7331780 -1.3553927 0.0000000
## East Long Lake-Central Long Lake   -6.9570473 -8.0227648 -5.8913298 0.0000000
## Hummingbird Lake-Central Long Lake -6.6985124 -8.1794348 -5.2175900 0.0000000
## Paul Lake-Central Long Lake        -3.9440682 -4.9727040 -2.9154324 0.0000000
## Peter Lake-Central Long Lake       -4.4837864 -5.5102613 -3.4573116 0.0000000
## Tuesday Lake-Central Long Lake     -6.3896413 -7.4341675 -5.3451152 0.0000000
## Ward Lake-Central Long Lake        -4.3082596 -5.6715463 -2.9449730 0.0000000
## West Long Lake-Central Long Lake   -5.6777623 -6.7395105 -4.6160141 0.0000000
## East Long Lake-Crampton Lake       -4.4127620 -5.1405823 -3.6849417 0.0000000
## Hummingbird Lake-Crampton Lake     -4.1542271 -5.4140285 -2.8944256 0.0000000
## Paul Lake-Crampton Lake            -1.3997828 -2.0721371 -0.7274286 0.0000000
## Peter Lake-Crampton Lake           -1.9395011 -2.6085446 -1.2704575 0.0000000
## Tuesday Lake-Crampton Lake         -3.8453560 -4.5417779 -3.1489341 0.0000000
## Ward Lake-Crampton Lake            -1.7639743 -2.8831342 -0.6448143 0.0000357
## West Long Lake-Crampton Lake       -3.1334769 -3.8554727 -2.4114812 0.0000000
## Hummingbird Lake-East Long Lake     0.2585349 -0.8857499  1.4028198 0.9987916
## Paul Lake-East Long Lake            3.0129792  2.5954288  3.4305296 0.0000000
## Peter Lake-East Long Lake           2.4732609  2.0610627  2.8854591 0.0000000
## Tuesday Lake-East Long Lake         0.5674060  0.1121132  1.0226989 0.0035472
## Ward Lake-East Long Lake            2.6487877  1.6614645  3.6361109 0.0000000
## West Long Lake-East Long Lake       1.2792850  0.7857610  1.7728091 0.0000000
## Paul Lake-Hummingbird Lake          2.7544443  1.6446129  3.8642756 0.0000000
## Peter Lake-Hummingbird Lake         2.2147260  1.1068972  3.3225548 0.0000000
## Tuesday Lake-Hummingbird Lake       0.3088711 -0.8157039  1.4334461 0.9952041
## Ward Lake-Hummingbird Lake          2.3902528  0.9647057  3.8157999 0.0000071
## West Long Lake-Hummingbird Lake     1.0207501 -0.1198389  2.1613391 0.1224797
## Peter Lake-Paul Lake               -0.5397183 -0.8434372 -0.2359993 0.0000013
## Tuesday Lake-Paul Lake             -2.4455731 -2.8056140 -2.0855323 0.0000000
## Ward Lake-Paul Lake                -0.3641914 -1.3113688  0.5829859 0.9582889
## West Long Lake-Paul Lake           -1.7336941 -2.1410071 -1.3263812 0.0000000
## Tuesday Lake-Peter Lake            -1.9058549 -2.2596746 -1.5520351 0.0000000
## Ward Lake-Peter Lake                0.1755268 -0.7693033  1.1203570 0.9997136
## West Long Lake-Peter Lake          -1.1939759 -1.5958003 -0.7921515 0.0000000
## Ward Lake-Tuesday Lake              2.0813817  1.1169709  3.0457925 0.0000000
## West Long Lake-Tuesday Lake         0.7118790  0.2659563  1.1578017 0.0000259
## West Long Lake-Ward Lake           -1.3695027 -2.3525401 -0.3864652 0.0005266
```

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:

#For July Peter Lake-Paul Lake -0.4979952°C difference Ward Lake-Peter Lake 0.1755268°C difference

Maybe Ward Lake-East Long Lake 4.1909554°C difference

#For All Months Peter Lake-Paul Lake -0.5397183°C difference Ward Lake-Peter Lake 0.1755268°C difference

Maybe Ward Lake-Central Long Lake -4.3082596°C difference

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:

Two Sample T-Test

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?

```
CramptonWard.NTL.LTER <-
 Raw.NTL.LTER %>%
  select(lakename, year4, daynum, depth, temperature_C) %>%
  filter(month(Raw.NTL.LTER$sampledate) %in% 7, lakename == "Ward Lake"|lakename =="Crampton Lake")%>%
  na.omit()
print(CramptonWard.NTL.LTER)
```

```
##          lakename year4 daynum depth temperature_C
## 1   Crampton Lake  1999    196  0.00          22.8
## 3   Crampton Lake  1999    196  0.50          22.6
## 5   Crampton Lake  1999    196  1.00          22.4
## 6   Crampton Lake  1999    196  1.50          22.2
## 7   Crampton Lake  1999    196  2.00          22.0
## 8   Crampton Lake  1999    196  2.50          21.9
## 9   Crampton Lake  1999    196  3.00          21.7
## 10  Crampton Lake  1999    196  3.50          21.3
## 11  Crampton Lake  1999    196  4.00          20.0
## 12  Crampton Lake  1999    196  4.50          17.1
## 13  Crampton Lake  1999    196  5.00          14.4
## 14  Crampton Lake  1999    196  5.50          12.1
## 15  Crampton Lake  1999    196  6.00          10.2
## 16  Crampton Lake  1999    196  6.50           9.1
## 17  Crampton Lake  1999    196  7.00           8.4
## 18  Crampton Lake  1999    196  8.00           7.1
## 19  Crampton Lake  1999    196  9.00           6.3
## 20  Crampton Lake  1999    196 10.00           5.8
## 21  Crampton Lake  1999    196 11.00           5.5
## 22  Crampton Lake  1999    196 12.00           5.4
## 23  Crampton Lake  2003    183  0.00          21.8
## 25  Crampton Lake  2003    183  0.50          21.9
## 27  Crampton Lake  2003    183  1.00          21.9
## 28  Crampton Lake  2003    183  1.50          21.8
## 29  Crampton Lake  2003    183  2.00          21.8
## 30  Crampton Lake  2003    183  2.50          21.3
## 31  Crampton Lake  2003    183  3.00          20.8
## 32  Crampton Lake  2003    183  3.50          19.9
## 33  Crampton Lake  2003    183  4.00          17.2
## 34  Crampton Lake  2003    183  4.50          15.2
## 35  Crampton Lake  2003    183  5.00          12.7
## 36  Crampton Lake  2003    183  5.50          11.2
## 37  Crampton Lake  2003    183  6.00          10.2
## 38  Crampton Lake  2003    183  6.50           8.8
## 39  Crampton Lake  2003    183  7.00           8.2
## 41  Crampton Lake  2003    183  8.00           6.8
```

```
## 42  Crampton Lake  2003    183  9.00           6.0
## 43  Crampton Lake  2003    183 10.00           5.4
## 44  Crampton Lake  2003    183 11.00           5.1
## 45  Crampton Lake  2003    183 12.00           5.0
## 46  Crampton Lake  2003    197  0.00          22.2
## 48  Crampton Lake  2003    197  0.50          21.9
## 50  Crampton Lake  2003    197  1.00          21.8
## 51  Crampton Lake  2003    197  1.50          21.8
## 52  Crampton Lake  2003    197  2.00          21.7
## 53  Crampton Lake  2003    197  2.50          21.7
## 54  Crampton Lake  2003    197  3.00          21.7
## 55  Crampton Lake  2003    197  3.50          21.6
## 56  Crampton Lake  2003    197  4.00          19.6
## 57  Crampton Lake  2003    197  4.50          17.3
## 58  Crampton Lake  2003    197  5.00          14.5
## 59  Crampton Lake  2003    197  5.50          12.5
## 60  Crampton Lake  2003    197  6.00          10.9
## 61  Crampton Lake  2003    197  6.50           9.8
## 62  Crampton Lake  2003    197  7.00           8.7
## 63  Crampton Lake  2003    197  8.00           7.0
## 64  Crampton Lake  2003    197  9.00           6.0
## 65  Crampton Lake  2003    197 10.00           5.5
## 66  Crampton Lake  2003    197 11.00           5.2
## 67  Crampton Lake  2003    197 12.00           5.1
## 68  Crampton Lake  2003    211  0.00          23.2
## 70  Crampton Lake  2003    211  0.50          23.3
## 72  Crampton Lake  2003    211  1.00          23.2
## 73  Crampton Lake  2003    211  1.50          23.3
## 74  Crampton Lake  2003    211  2.00          23.3
## 75  Crampton Lake  2003    211  2.50          23.3
## 76  Crampton Lake  2003    211  3.00          23.3
## 77  Crampton Lake  2003    211  3.50          23.2
## 78  Crampton Lake  2003    211  4.00          22.4
## 79  Crampton Lake  2003    211  4.50          20.6
## 80  Crampton Lake  2003    211  5.00          17.3
## 81  Crampton Lake  2003    211  5.50          14.6
## 82  Crampton Lake  2003    211  6.00          12.1
## 83  Crampton Lake  2003    211  6.50          11.0
## 84  Crampton Lake  2003    211  7.00           9.6
## 85  Crampton Lake  2003    211  8.00           7.4
## 86  Crampton Lake  2003    211  9.00           6.4
## 87  Crampton Lake  2003    211 10.00           5.7
## 88  Crampton Lake  2003    211 11.00           5.4
## 89  Crampton Lake  2003    211 12.00           5.2
## 90  Crampton Lake  2004    183  0.00          19.8
## 92  Crampton Lake  2004    183  0.50          19.8
## 94  Crampton Lake  2004    183  1.00          19.8
## 95  Crampton Lake  2004    183  1.50          19.8
## 96  Crampton Lake  2004    183  2.00          19.7
## 97  Crampton Lake  2004    183  2.50          19.5
## 98  Crampton Lake  2004    183  3.00          18.9
## 99  Crampton Lake  2004    183  3.50          18.4
## 100 Crampton Lake  2004    183  4.00          18.0
## 101 Crampton Lake  2004    183  4.50          17.5
```

```
## 102 Crampton Lake  2004    183  5.00          15.6
## 103 Crampton Lake  2004    183  5.50          13.4
## 104 Crampton Lake  2004    183  6.00          11.2
## 105 Crampton Lake  2004    183  6.50          10.2
## 106 Crampton Lake  2004    183  7.00           9.0
## 108 Crampton Lake  2004    183  8.00           7.6
## 109 Crampton Lake  2004    183  9.00           6.6
## 110 Crampton Lake  2004    183 10.00           6.0
## 111 Crampton Lake  2004    183 11.00           5.6
## 112 Crampton Lake  2004    183 12.00           5.5
## 113 Crampton Lake  2004    183 13.00           5.5
## 114 Crampton Lake  2004    183 14.00           5.5
## 115 Crampton Lake  2004    191  0.00          18.1
## 117 Crampton Lake  2004    191  0.50          18.1
## 119 Crampton Lake  2004    191  1.00          18.0
## 120 Crampton Lake  2004    191  1.50          18.0
## 121 Crampton Lake  2004    191  2.00          17.9
## 122 Crampton Lake  2004    191  2.50          17.9
## 123 Crampton Lake  2004    191  3.00          17.9
## 124 Crampton Lake  2004    191  3.50          17.8
## 125 Crampton Lake  2004    191  4.00          17.6
## 126 Crampton Lake  2004    191  4.50          17.4
## 127 Crampton Lake  2004    191  5.00          16.6
## 128 Crampton Lake  2004    191  5.50          13.8
## 129 Crampton Lake  2004    191  6.00          12.1
## 130 Crampton Lake  2004    191  6.50          10.9
## 131 Crampton Lake  2004    191  7.00           9.4
## 132 Crampton Lake  2004    191  8.00           7.6
## 133 Crampton Lake  2004    191  9.00           6.6
## 134 Crampton Lake  2004    191 10.00           6.0
## 135 Crampton Lake  2004    191 11.00           5.7
## 136 Crampton Lake  2004    191 12.00           5.6
## 137 Crampton Lake  2004    191 13.00           5.5
## 138 Crampton Lake  2004    191 14.00           5.5
## 139 Crampton Lake  2004    197  0.00          21.8
## 141 Crampton Lake  2004    197  0.50          21.8
## 143 Crampton Lake  2004    197  1.00          21.6
## 144 Crampton Lake  2004    197  1.50          21.6
## 145 Crampton Lake  2004    197  2.00          21.5
## 146 Crampton Lake  2004    197  2.50          20.9
## 147 Crampton Lake  2004    197  3.00          19.5
## 148 Crampton Lake  2004    197  3.50          19.1
## 149 Crampton Lake  2004    197  4.00          18.6
## 150 Crampton Lake  2004    197  4.50          17.9
## 151 Crampton Lake  2004    197  5.00          16.7
## 152 Crampton Lake  2004    197  5.50          14.8
## 153 Crampton Lake  2004    197  6.00          12.8
## 154 Crampton Lake  2004    197  6.50          11.1
## 155 Crampton Lake  2004    197  7.00           9.7
## 156 Crampton Lake  2004    197  8.00           7.7
## 157 Crampton Lake  2004    197  9.00           6.6
## 158 Crampton Lake  2004    197 10.00           6.1
## 159 Crampton Lake  2004    197 11.00           5.7
## 160 Crampton Lake  2004    197 12.00           5.6
```

```
## 161 Crampton Lake  2004    197 13.00           5.6
## 162 Crampton Lake  2004    197 14.00           5.5
## 163 Crampton Lake  2004    204  0.00          23.8
## 165 Crampton Lake  2004    204  0.50          23.8
## 167 Crampton Lake  2004    204  1.00          23.8
## 168 Crampton Lake  2004    204  1.50          23.8
## 169 Crampton Lake  2004    204  2.00          23.8
## 170 Crampton Lake  2004    204  2.50          23.2
## 171 Crampton Lake  2004    204  3.00          22.0
## 172 Crampton Lake  2004    204  3.50          20.5
## 173 Crampton Lake  2004    204  4.00          19.9
## 174 Crampton Lake  2004    204  4.50          18.5
## 175 Crampton Lake  2004    204  5.00          17.3
## 176 Crampton Lake  2004    204  5.50          15.5
## 177 Crampton Lake  2004    204  6.00          13.5
## 178 Crampton Lake  2004    204  6.50          11.3
## 179 Crampton Lake  2004    204  7.00          10.1
## 180 Crampton Lake  2004    204  8.00           7.8
## 181 Crampton Lake  2004    204  9.00           6.8
## 182 Crampton Lake  2004    204 10.00           6.2
## 183 Crampton Lake  2004    204 11.00           5.8
## 184 Crampton Lake  2004    204 12.00           5.7
## 185 Crampton Lake  2004    204 13.00           5.6
## 186 Crampton Lake  2004    204 14.00           5.6
## 187 Crampton Lake  2004    211  0.00          22.7
## 189 Crampton Lake  2004    211  0.50          22.7
## 191 Crampton Lake  2004    211  1.00          22.7
## 192 Crampton Lake  2004    211  1.50          22.7
## 193 Crampton Lake  2004    211  2.00          22.7
## 194 Crampton Lake  2004    211  2.50          22.7
## 195 Crampton Lake  2004    211  3.00          22.7
## 196 Crampton Lake  2004    211  3.50          22.6
## 197 Crampton Lake  2004    211  4.00          20.8
## 198 Crampton Lake  2004    211  4.50          18.1
## 199 Crampton Lake  2004    211  5.00          17.5
## 200 Crampton Lake  2004    211  5.50          15.8
## 201 Crampton Lake  2004    211  6.00          13.6
## 202 Crampton Lake  2004    211  6.50          11.5
## 203 Crampton Lake  2004    211  7.00          10.3
## 204 Crampton Lake  2004    211  8.00           7.8
## 205 Crampton Lake  2004    211  9.00           6.8
## 206 Crampton Lake  2004    211 10.00           6.2
## 207 Crampton Lake  2004    211 11.00           5.8
## 208 Crampton Lake  2004    211 12.00           5.7
## 209 Crampton Lake  2004    211 13.00           5.6
## 210 Crampton Lake  2004    211 14.00           5.6
## 211 Crampton Lake  2005    186  0.00          22.3
## 213 Crampton Lake  2005    186  0.50          22.3
## 215 Crampton Lake  2005    186  1.00          22.4
## 216 Crampton Lake  2005    186  1.50          22.4
## 217 Crampton Lake  2005    186  2.00          22.4
## 218 Crampton Lake  2005    186  2.50          22.4
## 219 Crampton Lake  2005    186  3.00          22.4
## 220 Crampton Lake  2005    186  3.50          22.3
```

```
## 221 Crampton Lake  2005    186  4.00           22.3
## 222 Crampton Lake  2005    186  4.50           21.5
## 223 Crampton Lake  2005    186  5.00           17.9
## 224 Crampton Lake  2005    186  5.50           15.3
## 225 Crampton Lake  2005    186  6.00           13.5
## 226 Crampton Lake  2005    186  6.50           12.3
## 227 Crampton Lake  2005    186  7.00           10.8
## 229 Crampton Lake  2005    186  8.00            8.8
## 231 Crampton Lake  2005    186  9.00            7.4
## 232 Crampton Lake  2005    186 10.00            6.0
## 233 Crampton Lake  2005    186 11.00            5.8
## 234 Crampton Lake  2005    186 12.00            5.7
## 235 Crampton Lake  2005    192  0.00           25.7
## 237 Crampton Lake  2005    192  0.50           25.7
## 239 Crampton Lake  2005    192  1.00           25.4
## 240 Crampton Lake  2005    192  1.50           25.4
## 241 Crampton Lake  2005    192  2.00           25.3
## 242 Crampton Lake  2005    192  2.50           24.2
## 243 Crampton Lake  2005    192  3.00           23.5
## 244 Crampton Lake  2005    192  3.50           22.9
## 245 Crampton Lake  2005    192  4.00           22.5
## 246 Crampton Lake  2005    192  4.50           21.4
## 247 Crampton Lake  2005    192  5.00           19.5
## 248 Crampton Lake  2005    192  5.50           16.5
## 249 Crampton Lake  2005    192  6.00           14.6
## 250 Crampton Lake  2005    192  6.50           12.9
## 251 Crampton Lake  2005    192  7.00           11.4
## 253 Crampton Lake  2005    192  8.00            9.0
## 255 Crampton Lake  2005    192  9.00            7.5
## 256 Crampton Lake  2005    192 10.00            6.5
## 257 Crampton Lake  2005    192 11.00            6.0
## 258 Crampton Lake  2005    192 12.00            5.7
## 259 Crampton Lake  2005    192 13.00            5.6
## 260 Crampton Lake  2005    199  0.00           27.5
## 262 Crampton Lake  2005    199  0.50           27.5
## 264 Crampton Lake  2005    199  1.00           27.5
## 265 Crampton Lake  2005    199  1.50           27.4
## 266 Crampton Lake  2005    199  2.00           27.4
## 267 Crampton Lake  2005    199  2.50           27.4
## 268 Crampton Lake  2005    199  3.00           26.0
## 269 Crampton Lake  2005    199  3.50           24.8
## 270 Crampton Lake  2005    199  4.00           23.7
## 271 Crampton Lake  2005    199  4.50           22.5
## 272 Crampton Lake  2005    199  5.00           19.8
## 273 Crampton Lake  2005    199  5.50           17.1
## 274 Crampton Lake  2005    199  6.00           15.3
## 275 Crampton Lake  2005    199  6.50           13.5
## 276 Crampton Lake  2005    199  7.00           12.0
## 278 Crampton Lake  2005    199  8.00            9.0
## 280 Crampton Lake  2005    199  9.00            7.7
## 281 Crampton Lake  2005    199 10.00            6.6
## 282 Crampton Lake  2005    199 11.00            6.1
## 283 Crampton Lake  2005    199 12.00            5.7
## 284 Crampton Lake  2005    199 13.00            5.7
```

```
## 285 Crampton Lake  2005    206  0.00           25.3
## 287 Crampton Lake  2005    206  0.50           25.1
## 289 Crampton Lake  2005    206  1.00           25.0
## 290 Crampton Lake  2005    206  1.50           24.9
## 291 Crampton Lake  2005    206  2.00           24.9
## 292 Crampton Lake  2005    206  2.50           24.9
## 293 Crampton Lake  2005    206  3.00           24.8
## 294 Crampton Lake  2005    206  3.50           24.8
## 295 Crampton Lake  2005    206  4.00           24.7
## 296 Crampton Lake  2005    206  4.50           24.5
## 297 Crampton Lake  2005    206  5.00           21.3
## 298 Crampton Lake  2005    206  5.50           18.8
## 299 Crampton Lake  2005    206  6.00           16.7
## 300 Crampton Lake  2005    206  6.50           14.4
## 301 Crampton Lake  2005    206  7.00           12.3
## 303 Crampton Lake  2005    206  8.00            9.9
## 305 Crampton Lake  2005    206  9.00            7.9
## 306 Crampton Lake  2005    206 10.00            6.8
## 307 Crampton Lake  2005    206 11.00            6.1
## 308 Crampton Lake  2005    206 12.00            5.8
## 309 Crampton Lake  2005    206 13.00            5.7
## 310 Crampton Lake  2006    186  0.00           22.7
## 312 Crampton Lake  2006    186  0.50           22.8
## 314 Crampton Lake  2006    186  1.00           22.8
## 315 Crampton Lake  2006    186  1.50           22.8
## 316 Crampton Lake  2006    186  2.00           22.8
## 317 Crampton Lake  2006    186  2.50           22.5
## 318 Crampton Lake  2006    186  3.00           22.6
## 319 Crampton Lake  2006    186  3.50           22.6
## 320 Crampton Lake  2006    186  4.00           20.3
## 321 Crampton Lake  2006    186  4.50           17.4
## 322 Crampton Lake  2006    186  5.00           15.2
## 323 Crampton Lake  2006    186  5.50           13.7
## 324 Crampton Lake  2006    186  6.00           12.1
## 325 Crampton Lake  2006    186  6.50           10.8
## 326 Crampton Lake  2006    186  7.00            9.6
## 327 Crampton Lake  2006    186  7.50            8.3
## 328 Crampton Lake  2006    186  8.00            7.4
## 329 Crampton Lake  2006    186  8.50            6.3
## 330 Crampton Lake  2006    186  9.00            6.0
## 331 Crampton Lake  2006    186 10.00            5.5
## 332 Crampton Lake  2006    186 11.00            5.2
## 333 Crampton Lake  2006    186 12.00            5.1
## 334 Crampton Lake  2006    200  0.00           25.4
## 336 Crampton Lake  2006    200  0.50           25.4
## 338 Crampton Lake  2006    200  1.00           25.4
## 339 Crampton Lake  2006    200  1.50           25.4
## 340 Crampton Lake  2006    200  2.00           25.4
## 341 Crampton Lake  2006    200  2.50           25.4
## 342 Crampton Lake  2006    200  3.00           25.4
## 343 Crampton Lake  2006    200  3.50           24.1
## 344 Crampton Lake  2006    200  4.00           22.5
## 345 Crampton Lake  2006    200  4.50           19.8
## 346 Crampton Lake  2006    200  5.00           17.5
```

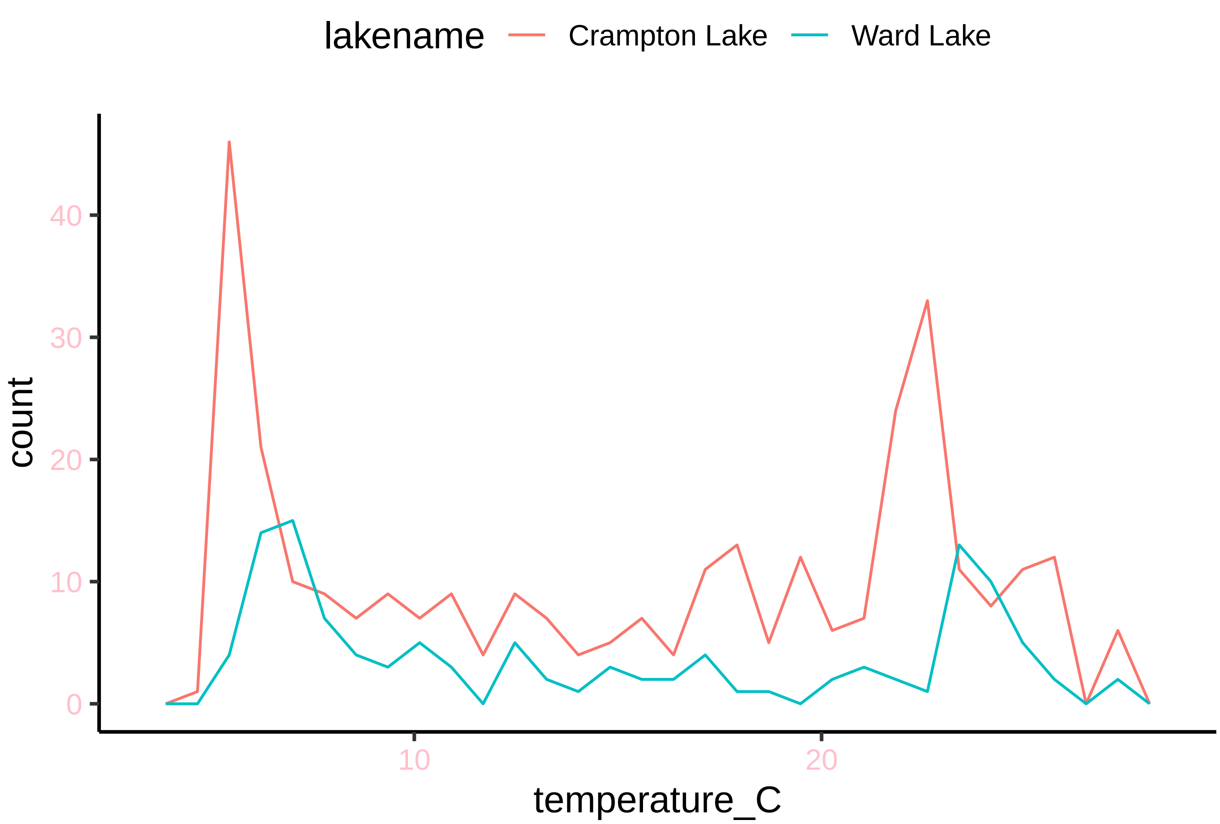
```
## 347 Crampton Lake  2006    200  5.50          15.0
## 348 Crampton Lake  2006    200  6.00          13.3
## 349 Crampton Lake  2006    200  6.50          11.4
## 350 Crampton Lake  2006    200  7.00           9.6
## 351 Crampton Lake  2006    200  7.50           8.7
## 352 Crampton Lake  2006    200  8.00           7.5
## 353 Crampton Lake  2006    200  8.50           6.7
## 354 Crampton Lake  2006    200  9.00           6.4
## 355 Crampton Lake  2006    200 10.00           5.7
## 356 Crampton Lake  2006    200 11.00           5.4
## 357 Crampton Lake  2006    200 12.00           5.1
## 358 Crampton Lake  2006    200 13.00           5.1
## 359     Ward Lake  2010    188  0.00          25.5
## 361     Ward Lake  2010    188  0.50          25.3
## 362     Ward Lake  2010    188  0.75          24.9
## 363     Ward Lake  2010    188  1.00          24.8
## 364     Ward Lake  2010    188  1.50          23.7
## 365     Ward Lake  2010    188  2.00          21.8
## 366     Ward Lake  2010    188  2.50          18.6
## 367     Ward Lake  2010    188  3.00          16.6
## 368     Ward Lake  2010    188  3.50          14.6
## 369     Ward Lake  2010    188  4.00          12.5
## 370     Ward Lake  2010    188  4.50          10.4
## 371     Ward Lake  2010    188  5.00           9.0
## 372     Ward Lake  2010    188  5.50           7.7
## 373     Ward Lake  2010    188  6.00           7.1
## 374     Ward Lake  2010    188  6.50           6.9
## 375     Ward Lake  2010    188  6.75           6.7
## 376     Ward Lake  2010    195  0.00          24.1
## 378     Ward Lake  2010    195  0.50          24.1
## 380     Ward Lake  2010    195  1.00          24.0
## 381     Ward Lake  2010    195  1.50          23.9
## 382     Ward Lake  2010    195  2.00          23.2
## 383     Ward Lake  2010    195  2.50          20.3
## 384     Ward Lake  2010    195  3.00          17.4
## 385     Ward Lake  2010    195  3.50          14.7
## 386     Ward Lake  2010    195  4.00          12.5
## 387     Ward Lake  2010    195  4.50          10.6
## 388     Ward Lake  2010    195  5.00           8.8
## 389     Ward Lake  2010    195  5.50           7.7
## 390     Ward Lake  2010    195  6.00           7.2
## 391     Ward Lake  2010    195  6.50           7.0
## 392     Ward Lake  2010    202  0.00          23.9
## 394     Ward Lake  2010    202  0.50          23.8
## 396     Ward Lake  2010    202  1.00          23.7
## 397     Ward Lake  2010    202  1.50          23.3
## 398     Ward Lake  2010    202  2.00          23.1
## 399     Ward Lake  2010    202  2.50          20.7
## 400     Ward Lake  2010    202  3.00          17.0
## 401     Ward Lake  2010    202  3.50          15.1
## 402     Ward Lake  2010    202  4.00          12.6
## 403     Ward Lake  2010    202  4.50          10.7
## 404     Ward Lake  2010    202  5.00           9.1
## 405     Ward Lake  2010    202  5.50           7.9
```

```
## 406     Ward Lake  2010    202  6.00            7.3
## 407     Ward Lake  2010    202  6.50            7.1
## 408     Ward Lake  2010    202  7.00            7.1
## 409     Ward Lake  2010    209  0.00           23.6
## 411     Ward Lake  2010    209  0.50           23.6
## 413     Ward Lake  2010    209  1.00           23.5
## 414     Ward Lake  2010    209  1.50           23.4
## 415     Ward Lake  2010    209  2.00           23.1
## 416     Ward Lake  2010    209  2.50           21.0
## 417     Ward Lake  2010    209  3.00           18.2
## 418     Ward Lake  2010    209  3.50           15.7
## 419     Ward Lake  2010    209  4.00           13.4
## 420     Ward Lake  2010    209  4.50           11.1
## 421     Ward Lake  2010    209  5.00            9.2
## 422     Ward Lake  2010    209  5.50            8.0
## 423     Ward Lake  2010    209  6.00            7.4
## 424     Ward Lake  2010    209  6.50            7.2
## 425     Ward Lake  2010    209  6.75            7.0
## 426     Ward Lake  2012    187  0.00           27.6
## 428     Ward Lake  2012    187  0.50           27.0
## 430     Ward Lake  2012    187  1.00           24.6
## 431     Ward Lake  2012    187  1.50           20.4
## 432     Ward Lake  2012    187  2.00           15.8
## 433     Ward Lake  2012    187  2.50           12.3
## 434     Ward Lake  2012    187  3.00           10.2
## 435     Ward Lake  2012    187  3.50            7.9
## 436     Ward Lake  2012    187  4.00            6.9
## 437     Ward Lake  2012    187  4.50            6.4
## 438     Ward Lake  2012    187  5.00            6.1
## 439     Ward Lake  2012    187  5.50            5.8
## 440     Ward Lake  2012    187  6.00            5.7
## 441     Ward Lake  2012    194  0.00           25.9
## 443     Ward Lake  2012    194  0.50           25.1
## 445     Ward Lake  2012    194  1.00           24.5
## 446     Ward Lake  2012    194  1.50           20.8
## 447     Ward Lake  2012    194  2.00           16.5
## 448     Ward Lake  2012    194  2.50           12.6
## 449     Ward Lake  2012    194  3.00           10.3
## 450     Ward Lake  2012    194  3.50            8.2
## 451     Ward Lake  2012    194  4.00            7.2
## 452     Ward Lake  2012    194  4.50            6.6
## 453     Ward Lake  2012    194  5.00            6.3
## 454     Ward Lake  2012    194  5.50            6.0
## 455     Ward Lake  2012    194  6.00            5.9
## 456     Ward Lake  2012    201  0.00           23.6
## 458     Ward Lake  2012    201  0.50           23.3
## 460     Ward Lake  2012    201  1.00           23.2
## 461     Ward Lake  2012    201  1.50           21.5
## 462     Ward Lake  2012    201  2.00           16.9
## 463     Ward Lake  2012    201  2.50           13.2
## 464     Ward Lake  2012    201  3.00           10.3
## 465     Ward Lake  2012    201  3.50            8.6
## 466     Ward Lake  2012    201  4.00            7.7
## 467     Ward Lake  2012    201  4.50            6.8
```

```
## 468      Ward Lake  2012    201  5.00           6.4
## 469      Ward Lake  2012    201  5.50           6.2
## 470      Ward Lake  2012    201  6.00           6.0
## 471      Ward Lake  2012    201  6.50           5.9
## 472      Ward Lake  2012    201  7.00           5.8
## 473      Ward Lake  2012    208  0.00          24.3
## 475      Ward Lake  2012    208  0.50          24.2
## 477      Ward Lake  2012    208  1.00          24.2
## 478      Ward Lake  2012    208  1.50          22.3
## 479      Ward Lake  2012    208  2.00          17.5
## 480      Ward Lake  2012    208  2.50          13.7
## 481      Ward Lake  2012    208  3.00          10.5
## 482      Ward Lake  2012    208  3.50           8.5
## 483      Ward Lake  2012    208  4.00           7.6
## 484      Ward Lake  2012    208  4.50           6.8
## 485      Ward Lake  2012    208  5.00           6.4
## 486      Ward Lake  2012    208  5.50           6.1
## 487      Ward Lake  2012    208  6.00           6.0
## 488      Ward Lake  2012    208  6.50           5.9
## 489      Ward Lake  2012    208  7.00           5.8
```

```
ggplot(CramptonWard.NTL.LTER, aes(x = temperature_C, color = lakename)) +
  geom_freqpoly()
```

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



```
twosample <- t.test(CramptonWard.NTL.LTER$temperature_C ~ CramptonWard.NTL.LTER$lakename)
twosample
```

```
##
##  Welch Two Sample t-test
##
## data:  CramptonWard.NTL.LTER$temperature_C by CramptonWard.NTL.LTER$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
```

```
twosample2 <- lm(CramptonWard.NTL.LTER$temperature_C ~ CramptonWard.NTL.LTER$lakename)
summary(twosample2)
```

```
##
## Call:
## lm(formula = CramptonWard.NTL.LTER$temperature_C ~ CramptonWard.NTL.LTER$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.NTL.LTER$lakenameWard Lake  -0.8933     0.7906   -1.13    0.259
##
## (Intercept)                             ***
## CramptonWard.NTL.LTER$lakenameWard Lake
## ---
## 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 in group Crampton Lake is 15.35189, and the mean in group Ward Lake is 14.45862, which are really close but not exact.The difference in TukeyHSD(JulyDepth.anova) for these two lakes is 0.8932661 which is the same as the result from the two-sample T-test we performed.