



# Under-Ice Water Quality Assessment in Perch Lake, Mud Lake, and Kimballs Bay

September 30, 2020

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**Abstract:** Previous studies have found lower-than-expected dissolved oxygen (DO) concentrations in a number of bays of the St. Louis River estuary. These hypoxic conditions, which can negatively impact fish and other organisms, are a concern for natural resource managers and anglers. In the current study, water quality was investigated under the ice in March 2020 at Perch Lake, Mud Lake, and Kimballs Bay. DO concentrations varied among sites but were consistent with previous findings, with higher DO near connections to the estuary than farther away, and higher at middle than at lower depths. This research indicates the importance of water exchange in maintaining higher DO concentrations, and the need for future research on mechanisms responsible for low DO in these bays.

## 1. Introduction

### 1.1 Hypoxia in the St. Louis River Estuary's Bays

Hypoxia has been found in a variety of locations in the lower St. Louis River, including some of its shallow, backwater areas (Garono et al. 2019). This report describes winter water quality research conducted in three locations in this river reach. Perch Lake, a small 21-acre backwater lake along the lower St. Louis River (Fig. 1), has a history of hypoxia during winter and summer months (Garono et al. 2019). The lake has been largely isolated from the St. Louis River by state highway 23 for over a century. It is currently connected to the main river channel by a 4 ft culvert and has become shallower over time, presumably due to reduced water velocity and subsequent sediment deposition. Perch Lake is part of the Lower St. Louis River Area of Concern Remedial Action Plan (SLRAOC RAP), which will involve the construction of a new waterway connection to the St. Louis River (Minnesota Department of Natural Resources and Wisconsin Department of Natural Resources 2020). Mud Lake, which is bisected by a railroad causeway, also has a restricted connection to the St. Louis River through a single short bridge, and will be a restoration site as part of the SLRAOC RAP. Water quality data collection at these two sites will help inform this restoration work and assessment of post-restoration conditions. Lastly, Kimballs Bay is a clay-influenced river mouth without natural or artificial constrictions (Fig. 1). All three of these locations were the subject of previous water quality research and were included in this study to generate additional longitudinal data. This research was designed to

investigate under-ice water quality at these locations, particularly with respect to water constriction proximity.

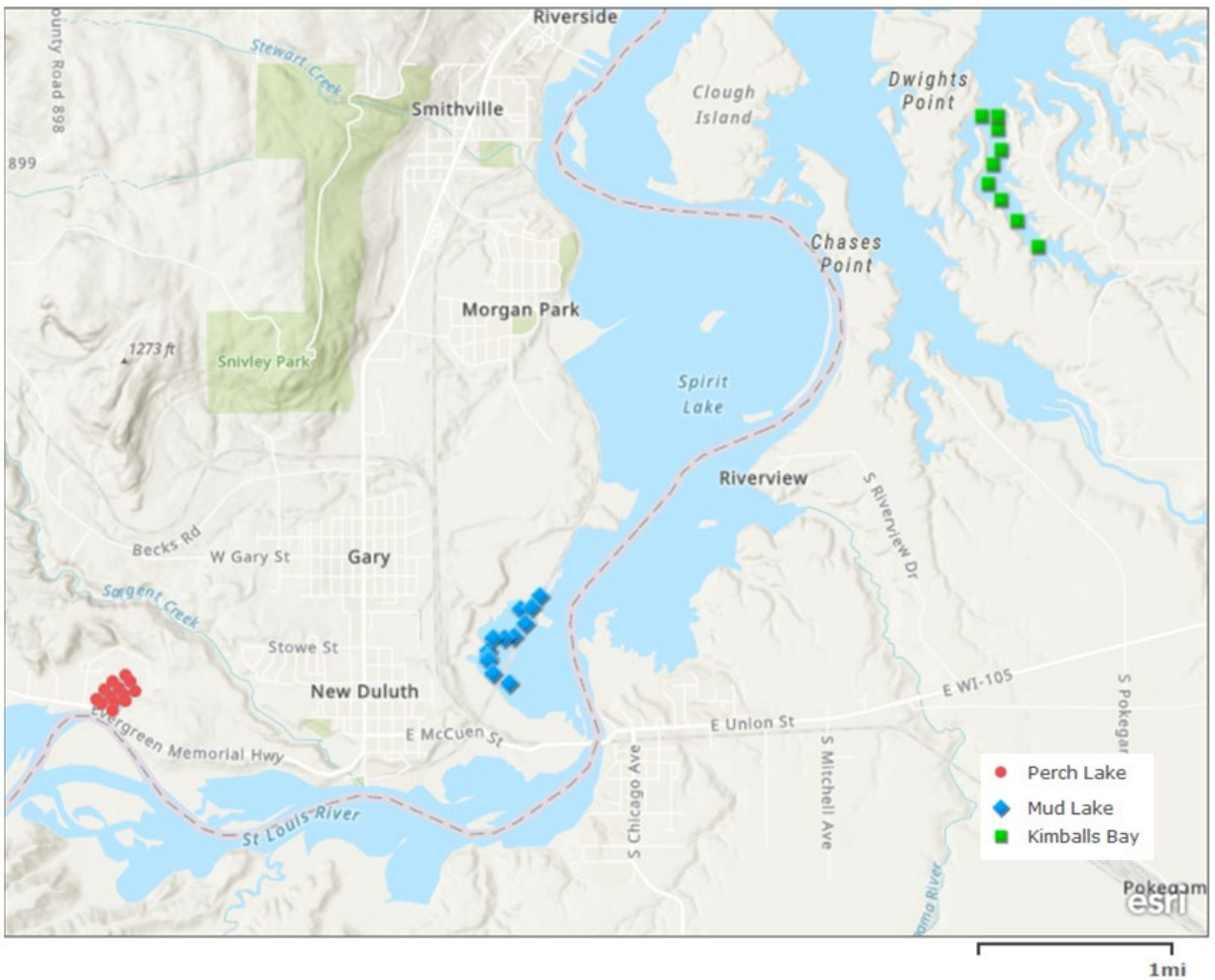


Figure 1. Sampling locations at Perch Lake (red circles), Mud Lake (blue diamonds), and Kimballs Bay (green squares).

### 1.2 Perch Lake Previous Study

Perch Lake was previously studied in comparison to other areas in the St. Louis River (Garono et al. 2019). The study found that Perch Lake had dramatically lower winter bottom dissolved oxygen (DO) levels than other sheltered bays (average 11.50 mg/L) with 4.64 mg/L. Perch Lake's depth integrated winter temperature (1.26°C) was also higher than all other areas surveyed, with the highest being 0.82°C.

### 1.3 Hypoxia

Hypoxia in water is low DO concentration. Waters with DO concentrations below 2 mg/L are generally considered to be hypoxic, although < 5 mg/L have also been considered hypoxic (Breitburg 2002). Hypoxia can happen across a wide variety of aquatic systems, and it can vary

in seasonality and persistence. It is generally caused by plant and animal respiration (Garono et al. 2019), but low atmospheric diffusion and poor circulation may also contribute (Saari et al. 2018). Although some aquatic ecosystems may be naturally low in DO, many aquatic ecosystems become hypoxic in response to anthropocentric activities (Diaz and Breitburg 2009).

## 2. Methods

### 2.1 Planning

Three bays, Perch Lake, Mud Lake, and Kimballs Bay, were selected based on previous research showing hypoxia and based on partner needs. Perch and Mud Lakes were requested by partners and colleagues to gather baseline information prior to restoration. In addition to the value of collecting longitudinal data at Kimballs Bay, Paul Piszczek with Wisconsin DNR had an interest in this location in response to fisherman concerns of low catches. Survey sites at Perch and Mud Lakes were planned at 50, 150, 250, and 350 meters away from their respective constriction points distributed throughout the lake. These two locations are relatively similar, as they are both shallow back bays with constricted connections to the St. Louis River, but Mud Lake has a wider connection with the river (a short bridge, compared to a culvert for Perch Lake). Kimballs Bay survey sites were planned down the middle of the bay spaced 200 meters apart. The Google Earth file was then converted to be compatible with ArcGIS, and a Survey 123 form was created to record all data. Upon completion of all preliminary work, a Lake Superior National Estuarine Research Reserve's YSI EXO3 multiparameter datasonde was calibrated and used to collect all under-ice data, as described below.

### 2.2 Data Collection

Dissolved oxygen and several associated variables were assessed under the ice at the above locations in March 2020. At all survey sites holes were augured in the ice to collect data. Perch Lake had an area of open water extending approximately two meters into the lake from the culvert, which did not modify the sampling plan. Mud Lake survey sites were chosen based on ice safety, with no sites being possible close to the bridge due to an area of open water. At Kimballs Bay, the survey site locations were altered according to partner needs, and sites were predominantly reaugured holes from previous fishing use. Depth (m), ice thickness (in), water temperature (°C), dissolved oxygen (mg/L and %), conductivity and distance from constriction points were recorded at each survey site. All but 4 surveys were recorded using Survey 123 and tracked using Survey 123's geolocating. For surveys that were paper recorded the locations were tracked using GPS XY coordinates. The dissolved oxygen data were collected at a bottom depth and a middle depth. The bottom depth was recorded roughly 2 inches off of the bottom and the middle depth was at roughly half of the total depth. Conductivity was recorded at the middle depth. The YSI EXO3 multiparameter datasonde was lowered to the bottom to record the total depth. The datasonde was then raised roughly 2 inches from the bottom to record the first dissolved oxygen measurement. The datasonde was raised to roughly half of the total depth and the rest of the measurements were recorded. The datasonde was allowed to stabilize for up to 3 minutes for data measurements at each depth.

### 2.3 Data Analysis

Data were analyzed using a combination of linear regressions, generalized regressions (for non-normally distributed data) and ANOVAs. Boxplots and linear regression figures with their associated regression line statistics were conducted in Microsoft Excel, and the remaining statistical analyses were conducted using JMP Pro v.15. *P*-values less than 0.05 were deemed significant.

### 3. Results

#### 3.1 Overall DO Patterns

DO concentrations in the three water bodies were generally lower at the bottom of the water column than at the middle, with the difference being significant at Perch Lake ( $F_{1,26} = 5.3$ ,  $P = 0.03$ ) and Kimballs Bay ( $F_{1,16} = 6.4$ ,  $P = 0.022$ ; Table 1 and Fig. 1). Overall DO concentrations were different among sites ( $F_{2,67} = 8.4$ ,  $P = 0.0006$ ), with DO higher at Mud Lake than at Perch Lake ( $t = 3.5$ ,  $P = 0.0021$ ) and Kimballs Bay ( $t = -3.5$ ,  $P = 0.0024$ ). These findings were similar when bottom and middle DO levels were analyzed separately among locations (see Appendix).

#### 3.2 Depth, Conductivity, and Temperature

Total depth was significantly deeper at Kimballs Bay than at the other two locations ( $\chi^2 = 112$ ,  $P < 0.0001$ ), and conductivity was significantly different among all locations ( $F_{2,67} = 61$ ,  $P < 0.0001$ ), with Kimballs Bay having the highest and Mud Lake having the lowest (Table 1). Temperatures were not different among locations ( $\chi^2 = 4.8$ ,  $P = 0.091$ ; see Appendix).

Table 1. Summary of dissolved oxygen (DO), depth, temperature, and conductivity of water under the ice at the three locations. Values are shown as average (minimum – maximum).

	Perch Lake	Mud Lake	Kimballs Bay
DO bottom (mg/L)	3.91 (0.29 – 12.88)	8.57 (2.02 – 12.24)	4.2 (1.8 – 10.48)
DO mid (mg/L)	7.79 (0.35 – 13.4)	10.77 (3.17 – 13.66)	6.69 (5.87 – 8.8)
Depth (m)	0.98 (0.59 – 1.51)	1.19 (0.58 – 1.86)	4.23 (2.8 – 5.4)
Temperature (°C)	1.4 (0.47 – 3.17)	0.99 (0.52 – 1.77)	1.79 (0.13 – 2.69)
Conductivity (ppt)	0.19 (0.11 – 0.23)	0.13 (0.11 – 0.16)	0.21 (0.2 – 0.24)

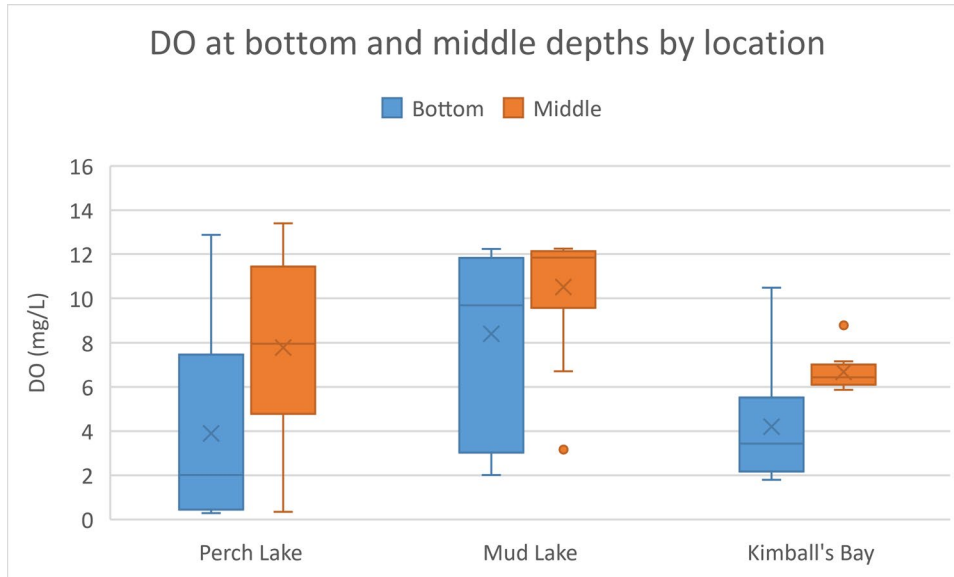


Figure 1. Dissolved oxygen (DO) concentrations in Perch Lake, Mud Lake, and Kimball's Bay by depth (bottom vs. middle of water column). Different capital letters indicate significant differences among locations (bottom and middle DO data combined), and asterisks indicate significantly different bottom and middle DO concentrations at the given location.

### 3.3 DO and Distance from Estuarine Connections

DO was significantly, negatively associated with distance from connections to the estuary at Perch ( $F_{1,26} = 12, P = 0.0016$ ) and Mud Lakes ( $F_{1,20} = 46, P < 0.0001$ ; Fig. 2 & 3). These findings were similar when the data were analyzed by bottom and middle of the water column, with the exception of bottom DO at Perch Lake, which was marginally non-significant ( $F_{1,12} = 4.3, P = 0.06$ ).

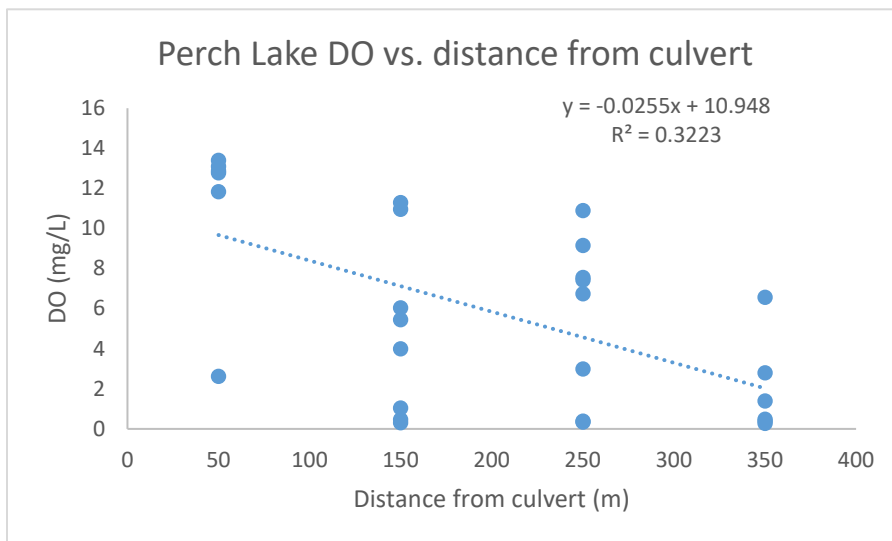


Figure 2. Perch Lake dissolved oxygen (DO) concentrations with respect to distance from the culvert with best linear fit regression line. Equation for the regression line and  $r^2$  value shown in the figure.

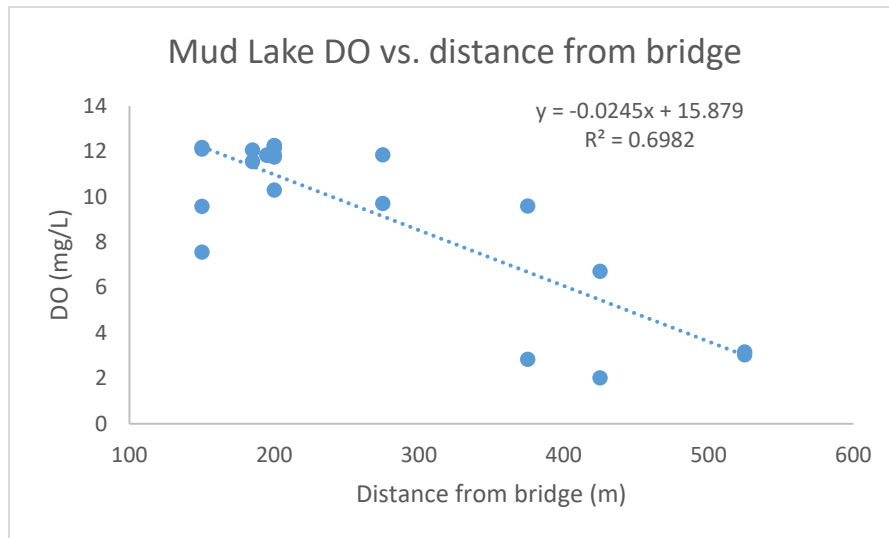


Figure 3. Mud Lake dissolved oxygen (DO) concentrations with respect to distance from the bridge with best linear fit regression line. Equation for the regression line and  $r^2$  value shown in the figure.

#### 4. Discussion

This snapshot of late-winter under-ice water quality in bays of the St. Louis River Estuary revealed three consistent patterns with respect to DO concentrations: 1) DO was, on average, relatively low, 2) DO is lower at the bottom than at the middle of the water column, and 3) DO decreases with increasing distance from connections to the estuary. All of these findings are consistent with previous research (Garono et al. 2019), and confirm that DO concentrations in these bays continue to be low immediately prior to ice-out. Ice out on the St. Louis River in 2020 occurred during the week of March 30<sup>th</sup>. The decreasing DO with increasing distance from connections to the estuary indicate the potential importance of water exchange with the estuary in increasing DO within the bays.

Other water quality indicators, however, differed between the current study and other work. Previous research found under-ice winter temperatures to be higher in Perch Lake than other locations in the estuary (Garono et al. 2019), but there were no differences among the three locations in the current research. Conductivity was also previously found to be higher in Perch Lake than most other locations (Garono et al. 2019), but Perch Lake conductivity in the current study was moderate compared to Kimballs Bay and Mud Lake. It is not known what would lead to the differences in temperature between studies, but conductivity in the previous research was only reported on for summer months and not under-ice conditions, which may be partly responsible for this inconsistency.

Garano et al. (2019) suggested that increased water exchange between the river and these bays could remove highly organic sediments that are presumably responsible for low DO concentrations, an assertion which the current authors support. Restoration projects designed to address issues with connectivity to the St. Louis River at Perch Lake and Mud Lake through the St. Louis River Area of Concern are scheduled to be completed by 2021 and 2022, respectively. Duplication of this methodology following modifications to the road, culverts and railroad bridge may detect changes in hypoxia and overall ecosystem health in two of the surveyed bays.

## 5. Acknowledgments

The authors would like to thank Lake Superior Reserve staff members Deanna Erickson, Hannah Ramage, Jenny Sherren, Sara Rybak as well as Paul Piszczek (Wisconsin DNR) and Anna Hall (USEPA) for helping support this research.

## 6. Citation:

Bockenstedt, V., D. Haines. (2020). Under-Ice Water Quality Assessment in Perch Lake, Mud Lake, and Kimballs Bay. *Lake Superior National Estuarine Research Reserve, UW-Madison Division of Extension Natural Resources Institute.*

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# Appendix:

## Analysis of Under Ice Water Quality Assessment in Perch Lake, Mud Lake, and Kimballs Bay

These are analyses on water quality data (dissolved oxygen levels, temperature, and conductivity) collected by Victoria Bockenstedt in March 2020 under the ice at three locations (Perch Lake, Mud Lake, and Kimballs Bay) in the St. Louis River Estuary. Some of these analyses were used in the Report; additional exploratory analyses are also provided. Analyses completed by Dustin Haines using JMP 15 Pro.

For clarification, the meaning of terms used as section headings is as follows:

- DO = dissolved oxygen (in mg/L)
- Depth = the recorded depth of the sonde (continuous data)
- Water Column Position = middle or bottom of water column (categorical data)
- Location = lake that was sampled (Kimball, Mud, or Perch)
- Distance from constriction = horizontal distance on ice from constriction (culvert or bridge)

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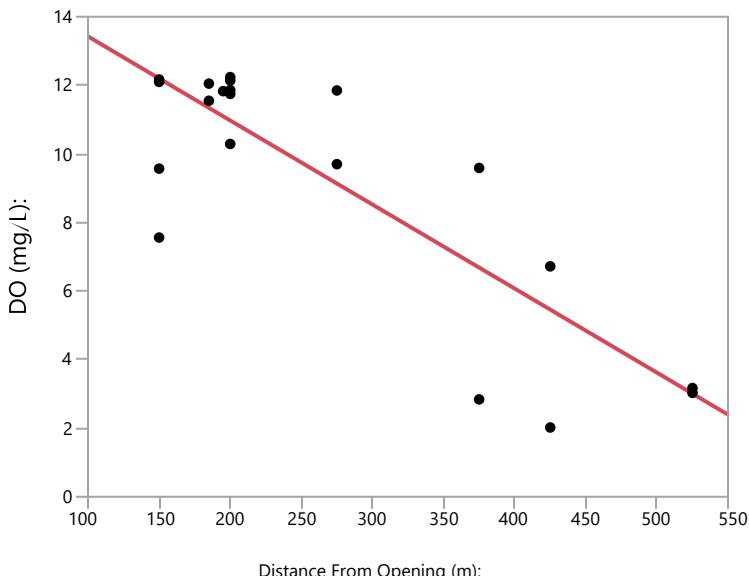


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## DO vs. Distance by Location (linear regression)

Mud Lake

**Bivariate Fit of DO (mg/L): By Distance From Opening (m): Location=Mud**



— Linear Fit

### Linear Fit

DO (mg/L): = 15.878692 - 0.0245158\*Distance From Opening (m):

### Summary of Fit

RSquare	0.698233
RSquare Adj	0.683145
Root Mean Square Error	2.011154
Mean of Response	9.46
Observations (or Sum Wgts)	22

### Analysis of Variance

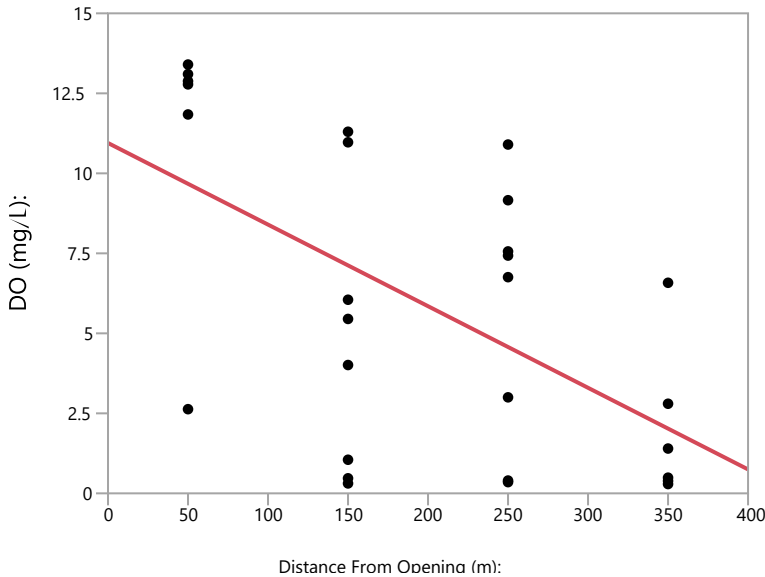
Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	187.17596	187.176	46.2764
Error	20	80.89484	4.045	<b>Prob &gt; F</b>
C. Total	21	268.07080		<.0001*

### Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob> t
Intercept	15.878692	1.03641	15.32	<.0001*
Distance From Opening (m):	-0.024516	0.003604	-6.80	<.0001*

## Perch Lake

### Bivariate Fit of DO (mg/L): By Distance From Opening (m): Location=Perch



#### Linear Fit

DO (mg/L): = 10.947874 - 0.0254992\*Distance From Opening (m):

#### Summary of Fit

RSquare	0.322347
RSquare Adj	0.296283
Root Mean Square Error	4.037034
Mean of Response	5.848036
Observations (or Sum Wgts)	28

#### Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	201.56475	201.565	12.3677
Error	26	423.73877	16.298	<b>Prob &gt; F</b>
C. Total	27	625.30352		0.0016*

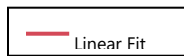
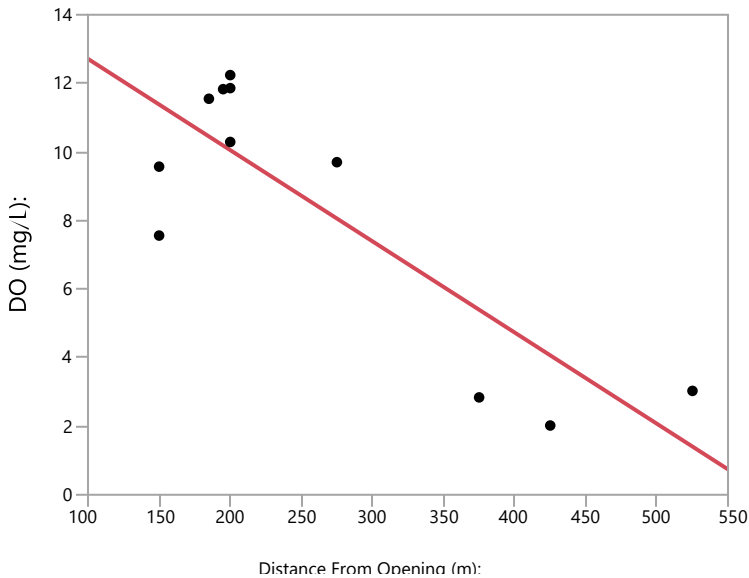
#### Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob> t
Intercept	10.947874	1.638591	6.68	<.0001*
Distance From Opening (m):	-0.025499	0.007251	-3.52	0.0016*

## DO vs. Distance by Location and Depth (linear regression)

Mud Lake, bottom

**Bivariate Fit of DO (mg/L): By Distance From Opening (m): Location=Mud, Water column position=Bottom**



### Linear Fit

DO (mg/L): = 15.373774 - 0.0266047\*Distance From Opening (m):

### Summary of Fit

RSquare	0.705627
RSquare Adj	0.672919
Root Mean Square Error	2.260279
Mean of Response	8.408182
Observations (or Sum Wgts)	11

### Analysis of Variance

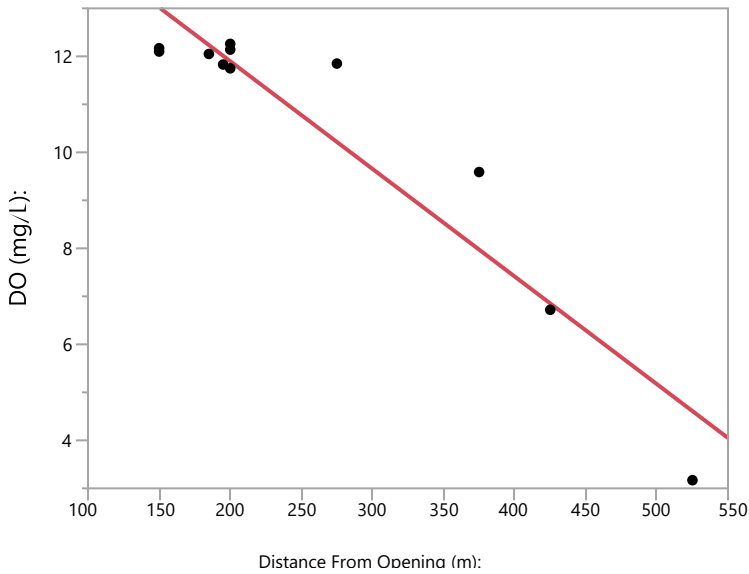
Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	110.21563	110.216	21.5734
Error	9	45.97974	5.109	<b>Prob &gt; F</b>
C. Total	10	156.19536		0.0012*

### Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob> t
Intercept	15.373774	1.647265	9.33	<.0001*
Distance From Opening (m):	-0.026605	0.005728	-4.64	0.0012*

## Mud Lake, Middle

### Bivariate Fit of DO (mg/L): By Distance From Opening (m): Location=Mud, Water column position=Mid



#### Linear Fit

DO (mg/L): = 16.383609 - 0.022427\*Distance From Opening (m):

#### Summary of Fit

RSquare	0.894705
RSquare Adj	0.883005
Root Mean Square Error	1.011993
Mean of Response	10.51182
Observations (or Sum Wgts)	11

#### Analysis of Variance

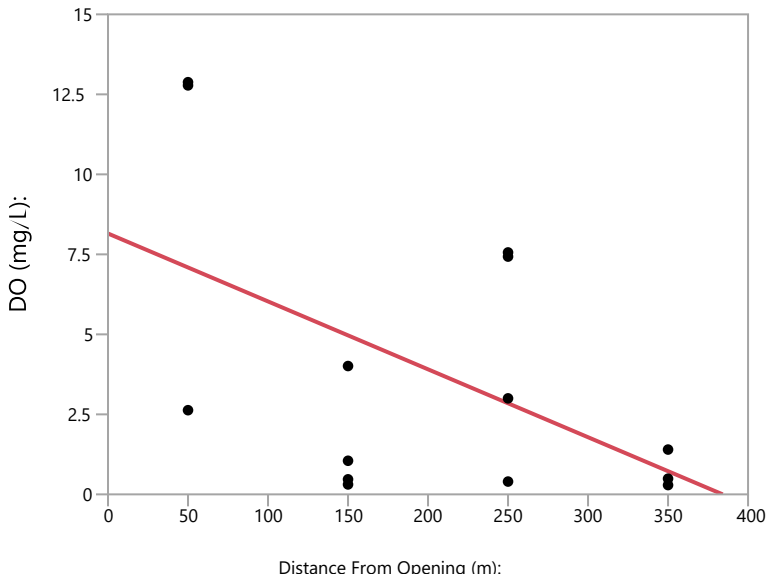
Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	78.319188	78.3192	76.4738
Error	9	9.217175	1.0241	<b>Prob &gt; F</b>
C. Total	10	87.536364		<.0001*

#### Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob> t
Intercept	16.383609	0.737529	22.21	<.0001*
Distance From Opening (m):	-0.022427	0.002565	-8.74	<.0001*

## Perch Lake, Bottom

### Bivariate Fit of DO (mg/L): By Distance From Opening (m): Location=Perch, Water column position=Bottom



— Linear Fit

#### Linear Fit

DO (mg/L): = 8.1510138 - 0.0212194\*Distance From Opening (m):

#### Summary of Fit

RSquare	0.264637
RSquare Adj	0.203357
Root Mean Square Error	4.020062
Mean of Response	3.907143
Observations (or Sum Wgts)	14

#### Analysis of Variance

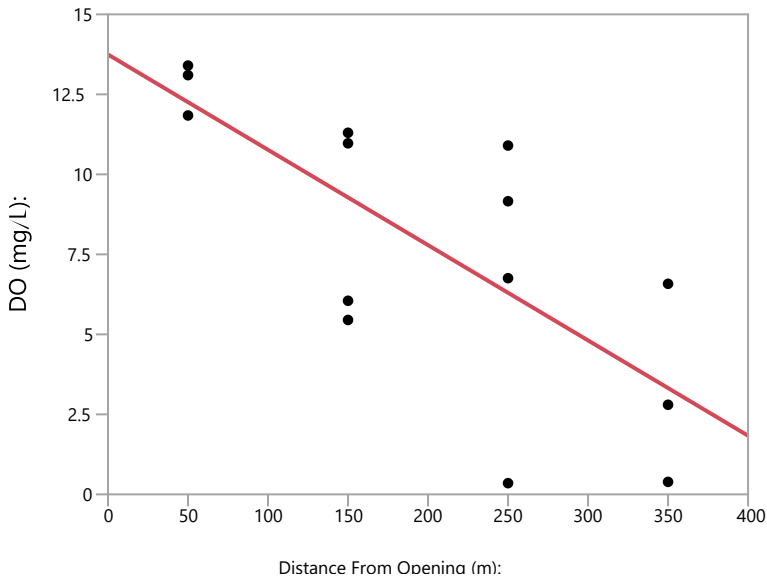
Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	69.79046	69.7905	4.3185
Error	12	193.93083	16.1609	<b>Prob &gt; F</b>
C. Total	13	263.72129		0.0598

#### Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob> t
Intercept	8.1510138	2.307576	3.53	0.0041*
Distance From Opening (m):	-0.021219	0.010211	-2.08	0.0598

## Perch Lake, Middle

### Bivariate Fit of DO (mg/L): By Distance From Opening (m): Location=Perch, Water column position=Mid



#### Linear Fit

DO (mg/L): = 13.744735 - 0.029779\*Distance From Opening (m):

#### Summary of Fit

RSquare	0.536705
RSquare Adj	0.498097
Root Mean Square Error	3.144464
Mean of Response	7.788929
Observations (or Sum Wgts)	14

#### Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	137.45257	137.453	13.9014
Error	12	118.65184	9.888	<b>Prob &gt; F</b>
C. Total	13	256.10441		0.0029*

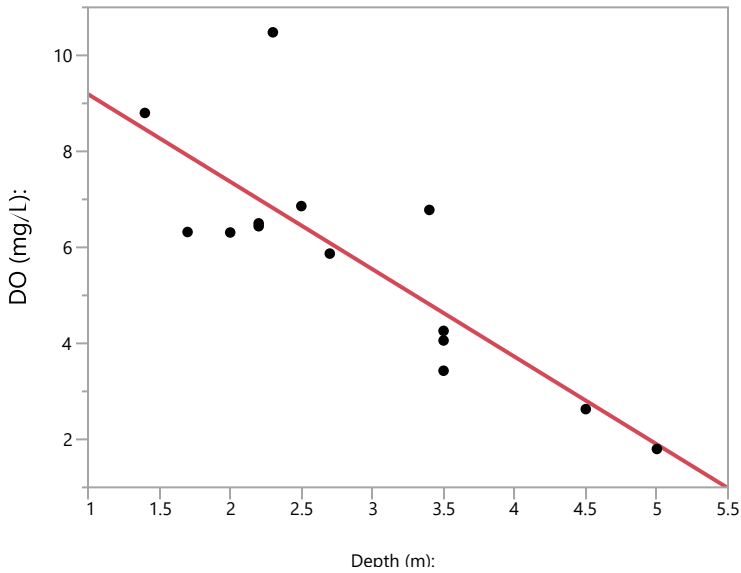
#### Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob> t
Intercept	13.744735	1.804969	7.61	<.0001*
Distance From Opening (m):	-0.029779	0.007987	-3.73	0.0029*

## DO vs. Depth by Location (linear regression)

Kimballs Bay

### Bivariate Fit of DO (mg/L): By Depth (m): Location=Kimball



#### Linear Fit

DO (mg/L): = 11.015893 - 1.8238242\*Depth (m):

#### Summary of Fit

RSquare	0.667412
RSquare Adj	0.639697
Root Mean Square Error	1.407277
Mean of Response	5.752857
Observations (or Sum Wgts)	14

#### Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	47.690138	47.6901	24.0807
Error	12	23.765148	1.9804	<b>Prob &gt; F</b>
C. Total	13	71.455286		0.0004*

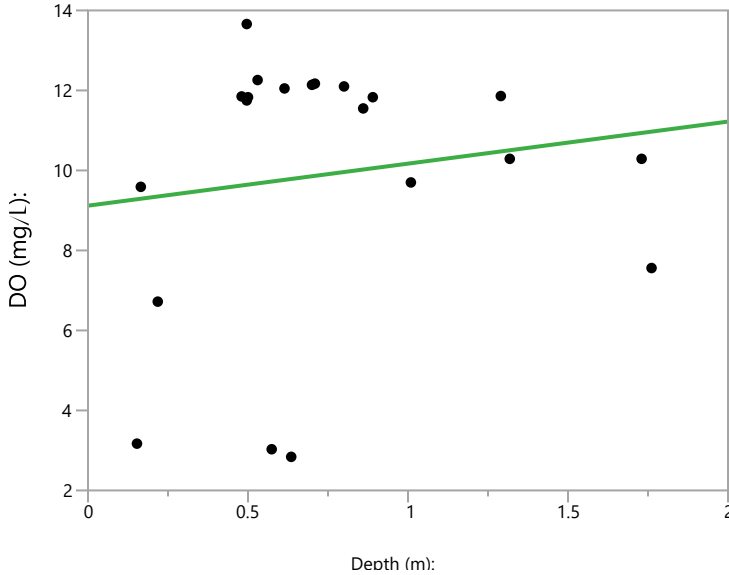
#### Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob> t
Intercept	11.015893	1.136547	9.69	<.0001*
Depth (m):	-1.823824	0.371662	-4.91	0.0004*



## Mud Lake

### Bivariate Fit of DO (mg/L): By Depth (m): Location=Mud



#### Linear Fit

DO (mg/L): = 9.1190524 + 1.0509731\*Depth (m):

#### Summary of Fit

RSquare	0.020472
RSquare Adj	-0.03108
Root Mean Square Error	3.359614
Mean of Response	9.91619
Observations (or Sum Wgts)	21

#### Analysis of Variance

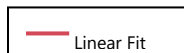
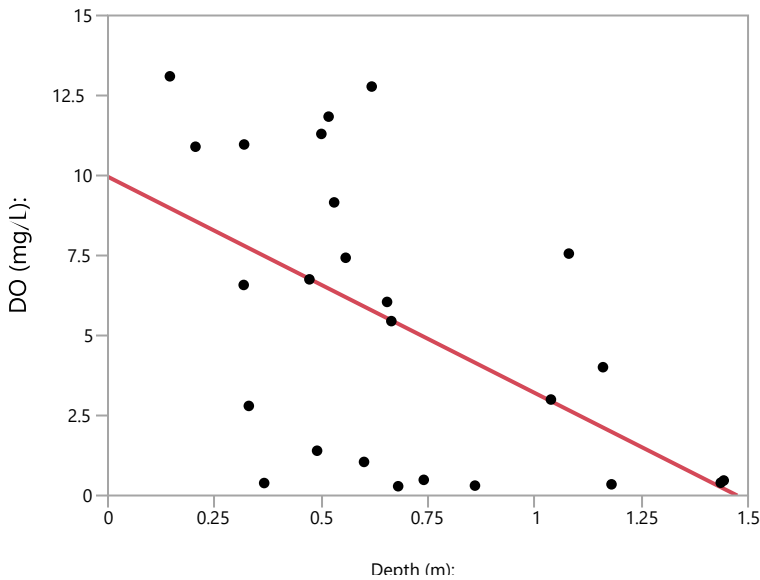
Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	4.48211	4.4821	0.3971
Error	19	214.45318	11.2870	<b>Prob &gt; F</b>
C. Total	20	218.93530		0.5361

#### Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob> t
Intercept	9.1190524	1.462065	6.24	<.0001*
Depth (m):	1.0509731	1.667783	0.63	0.5361

## Perch Lake

### Bivariate Fit of DO (mg/L): By Depth (m): Location=Perch



#### Linear Fit

DO (mg/L): = 9.9593592 - 6.7535783\*Depth (m):

#### Summary of Fit

RSquare	0.284498
RSquare Adj	0.253389
Root Mean Square Error	3.956899
Mean of Response	5.3934
Observations (or Sum Wgts)	25

#### Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	143.18759	143.188	9.1452
Error	23	360.11215	15.657	<b>Prob &gt; F</b>
C. Total	24	503.29974		0.0060*

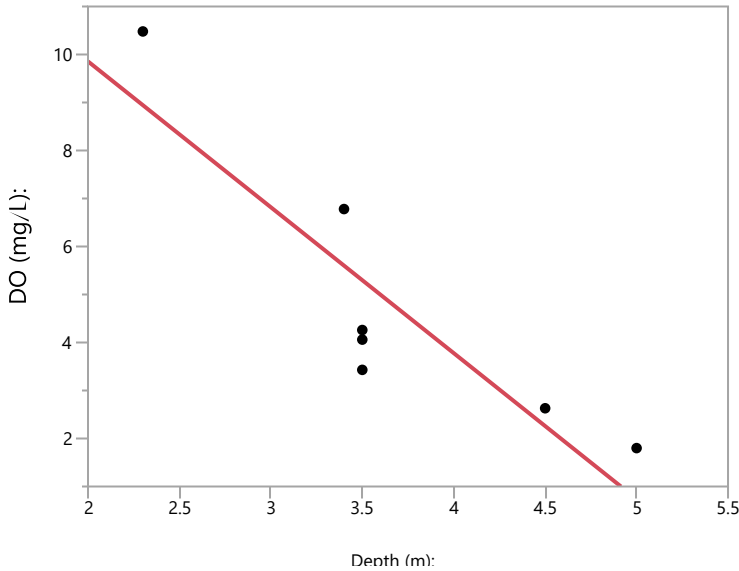
#### Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob> t
Intercept	9.9593592	1.70468	5.84	<.0001*
Depth (m):	-6.753578	2.233244	-3.02	0.0060*

# DO vs Depth by Water Column Position and Location (linear regression)

Kimballs Bay, Bottom DO

## Bivariate Fit of DO (mg/L): By Depth (m): Location=Kimball, Water column position=Bottom



— Linear Fit

### Linear Fit

$$\text{DO (mg/L)} = 15.933338 - 3.0386523 \times \text{Depth (m)}$$

### Summary of Fit

RSquare 0.788865  
 RSquare Adj 0.746638  
 Root Mean Square Error 1.490407  
 Mean of Response 4.777143  
 Observations (or Sum Wgts) 7

### Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	41.497572	41.4976	18.6815
Error	5	11.106571	2.2213	<b>Prob &gt; F</b>
C. Total	6	52.604143		0.0076*

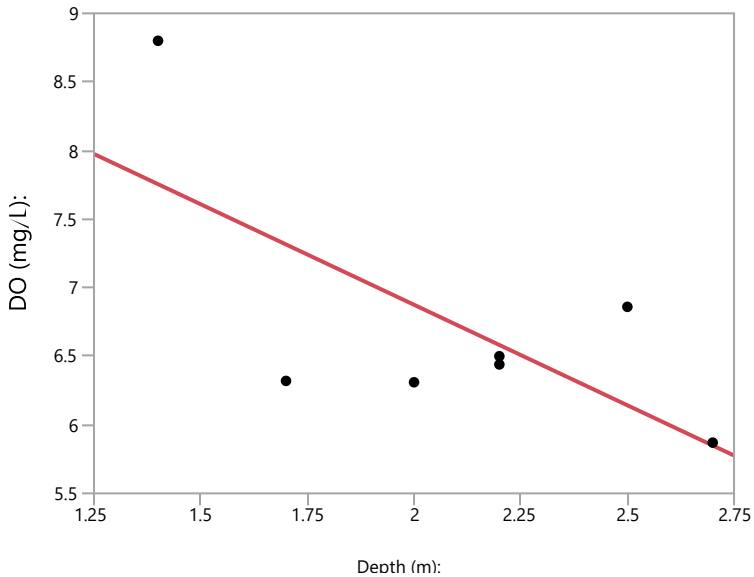
### Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob> t
Intercept	15.933338	2.641885	6.03	0.0018*

Term	Estimate	Std Error	t Ratio	Prob> t
Depth (m):	-3.038652	0.703031	-4.32	0.0076*

### Kimballs Bay, Middle DO

#### Bivariate Fit of DO (mg/L): By Depth (m): Location=Kimball, Water column position=Mid



#### Linear Fit

DO (mg/L): = 9.8068214 - 1.4658333\*Depth (m):

#### Summary of Fit

RSquare	0.466858
RSquare Adj	0.360229
Root Mean Square Error	0.767396
Mean of Response	6.728571
Observations (or Sum Wgts)	7

#### Analysis of Variance

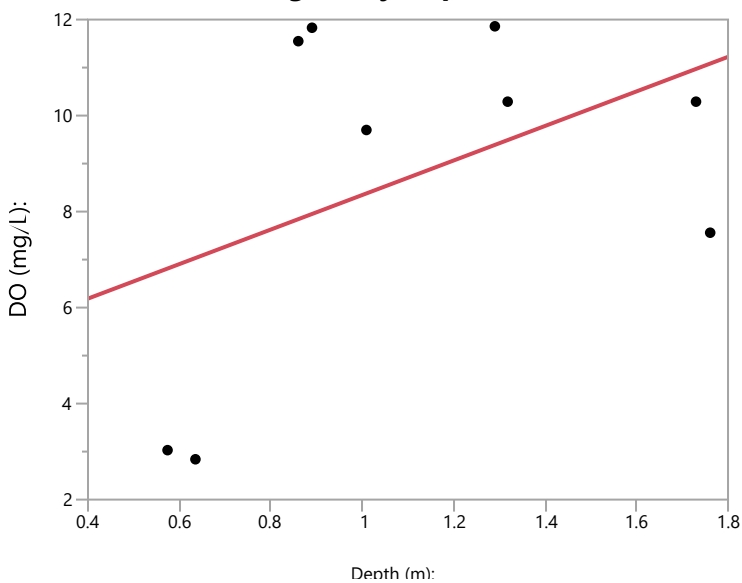
Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	2.5784008	2.57840	4.3784
Error	5	2.9444849	0.58890	<b>Prob &gt; F</b>
C. Total	6	5.5228857		0.0906

#### Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob> t
Intercept	9.8068214	1.499441	6.54	0.0013*
Depth (m):	-1.465833	0.700534	-2.09	0.0906

## Mud Lake, Bottom DO

### Bivariate Fit of DO (mg/L): By Depth (m): Location=Mud, Water column position=Bottom



#### Linear Fit

DO (mg/L): = 4.7482847 + 3.5974409\*Depth (m):

#### Summary of Fit

RSquare	0.193067
RSquare Adj	0.07779
Root Mean Square Error	3.424012
Mean of Response	8.772222
Observations (or Sum Wgts)	9

#### Analysis of Variance

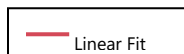
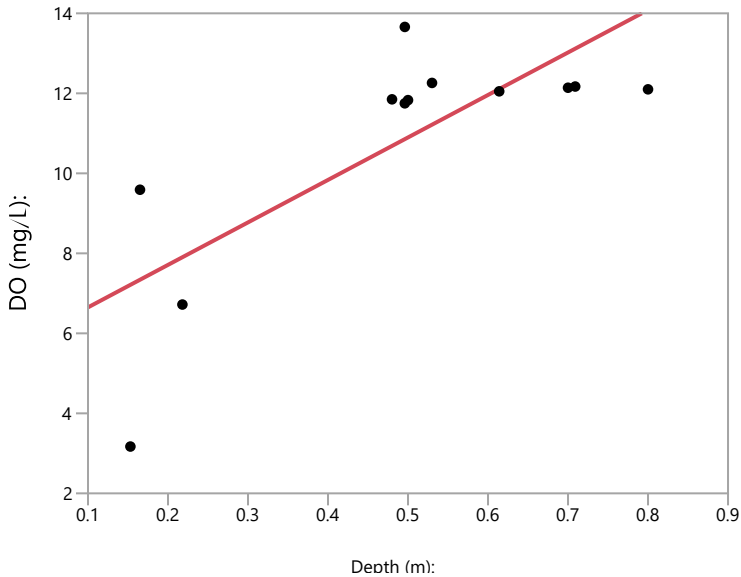
Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	19.63533	19.6353	1.6748
Error	7	82.06702	11.7239	<b>Prob &gt; F</b>
C. Total	8	101.70236		0.2367

#### Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob> t
Intercept	4.7482847	3.312191	1.43	0.1948
Depth (m):	3.5974409	2.779776	1.29	0.2367

## Mud Lake, Middle DO

### Bivariate Fit of DO (mg/L): By Depth (m): Location=Mud, Water column position=Mid



#### Linear Fit

DO (mg/L): = 5.5875297 + 10.619287\*Depth (m):

#### Summary of Fit

RSquare	0.581878
RSquare Adj	0.540066
Root Mean Square Error	2.009965
Mean of Response	10.77417
Observations (or Sum Wgts)	12

#### Analysis of Variance

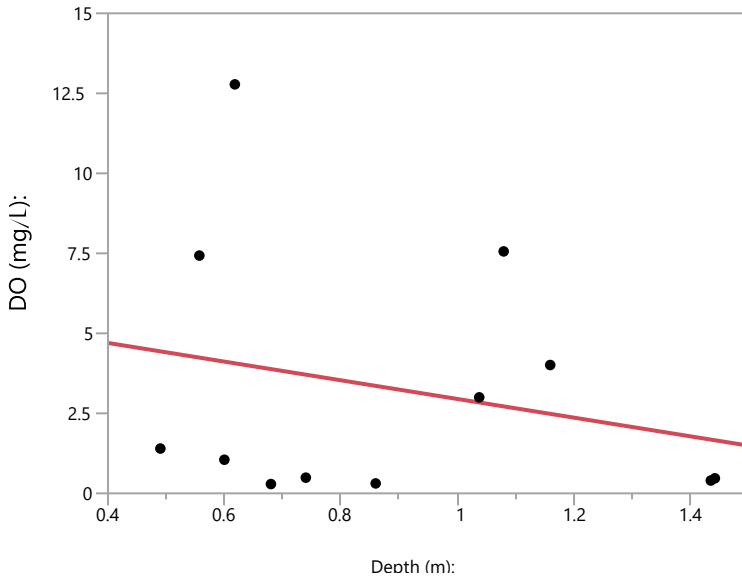
Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	56.221897	56.2219	13.9165
Error	10	40.399595	4.0400	<b>Prob &gt; F</b>
C. Total	11	96.621492		0.0039*

#### Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob> t
Intercept	5.5875297	1.506557	3.71	0.0040*
Depth (m):	10.619287	2.846631	3.73	0.0039*

## Perch Lake, Bottom DO

### Bivariate Fit of DO (mg/L): By Depth (m): Location=Perch, Water column position=Bottom



#### Linear Fit

DO (mg/L): = 5.8654265 - 2.9148868\*Depth (m):

#### Summary of Fit

RSquare	0.059224
RSquare Adj	-0.03485
Root Mean Square Error	4.076533
Mean of Response	3.265833
Observations (or Sum Wgts)	12

#### Analysis of Variance

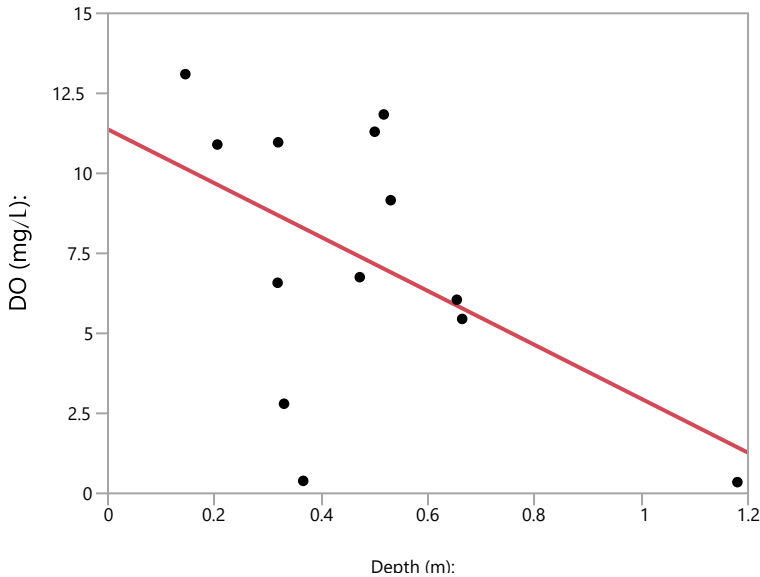
Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	10.46149	10.4615	0.6295
Error	10	166.18120	16.6181	<b>Prob &gt; F</b>
C. Total	11	176.64269		0.4459

#### Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob> t
Intercept	5.8654265	3.481345	1.68	0.1229
Depth (m):	-2.914887	3.673802	-0.79	0.4459

## Perch Lake, Middle DO

### Bivariate Fit of DO (mg/L): By Depth (m): Location=Perch, Water column position=Mid



#### Linear Fit

DO (mg/L): = 11.372266 - 8.4184603\*Depth (m):

#### Summary of Fit

RSquare	0.265958
RSquare Adj	0.199227
Root Mean Square Error	3.850654
Mean of Response	7.357308
Observations (or Sum Wgts)	13

#### Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	59.09555	59.0956	3.9855
Error	11	163.10288	14.8275	<b>Prob &gt; F</b>
C. Total	12	222.19843		0.0712

#### Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob> t
Intercept	11.372266	2.2771	4.99	0.0004*
Depth (m):	-8.41846	4.216865	-2.00	0.0712



## DO vs Depth by Location (ANOVA)

Kimballs Bay

**Response DO (mg/L): Location=Kimball**

### Summary of Fit

RSquare	0.285828
RSquare Adj	0.241192
Root Mean Square Error	2.084555
Mean of Response	5.442222
Observations (or Sum Wgts)	18

### Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	27.825800	27.8258	6.4036
Error	16	69.525911	4.3454	<b>Prob &gt; F</b>
C. Total	17	97.351711		0.0223*

### Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob> t
Intercept	5.4422222	0.491334	11.08	<.0001*
Water column position[Bottom]	-1.243333	0.491334	-2.53	0.0223*

Mud Lake

**Response DO (mg/L): Location=Mud**

### Summary of Fit

RSquare	0.102621
RSquare Adj	0.061831
Root Mean Square Error	3.411631
Mean of Response	9.669583
Observations (or Sum Wgts)	24

### Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	29.28250	29.2825	2.5158
Error	22	256.06299	11.6392	<b>Prob &gt; F</b>
C. Total	23	285.34550		0.1270

### Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob> t
Intercept	9.6695833	0.696396	13.89	<.0001*
Water column position[Bottom]	-1.104583	0.696396	-1.59	0.1270

## Perch Lake

### Response DO (mg/L): Location=Perch

#### Summary of Fit

RSquare	0.168683
RSquare Adj	0.136709
Root Mean Square Error	4.471386
Mean of Response	5.848036
Observations (or Sum Wgts)	28

#### Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	105.47782	105.478	5.2757
Error	26	519.82569	19.993	<b>Prob &gt; F</b>
C. Total	27	625.30352		0.0299*

#### Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob> t
Intercept	5.8480357	0.845013	6.92	<.0001*
Water column position[Bottom]	-1.940893	0.845013	-2.30	0.0299*

## DO vs Location (ANOVA)

### Response DO (mg/L):

#### Summary of Fit

RSquare	0.199792
RSquare Adj	0.175906
Root Mean Square Error	3.878761
Mean of Response	7.053929
Observations (or Sum Wgts)	70

#### Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	2	251.6733	125.837	8.3641
Error	67	1008.0007	15.045	<b>Prob &gt; F</b>
C. Total	69	1259.6740		0.0006*

## Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Location	2	2	251.67332	8.3641	0.0006*

## Multiple Comparisons for Location Least Squares Means Estimates

Location	Estimate	Std Error	DF	Lower 95%	Upper 95%	Arithmetic Mean Estimate	N
Kimball	5.4422222	0.91423274	67	3.6174060	7.267038	5.4422222	18
Mud	9.6695833	0.79174877	67	8.0892462	11.249921	9.6695833	24
Perch	5.8480357	0.73301693	67	4.3849278	7.311144	5.8480357	28

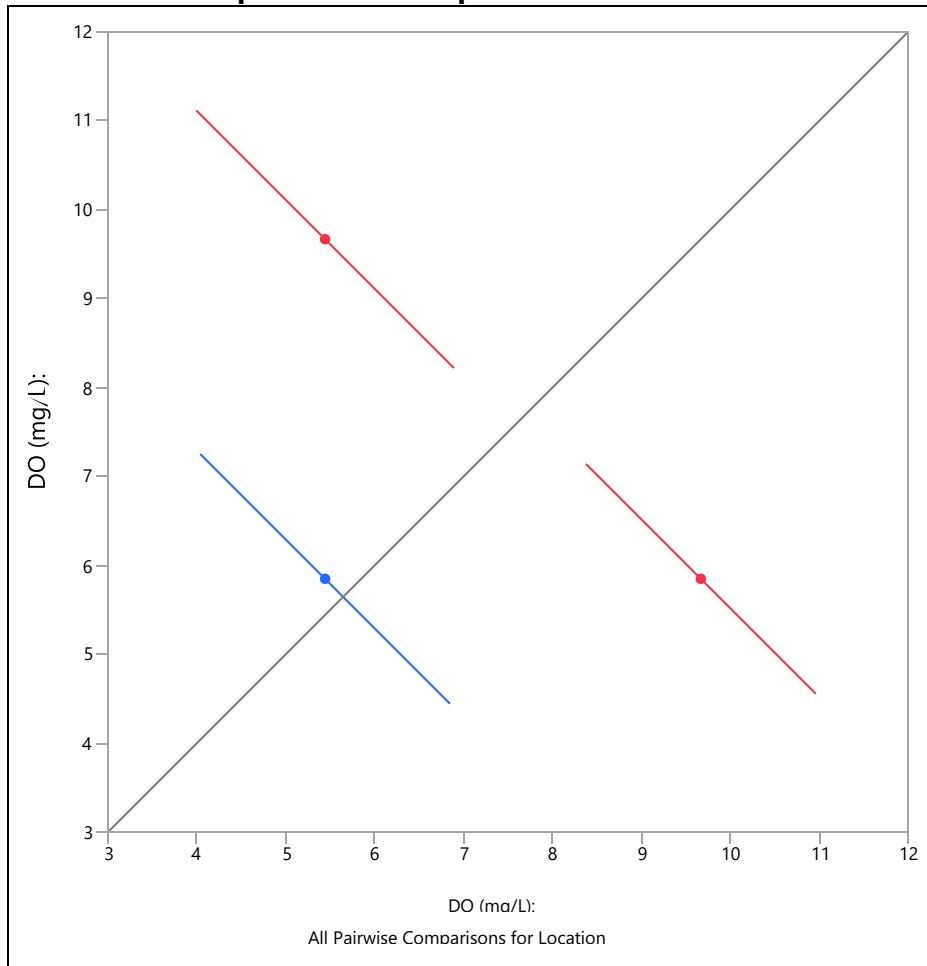
## Tukey HSD All Pairwise Comparisons

Quantile = 2.39689, Adjusted DF = 67.0, Adjustment = Tukey-Kramer

### All Pairwise Differences

Location	-Location	Difference	Std Error	t Ratio	Prob> t	Lower 95%	Upper 95%
Kimball	Mud	-4.22736	1.209416	-3.50	0.0024*	-7.12620	-1.32852
Kimball	Perch	-0.40581	1.171809	-0.35	0.9361	-3.21451	2.40288
Mud	Perch	3.82155	1.078972	3.54	0.0021*	1.23537	6.40772

### All Pairwise Comparisons Scatterplot



Legend

- Significant
- Not Significant

### DO vs Location by Depth (ANOVA)

Bottom

**Response DO (mg/L): Water column position=Bottom**

#### Summary of Fit

RSquare	0.251348
RSquare Adj	0.204558
Root Mean Square Error	3.898321
Mean of Response	5.579143
Observations (or Sum Wgts)	35

## Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	2	163.26820	81.6341	5.3718
Error	32	486.30107	15.1969	<b>Prob &gt; F</b>
C. Total	34	649.56927		0.0097*

## Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Location	2	2	163.26820	5.3718	0.0097*

## Multiple Comparisons for Location Least Squares Means Estimates

Location	Estimate	Std Error	DF	Lower 95%	Upper 95%	Arithmetic Mean Estimate	N
Kimball	4.1988889	1.2994404	32	1.5520154	6.845762	4.1988889	9
Mud	8.5650000	1.1253484	32	6.2727403	10.857260	8.5650000	12
Perch	3.9071429	1.0418702	32	1.7849227	6.029363	3.9071429	14

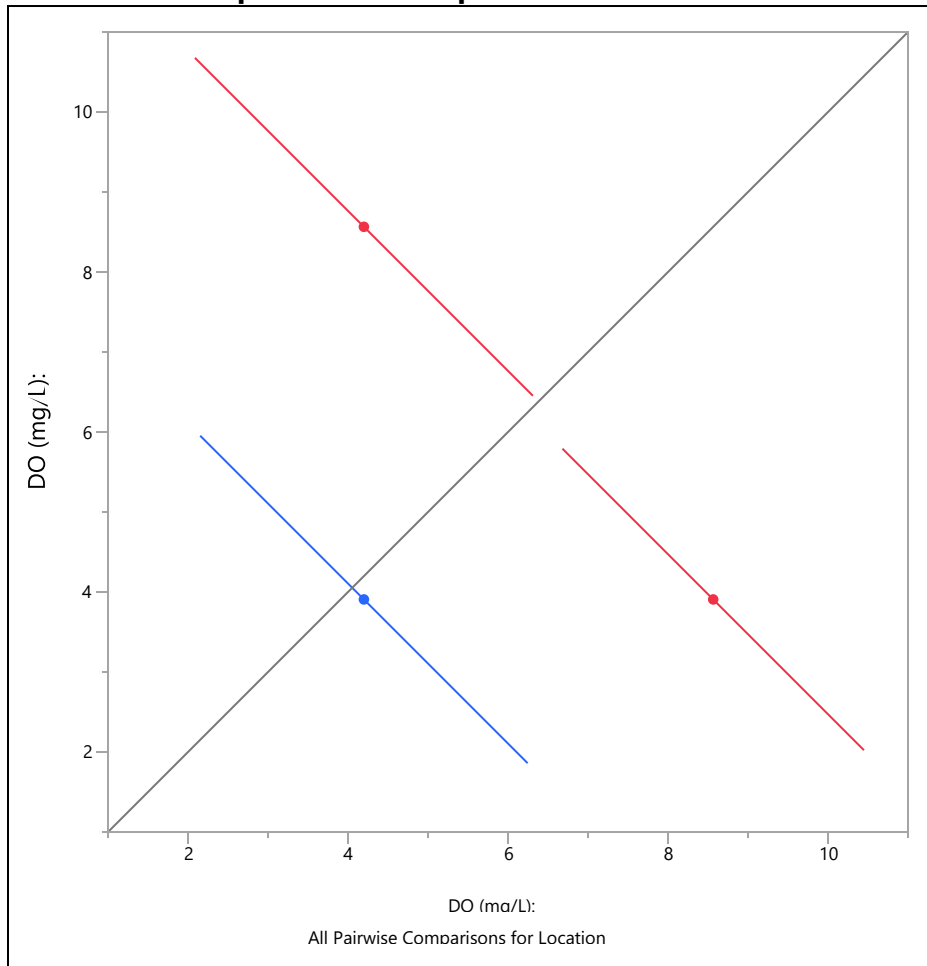
## Tukey HSD All Pairwise Comparisons

Quantile = 2.45737, Adjusted DF = 32.0, Adjustment = Tukey-Kramer

### All Pairwise Differences

Location	-Location	Difference	Std Error	t Ratio	Prob> t	Lower 95%	Upper 95%
Kimball	Mud	-4.36611	1.718998	-2.54	0.0416*	-8.59033	-0.14189
Kimball	Perch	0.29175	1.665545	0.18	0.9832	-3.80112	4.38461
Mud	Perch	4.65786	1.533591	3.04	0.0128*	0.88925	8.42646

### All Pairwise Comparisons Scatterplot



Legend

- Significant
- Not Significant

### Middle

#### Response DO (mg/L): Water column position=Mid

#### Summary of Fit

RSquare	0.215661
RSquare Adj	0.16664
Root Mean Square Error	3.34997
Mean of Response	8.528714
Observations (or Sum Wgts)	35

#### Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	2	98.74174	49.3709	4.3994
Error	32	359.11352	11.2223	<b>Prob &gt; F</b>
C. Total	34	457.85527		0.0205*

### Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Location	2	2	98.741744	4.3994	0.0205*

### Multiple Comparisons for Location Least Squares Means Estimates

Location	Estimate	Std Error	DF	Lower 95%	Upper 95%	Arithmetic Mean Estimate	N
Kimball	6.685556	1.1166566	32	4.4110005	8.960111	6.685556	9
Mud	10.774167	0.9670530	32	8.8043442	12.743989	10.774167	12
Perch	7.788929	0.8953171	32	5.9652273	9.612630	7.788929	14

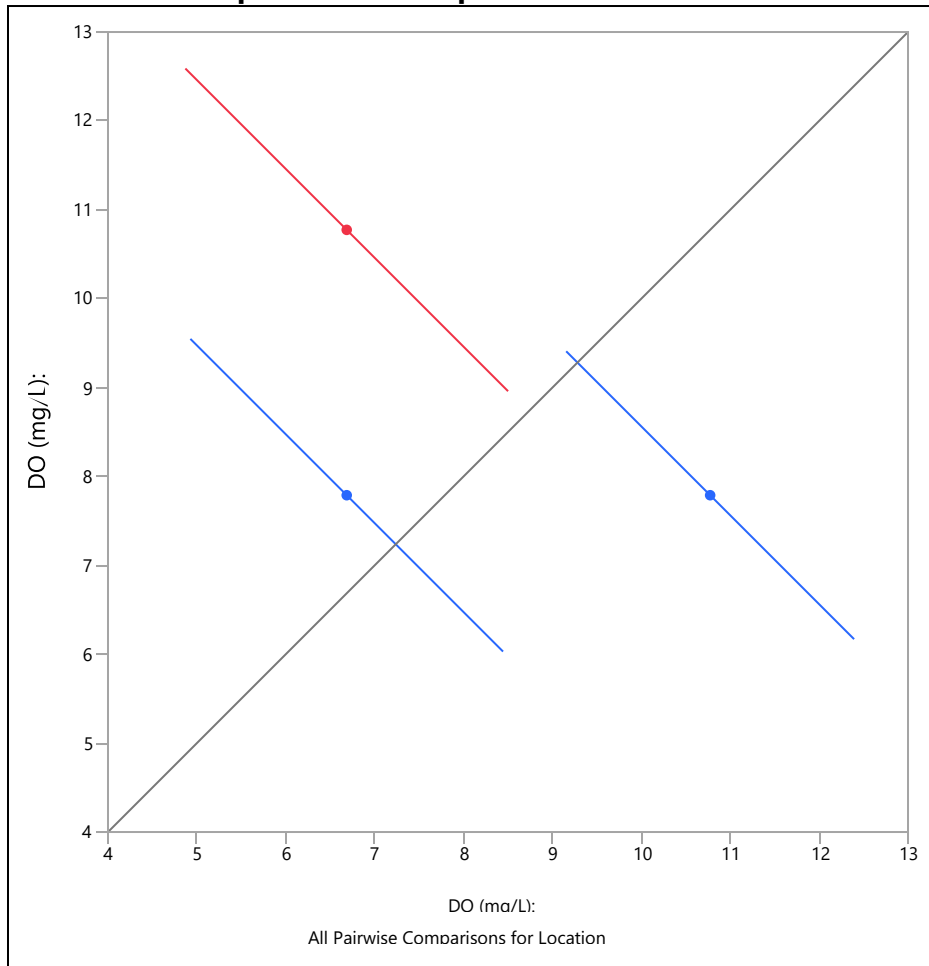
### Tukey HSD All Pairwise Comparisons

Quantile = 2.45737, Adjusted DF = 32.0, Adjustment = Tukey-Kramer

### All Pairwise Differences

Location	-Location	Difference	Std Error	t Ratio	Prob> t	Lower 95%	Upper 95%
Kimball	Mud	-4.08861	1.477198	-2.77	0.0246*	-7.71864	-0.45859
Kimball	Perch	-1.10337	1.431263	-0.77	0.7233	-4.62052	2.41377
Mud	Perch	2.98524	1.317871	2.27	0.0756	-0.25326	6.22374

### All Pairwise Comparisons Scatterplot



Legend

- Significant
- Not Significant

### DO vs. Water Column Position by Location (ANOVA)

Kimballs Bay

#### Response DO (mg/L): Location=Kimball

##### Summary of Fit

RSquare	0.285828
RSquare Adj	0.241192
Root Mean Square Error	2.084555
Mean of Response	5.442222
Observations (or Sum Wgts)	18



## Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	27.825800	27.8258	6.4036
Error	16	69.525911	4.3454	<b>Prob &gt; F</b>
C. Total	17	97.351711		0.0223*

## Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob> t
Intercept	5.4422222	0.491334	11.08	<.0001*
Water column position[Bottom]	-1.243333	0.491334	-2.53	0.0223*

## Mud Lake

### Response DO (mg/L): Location=Mud

#### Summary of Fit

RSquare	0.102621
RSquare Adj	0.061831
Root Mean Square Error	3.411631
Mean of Response	9.669583
Observations (or Sum Wgts)	24

#### Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	29.28250	29.2825	2.5158
Error	22	256.06299	11.6392	<b>Prob &gt; F</b>
C. Total	23	285.34550		0.1270

#### Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob> t
Intercept	9.6695833	0.696396	13.89	<.0001*
Water column position[Bottom]	-1.104583	0.696396	-1.59	0.1270

## Perch Lake

### Response DO (mg/L): Location=Perch

#### Summary of Fit

RSquare	0.168683
RSquare Adj	0.136709

Root Mean Square Error 4.471386  
 Mean of Response 5.848036  
 Observations (or Sum Wgts) 28

### Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	105.47782	105.478	5.2757
Error	26	519.82569	19.993	<b>Prob &gt; F</b>
C. Total	27	625.30352		0.0299*

### Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob> t
Intercept	5.8480357	0.845013	6.92	<.0001*
Water column position[Bottom]	-1.940893	0.845013	-2.30	0.0299*

## DO vs. distances from constriction at Perch Lake (ANOVA)

### Bottom

### Response DO Bottom (mg/L):

#### Summary of Fit

RSquare 0.560109  
 RSquare Adj 0.428141  
 Root Mean Square Error 3.406006  
 Mean of Response 3.907143  
 Observations (or Sum Wgts) 14

### Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	3	147.71254	49.2375	4.2443
Error	10	116.00874	11.6009	<b>Prob &gt; F</b>
C. Total	13	263.72129		0.0354*

### Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Distance From Opening (m):	3	3	147.71254	4.2443	0.0354*

**Multiple Comparisons for Distance From Opening (m):  
Least Squares Means Estimates**

Distance From Opening (m):	Estimate	Std Error	DF	Lower 95%	Upper 95%	Arithmetic Mean Estimate	N
50	9.4300000	1.9664583	10	5.048458	13.811542	9.4300000	3
150	1.4600000	1.7030028	10	-2.334527	5.254527	1.4600000	4
250	4.5975000	1.7030028	10	0.802973	8.392027	4.5975000	4
350	0.7266667	1.9664583	10	-3.654875	5.108209	0.7266667	3

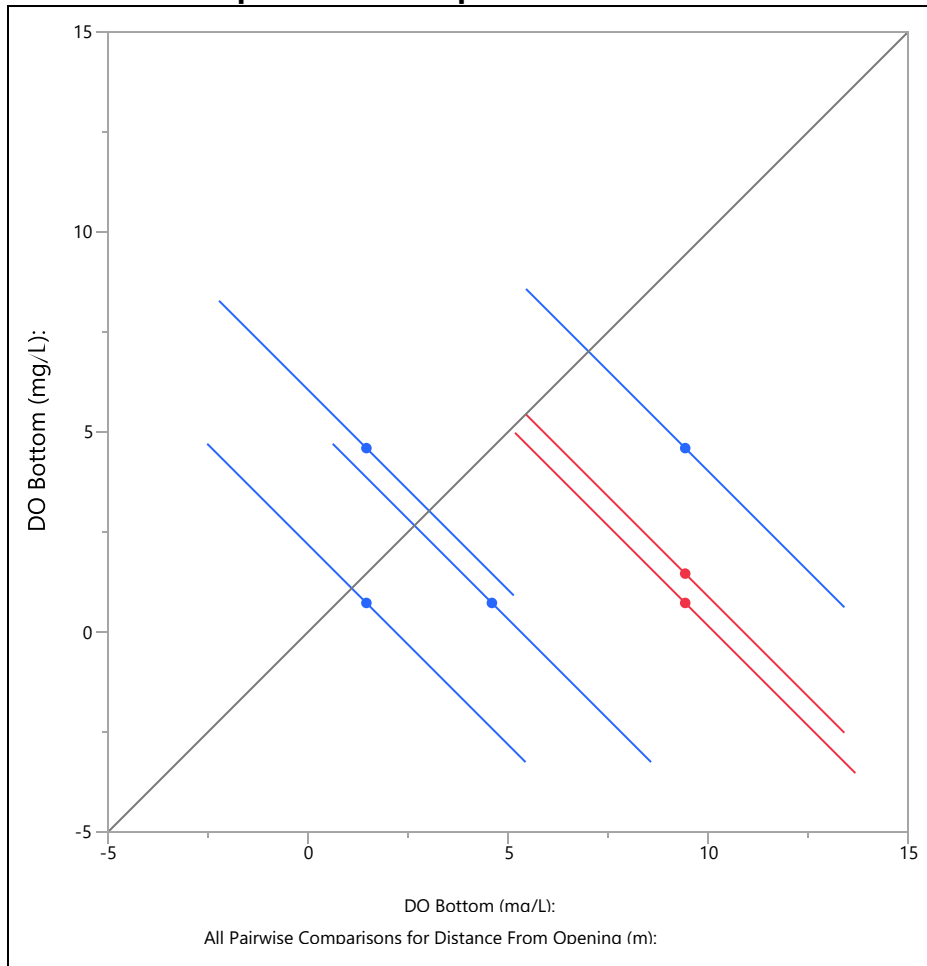
**Tukey HSD All Pairwise Comparisons**

Quantile = 3.05935, Adjusted DF = 10.0, Adjustment = Tukey-Kramer

**All Pairwise Differences**

Distance From Opening (m):	-Distance From Opening (m):	Difference	Std Error	t Ratio	Prob> t	Lower 95%	Upper 95%
50	150	7.97000	2.601380	3.06	0.0497*	0.0115	15.92854
50	250	4.83250	2.601380	1.86	0.3041	-3.1260	12.79104
50	350	8.70333	2.780992	3.13	0.0447*	0.1953	17.21137
150	250	-3.13750	2.408410	-1.30	0.5816	-10.5057	4.23067
150	350	0.73333	2.601380	0.28	0.9917	-7.2252	8.69187
250	350	3.87083	2.601380	1.49	0.4789	-4.0877	11.82937

### All Pairwise Comparisons Scatterplot



Legend

- Significant
- Not Significant

### Middle

#### Response DO Mid (mg/L):

##### Summary of Fit

RSquare	0.554644
RSquare Adj	0.421037
Root Mean Square Error	3.377244
Mean of Response	7.788929
Observations (or Sum Wgts)	14

##### Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	3	142.04665	47.3489	4.1513
Error	10	114.05776	11.4058	<b>Prob &gt; F</b>
C. Total	13	256.10441		0.0376*

### Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Distance From Opening (m):	3	3	142.04665	4.1513	0.0376*

### Multiple Comparisons for Distance From Opening (m): Least Squares Means Estimates

Distance From Opening (m):	Estimate	Std Error	DF	Lower 95%	Upper 95%	Arithmetic Mean Estimate	N
50	12.780000	1.9498526	10	8.435458	17.124542	12.780000	3
150	8.442500	1.6886219	10	4.680016	12.204984	8.442500	4
250	6.791250	1.6886219	10	3.028766	10.553734	6.791250	4
350	3.256667	1.9498526	10	-1.087876	7.601209	3.256667	3

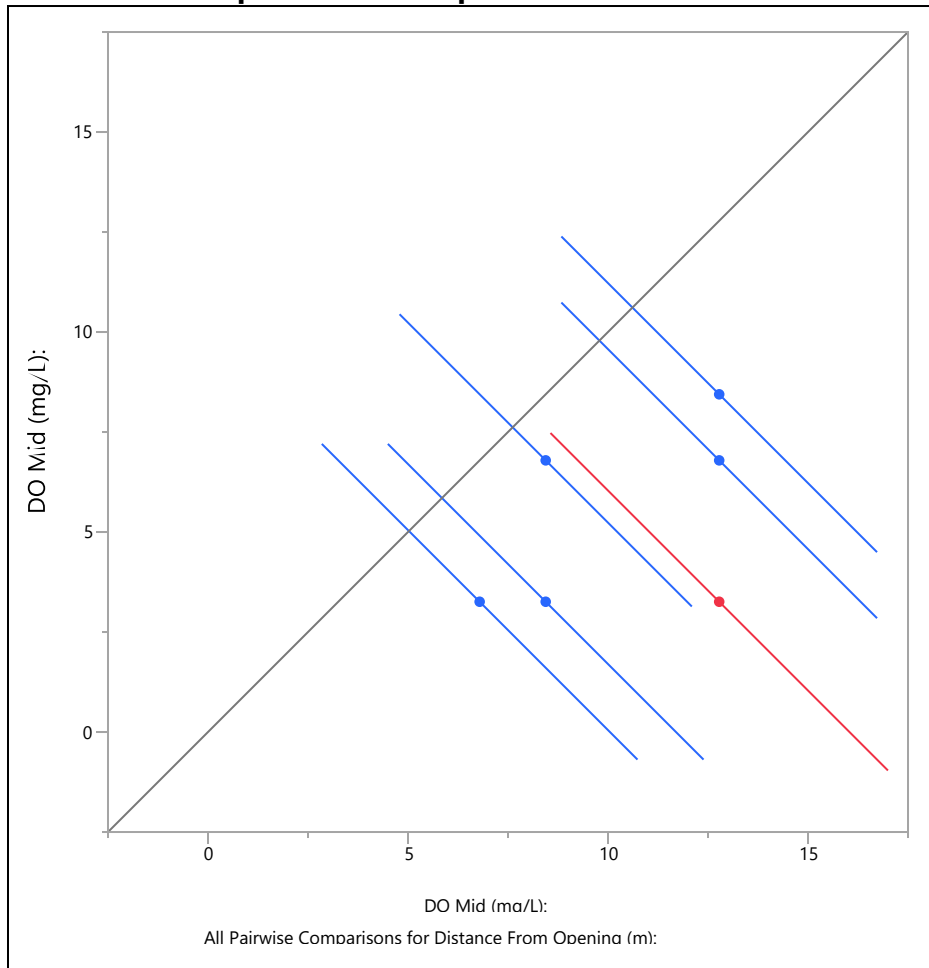
### Tukey HSD All Pairwise Comparisons

Quantile = 3.05935, Adjusted DF = 10.0, Adjustment = Tukey-Kramer

### All Pairwise Differences

Distance From Opening (m):	-Distance From Opening (m):	Difference	Std Error	t Ratio	Prob> t	Lower 95%	Upper 95%
50	150	4.337500	2.579413	1.68	0.3812	-3.55383	12.22883
50	250	5.988750	2.579413	2.32	0.1574	-1.90258	13.88008
50	350	9.523333	2.757508	3.45	0.0267*	1.08714	17.95952
150	250	1.651250	2.388072	0.69	0.8980	-5.65470	8.95720
150	350	5.185833	2.579413	2.01	0.2469	-2.70550	13.07717
250	350	3.534583	2.579413	1.37	0.5434	-4.35675	11.42592

### All Pairwise Comparisons Scatterplot



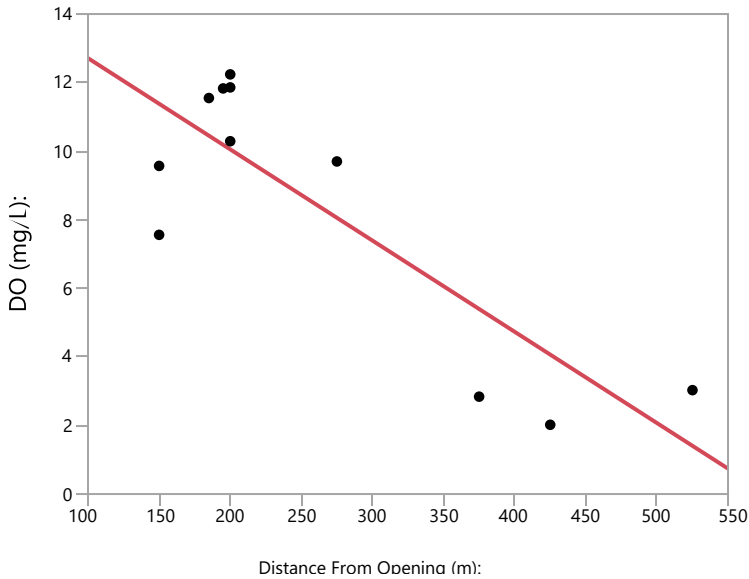
Legend

- Significant
- Not Significant

DO vs. Distance from constriction by Location and Water Column Position (ANOVA)

Mud Lake, Bottom

**Bivariate Fit of DO (mg/L): By Distance From Opening (m): Location=Mud, Water column position=Bottom**



**Linear Fit**

DO (mg/L): = 15.373774 - 0.0266047\*Distance From Opening (m):

**Summary of Fit**

RSquare 0.705627  
 RSquare Adj 0.672919  
 Root Mean Square Error 2.260279  
 Mean of Response 8.408182  
 Observations (or Sum Wgts) 11

**Analysis of Variance**

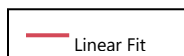
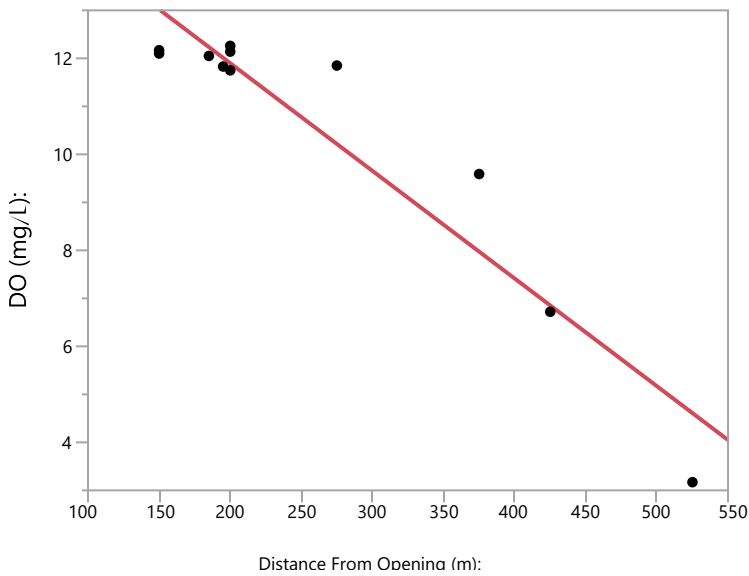
Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	110.21563	110.216	21.5734
Error	9	45.97974	5.109	<b>Prob &gt; F</b>
C. Total	10	156.19536		0.0012*

**Parameter Estimates**

Term	Estimate	Std Error	t Ratio	Prob> t
Intercept	15.373774	1.647265	9.33	<.0001*
Distance From Opening (m):	-0.026605	0.005728	-4.64	0.0012*

## Mud Lake, Middle

### Bivariate Fit of DO (mg/L): By Distance From Opening (m): Location=Mud, Water column position=Mid



#### Linear Fit

DO (mg/L): = 16.383609 - 0.022427\*Distance From Opening (m):

#### Summary of Fit

RSquare	0.894705
RSquare Adj	0.883005
Root Mean Square Error	1.011993
Mean of Response	10.51182
Observations (or Sum Wgts)	11

#### Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	78.319188	78.3192	76.4738
Error	9	9.217175	1.0241	<b>Prob &gt; F</b>
C. Total	10	87.536364		<.0001*

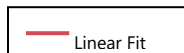
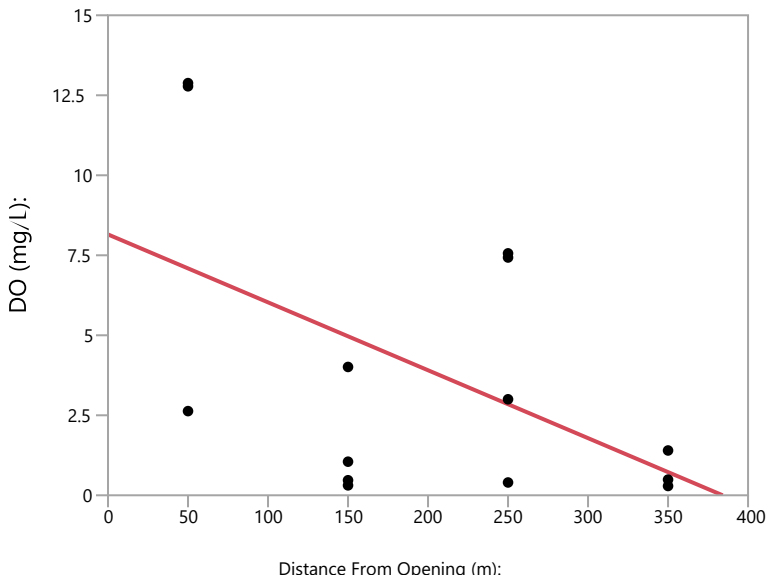
#### Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob> t
Intercept	16.383609	0.737529	22.21	<.0001*
Distance From Opening (m):	-0.022427	0.002565	-8.74	<.0001*



## Perch Lake, Bottom

### Bivariate Fit of DO (mg/L): By Distance From Opening (m): Location=Perch, Water column position=Bottom



#### Linear Fit

DO (mg/L): = 8.1510138 - 0.0212194\*Distance From Opening (m):

#### Summary of Fit

RSquare	0.264637
RSquare Adj	0.203357
Root Mean Square Error	4.020062
Mean of Response	3.907143
Observations (or Sum Wgts)	14

#### Analysis of Variance

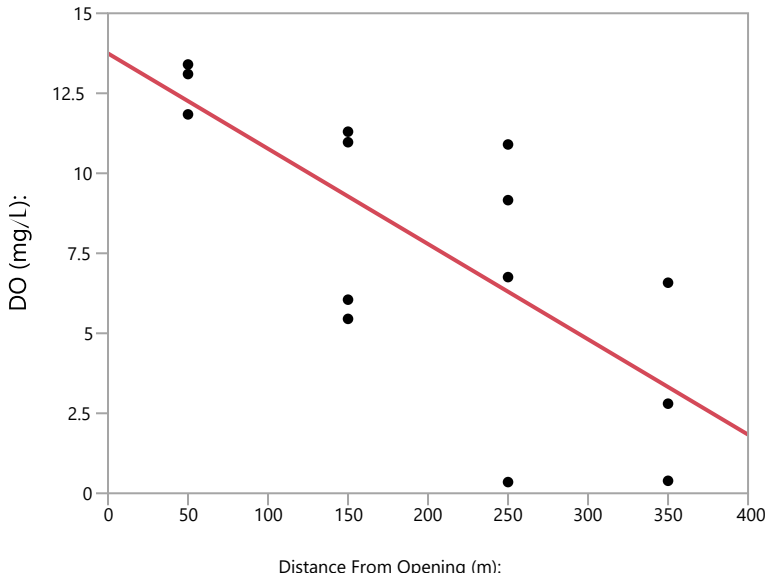
Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	69.79046	69.7905	4.3185
Error	12	193.93083	16.1609	<b>Prob &gt; F</b>
C. Total	13	263.72129		0.0598

#### Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob> t
Intercept	8.1510138	2.307576	3.53	0.0041*
Distance From Opening (m):	-0.021219	0.010211	-2.08	0.0598

## Perch Lake, Middle

### Bivariate Fit of DO (mg/L): By Distance From Opening (m): Location=Perch, Water column position=Mid



#### Linear Fit

DO (mg/L): = 13.744735 - 0.029779\*Distance From Opening (m):

#### Summary of Fit

RSquare	0.536705
RSquare Adj	0.498097
Root Mean Square Error	3.144464
Mean of Response	7.788929
Observations (or Sum Wgts)	14

#### Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	137.45257	137.453	13.9014
Error	12	118.65184	9.888	<b>Prob &gt; F</b>
C. Total	13	256.10441		0.0029*

#### Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob> t
Intercept	13.744735	1.804969	7.61	<.0001*
Distance From Opening (m):	-0.029779	0.007987	-3.73	0.0029*

## Temperature vs. Location (generalized regression)

### Generalized Regression for Water Temp (C): Model Comparison

Show	Response Distribution	Estimation Method	Validation Method	Nonzero Parameters	AICc	BIC	R-Square
[x]	Gamma	Maximum Likelihood	None	4	141.85095	150.09406	0.068781

### Model Launch

Gamma

Lasso [ ] Adaptive

AICc

[ ] Early  
Stopping

### Gamma Maximum Likelihood Model Summary

Response Water Temp (C):  
 Distribution Gamma  
 Estimation Method Maximum Likelihood  
 Validation Method None  
 Mean Model Link Log  
 Dispersion Model Link Identity

#### Measure

Number of rows	82
Sum of Frequencies	68
-LogLikelihood	66.608017
Number of Parameters	4
BIC	150.09406
AICc	141.85095
Generalized RSquare	0.068781

### Parameter Estimates for Original Predictors

Term	Estimate	Std Error	Wald ChiSquare	Prob > ChiSquare	Lower 95%	Upper 95%
Intercept	0.3588794	0.0927477	14.972396	0.0001*	0.1770974	0.5406615
Location[Kimball-Perch]	0.0954272	0.1405915	0.4607082	0.4973	-0.180127	0.3709814
Location[Mud-Perch]	-0.236088	0.1442295	2.6794145	0.1017	-0.518773	0.0465966

Gamma Distribution Parameters	Estimate	Std Error	Wald ChiSquare	Prob > ChiSquare	Lower 95%	Upper 95%
Dispersion	0.3717913	0.0654891	32.230016	<.0001*	0.243435	0.5001476

### Effect Tests

Source	Nparm	DF	Wald ChiSquare	Prob > ChiSquare
Location	2	2	4.7990957	0.0908

### Multiple Comparisons for Location Least Squares Means Estimates

Location	Estimate	Std Error	DF	Lower 95%	Upper 95%
Kimball	0.45430662	0.10967631	65	0.2352679	0.67334534
Mud	0.12279135	0.11567495	65	-0.1082275	0.35381018
Perch	0.35887945	0.09274765	65	0.1736496	0.54410930

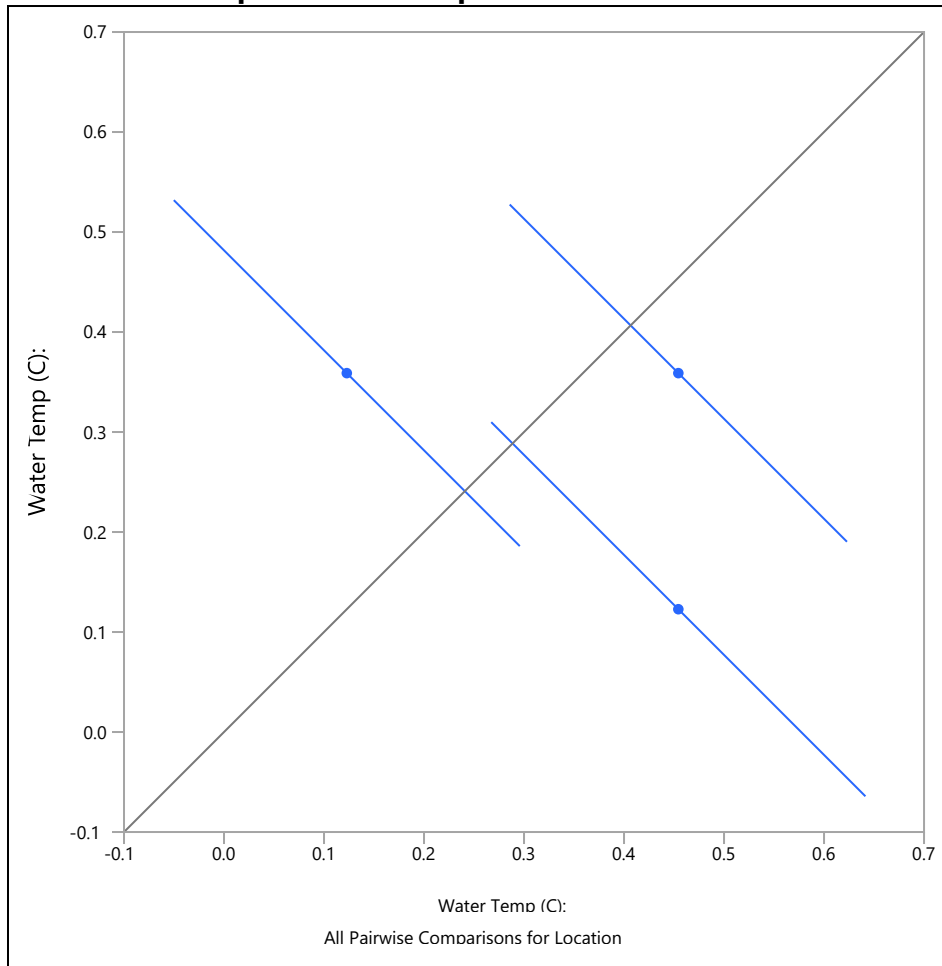
### Tukey HSD All Pairwise Comparisons

Quantile = 2.39856, Adjusted DF = 65.0, Adjustment = Tukey-Kramer

### All Pairwise Differences

Location	-Location	Difference	Std Error	t Ratio	Prob> t	Lower 95%	Upper 95%
Kimball	Mud	0.331515	0.1559837	2.13	0.0926	-0.042621	0.7056512
Kimball	Perch	0.095427	0.1405915	0.68	0.7767	-0.241790	0.4326440
Mud	Perch	-0.236088	0.1442295	-1.64	0.2376	-0.582031	0.1098547

### All Pairwise Comparisons Scatterplot



Legend

- Significant
- Not Significant

### Total Depth vs. Location (generalized regression)

#### Generalized Regression for Total Depth (m):

#### Model Comparison

Show	Response Distribution	Estimation Method	Validation Method	Nonzero Parameters	AICc	BIC	R-Square
[x]	LogNormal	Maximum Likelihood	None	4	84.344908	91.662001	0.777357

#### Model Launch

LogNormal  
 Lasso [ ] Adaptive

AICc

[ ] Early  
Stopping

## LogNormal Maximum Likelihood Model Summary

Response Total Depth (m):  
 Distribution LogNormal  
 Estimation Method Maximum Likelihood  
 Validation Method None  
 Location Model Link Identity  
 Scale Model Link Identity

Measure	
Number of rows	82
Sum of Frequencies	56
-LogLikelihood	37.780297
Number of Parameters	4
BIC	91.662001
AICc	84.344908
Generalized RSquare	0.777357

## Parameter Estimates for Original Predictors

Term	Estimate	Std Error	Wald ChiSquare	Prob > ChiSquare	Lower 95%	Upper 95%
Intercept	-0.071658	0.0765883	0.8753859	0.3495	-0.221768	0.0784527
Location[Kimball-Perch]	1.4944396	0.1157906	166.57517	<.0001*	1.2674942	1.721385
Location[Mud-Perch]	0.1817274	0.1013168	3.2172029	0.0729	-0.01685	0.3803046

LogNormal Distribution Parameters	Estimate	Std Error	Wald ChiSquare	Prob > ChiSquare	Lower 95%	Upper 95%
Scale	0.3249365	0.0307036	111.99985	<.0001*	0.2647585	0.3851145

## Multiple Comparisons for Location Least Squares Means Estimates

Location	Estimate	Std Error	DF	Lower 95%	Upper 95%
Kimball	1.422782	0.08684294	53	1.248597	1.5969669
Mud	0.110070	0.06632739	53	-0.022966	0.2431058
Perch	-0.071658	0.07658827	53	-0.225274	0.0819591

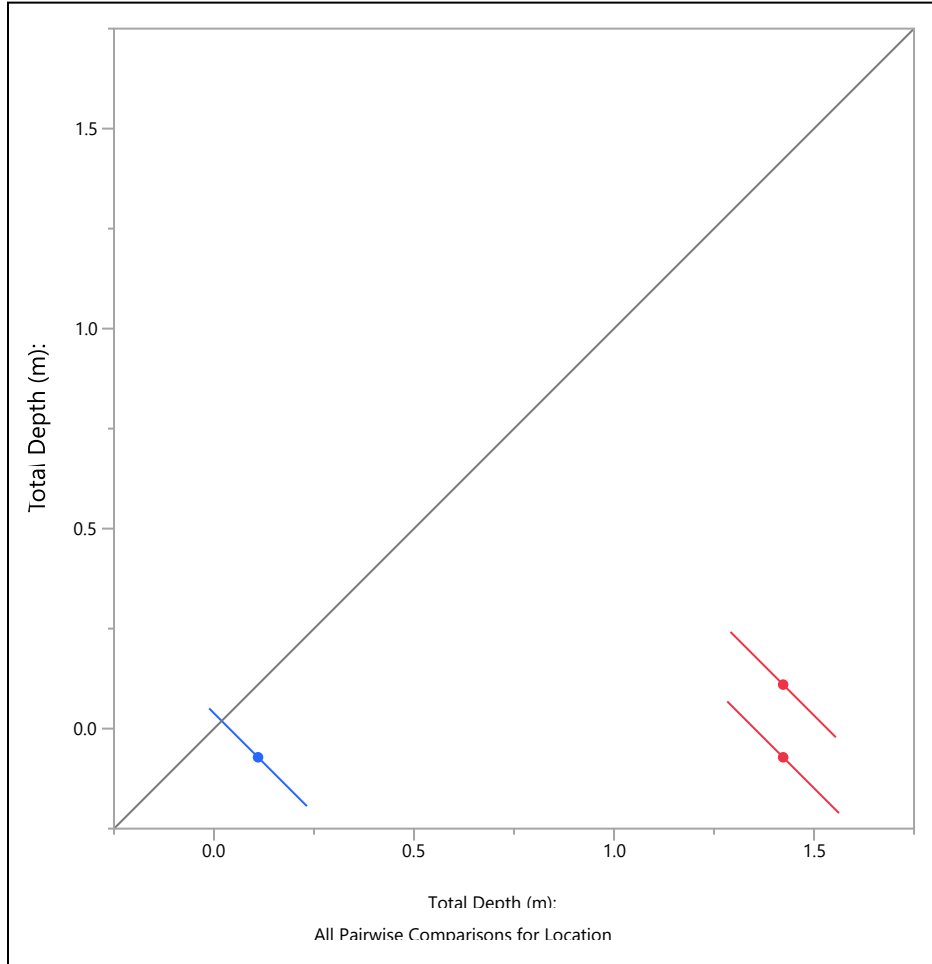
## Tukey HSD All Pairwise Comparisons

Quantile = 2.41127, Adjusted DF = 53.0, Adjustment = Tukey-Kramer

## All Pairwise Differences

Location	-Location	Difference	Std Error	t Ratio	Prob> t	Lower 95%	Upper 95%
Kimball	Mud	1.312712	0.1092750	12.01	<.0001*	1.04922	1.576203
Kimball	Perch	1.494440	0.1157906	12.91	<.0001*	1.21524	1.773642
Mud	Perch	0.181727	0.1013168	1.79	0.1815	-0.06257	0.426029

### All Pairwise Comparisons Scatterplot



Legend

- Significant
- Not Significant

## Conductivity vs. Location (ANOVA)

### Response Conductivity (SAL-ppt):

#### Summary of Fit

RSquare	0.646087
RSquare Adj	0.635522
Root Mean Square Error	0.027032
Mean of Response	0.173114

Observations (or Sum Wgts)

70

### Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	2	0.08937909	0.044690	61.1560
Error	67	0.04896000	0.000731	<b>Prob &gt; F</b>
C. Total	69	0.13833909		<.0001*

### Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob> t
Intercept	0.1753333	0.003285	53.37	<.0001*
Location[Kimball]	0.0356667	0.004932	7.23	<.0001*
Location[Mud]	-0.050333	0.004576	-11.00	<.0001*

### Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Location	2	2	0.08937909	61.1560	<.0001*

### Effect Details

#### Location

#### Least Squares Means Table

Level	Least Sq Mean	Std Error	Mean
Kimball	0.21100000	0.00637158	0.211000
Mud	0.12500000	0.00551795	0.125000
Perch	0.19000000	0.00510863	0.190000

### LSMeans Differences Tukey HSD

$\alpha=0.050$  Q=2.39689

LSMean[i] By LSMean[j]

Mean[i]-Mean[j]	Kimball	Mud	Perch
Std Err Dif			
Lower CL Dif			
Upper CL Dif			
Kimball	0	0.086	0.021
	0	0.00843	0.00817
	0	0.0658	0.00143
	0	0.1062	0.04057
Mud	-0.086	0	-0.065
	0.00843	0	0.00752
	-0.1062	0	-0.083
	-0.0658	0	-0.047
Perch	-0.021	0.065	0
	0.00817	0.00752	0
	-0.0406	0.04698	0



	-0.0014	0.08302	0
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Level		Least Sq Mean
Kimball	A	0.21100000
Perch	B	0.19000000
Mud	C	0.12500000

Levels not connected by same letter are significantly different.

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
Kimball	Mud	0.0860000	0.0084288	0.0657971	0.1062029	<.0001*
Perch	Mud	0.0650000	0.0075197	0.0469761	0.0830239	<.0001*
Kimball	Perch	0.0210000	0.0081667	0.0014253	0.0405747	0.0327*

### Least Squares Means Plot

