Effects of Flow, Reservoir Storage, and Water Temperatures on Trout in Lower Rush and Lee Vining Creeks, Mono County, California

Shepard, B., Taylor, R., Knudson, K., and C. Hunter

Report to Los Angeles Department of Water and Power

May 2009 report (Addendum of September 1, 2009)

The final report **Effects of Flow, Reservoir Storage, and Water Temperatures on Trout in Lower Rush and Lee Vining Creeks, Mono County, California** by B. Shepard, R. Taylor, K. Knudson, and C. Hunter (May 2009) failed to include flows delivered to Rush Creek via the 5-siphon from the LADWP conduit (Greg Reis, Mono Lake Committee email of July 27, 2009). The Fish Team obtained 5-siphon flow data for the period 1999 to 2008 from LADWP and evaluated its inclusion on analyses conducted without these flows in the original May 2009 report. Rush Creek was augmented with 5-siphon flows only during the years 2005, 2006, and 2008 and only during the months of June and July. Additions of 5-siphon flows occurred primarily during the high flow period and generally made up a relatively small proportion of total flows (Figure 1). Correlation analyses and regression analyses conducted with and without inclusion of these 5-siphon flows were conducted and compared (Appendix J) and the Fish Team determined that conclusions reached in the original May 2009 report that was conducted without 5-siphon flows were valid if 5-siphon flows would have been included. This determination was based on the fact that estimates of parameters used in correlation and regression analyses changed only slightly, but more importantly, that actual correlation and regression coefficients changed very slightly and relationships remained statistically significant and the relative effects of correlations and covariates were the same with or without 5-siphon flows (Appendix J).

Acknowledgements

The Fish Team would like to thank Greg Reis of the Mono Lake Committee for making a thorough review of the report and discovering the omission of the 5-siphon flows from the original analyses and Bruk Moges of LADWP for providing the missing flow data.

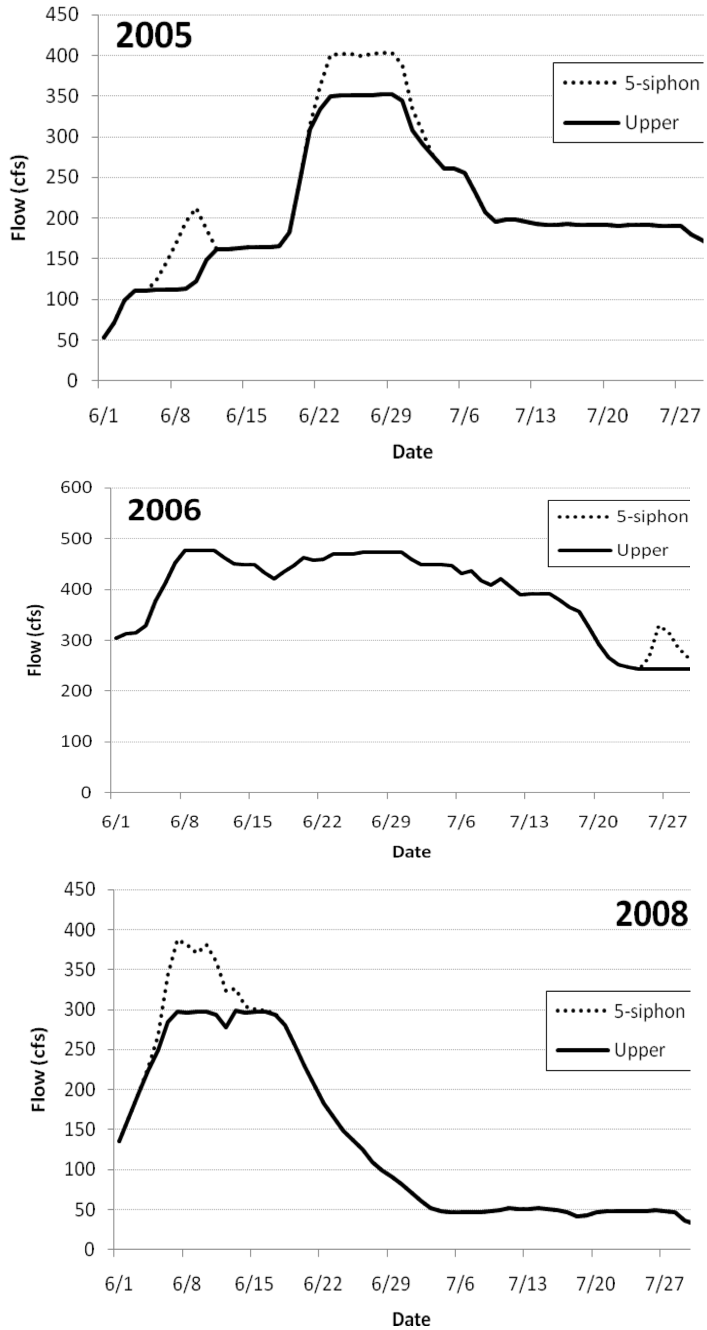

Figure 1. Flows (cubic feet per second, cfs) in Rush Creek below the Mono Gate One Return Ditch ("Upper") and from the 5-siphon for the period June 1 until July 31 and the years 2005, 2006, and 2008.

Addendum Appendix J - Inclusion or exclusion of 5-siphon flow data

The original analyses to evaluate effects of flow and temperature on abundance and condition of brown trout in Rush Creek did not include 5-siphon flow augmentation that occurred in Rush Creek in 2005, 2006, and 2008 (Table J1). Adding these 5-siphon flows slightly changed the estimates of maximum flow, average summer flow, average June flow, average July flow, and number of days during the summer that flows exceeded 150 cfs, but did not change estimates of any other variables, used in the analyses (Table J2).

Spearman rank correlations were re-computed based on the estimates of the flow variables that included the 5-siphon flows and compared to correlations without the 5-siphon flows (Table J3). There were no differences in which correlations were significant and only occasional and very slight differences in actual estimated correlation coefficients.

Since differences in estimated flow variables were minor and there were almost no differences in Spearman correlations, the preliminary data screening that was done for the dataset that did not include the 5-siphon flows was considered adequate for selecting uncorrelated variables to use in final modeling. The models that were deemed the best models using the dataset that did not include the 5-siphon flows were re-run with the data that included the 5-siphon flows and these model results are reported. For condition factor (K) of brown trout 150 to 250 mm there was almost no difference in the models (Table J4). Since the flow variables that were included in the “best” model to explain fish biomass using only flow variables did not include high flow variables, the model did not change at all with the inclusion of the 5-siphon flows (Table J5). When the model that evaluated brown trout biomass with both flow and temperature variables included the 5-siphon flows some of the variable coefficients and the intercept changed slightly, but this is unlikely to be biologically significant (Table J6).

Average length of age-0 brown trout Spearman rank correlations were nearly the same and their relative strengths were the same with the 5-siphon flows as they were without the 5-siphon flows (Table J4). When age-0 brown trout densities were analyzed against just flow variables and for both flow and temperature variables with and without the 5-siphon flows only very minor differences were seen (Table J7 and J8).

Table J1. Flows provided to upper Rush Creek via the 5-siphon from 1999 through 2008 (data provided by LADWP).

				Year		
Site	**Month**	**Day**		**2005**	**2006**	**2008**
5_siphon	6	3				0.4
5_siphon	6	4				3.76
5_siphon	6	5		9		18.5
5_siphon	6	6				58.5
5_siphon	6	7		31		90.9
5_siphon	6	8		56		84.4
5_siphon	6	9		82		73.1
5_siphon	6	10		89		84
5_siphon	6	11		38		66.7
5_siphon	6	12				45.4
5_siphon	6	13				27
5_siphon	6	14				7.89
5_siphon	6	15				2.35
5_siphon	6	16				1.4
5_siphon	6	17				0.32
5_siphon	6	20		0.76		
5_siphon	6	21		5.05		
5_siphon	6	22		28.3		
5_siphon	6	23		51.2		
5_siphon	6	24		51.1		
5_siphon	6	25		50.5		
5_siphon	6	26		48.6		
5_siphon	6	27		50.3		
5_siphon	6	28		51.1		
5_siphon	6	29		51.1		
5_siphon	6	30		44.3		
5_siphon	7	1		25.6		
5_siphon	7	2		13.6		
5_siphon	7	3		0.86		
5_siphon	7	25			21.6	
5_siphon	7	26			85.6	
5_siphon	7	27			73	
5_siphon	7	28			42.8	
5_siphon	7	29			22.6	
5_siphon	7	30			3.67	

Table J2. Differences (**bold values indicate difference >0**) in estimates of variables used in the flow-temperature-fish analyses when 5-siphon flows are (With 5_siph) and are not (No 5_siph) included.

	Site	Upper				Below Narrows			
	Year	2005	2006	2007	2008	2005	2006	2007	2008
Max Ann Flow	No 5_siph	352.0	477.0	59.7	299.0	416.9	583.7	66.6	341.4
	With 5_siph	403.1	477.0	59.7	387.9	467.1	583.7	66.6	422.6
	Difference	**51.1**	0.0	0.0	**88.9**	**50.2**	0.0	0.0	**81.2**
Mean Sum Flow	No 5_siph	131.2	233.1	34.2	84.6	184.1	287.1	49.5	105.2
	With 5_siph	137.6	235.1	34.2	89.2	190.5	289.1	49.5	109.8
	Difference	**6.4**	**2.0**	**0.0**	**4.6**	**6.4**	**2.0**	**0.0**	**4.6**
Sum Days >150cfs	No 5_siph	50	64	0	22	64	70	0	27
	With 5_siph	54	64	0	22	64	70	0	27
	Difference	**4.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mean June Flow	No 5_siph	206.0	437.1	32.6	220.3	271.7	526.7	55.2	259.9
	With 5_siph	230.6	437.1	32.6	239.1	296.3	526.7	55.2	278.7
	Difference	**24.6**	0.0	0.0	**18.8**	**24.6**	**0.0**	0.0	**18.8**
Mean July Flow	No 5_siph	207.1	346.8	33.0	48.1	300.5	427.6	50.5	75.6
	With 5_siph	208.4	354.8	33.0	48.1	301.8	435.6	50.5	75.6
	Difference	**1.3**	**8.0**	0.0	0.0	**1.3**	**8.0**	0.0	0.0

Table J3. Spearman rank correlations without and with the 5-siphon flows. Bold values are significant at $P < 0.05$.

	Without 5-siphon					With 5-siphon				
Variable	**K**	**Biom**	**Dens0**	**AvgL.0**	**Dens1**	**K**	**Biom**	**Dens0**	**AvgL.0**	**Dens1**
K	-	0.187	0.208	-	-0.174	-	0.187	0.208	-	-0.174
Biom	0.187	-	**0.693**	0.209	**0.724**	0.187	-	**0.693**	-0.310	**0.724**
Dens0	0.208	**0.693**	-	**-0.669**	0.408	0.208	**0.693**	-	**-0.669**	0.408
Dens1	-0.174	**0.724**	0.408	**-0.512**	-	-0.174	**0.724**	0.408	**-0.512**	-
MinAnnFlow	0.281	-0.307	-0.082	0.126	**-0.500**	0.282	-0.311	-0.080	0.126	**-0.488**
MaxAnnFlow	0.187	-0.170	-0.436	**0.587**	-0.412	0.155	-0.132	-0.441	**0.550**	-0.325
Mean6_9Flow	0.183	-0.118	-0.385	-0.335	-0.263	0.179	-0.121	-0.392	0.378	-0.258
SumDays.50	-0.206	0.351	0.195	0.165	0.405	-0.206	0.351	0.195	-0.021	0.405
SumDays.150	0.075	-0.102	**-0.522**	0.004	-0.169	0.075	-0.102	**-0.522**	**0.524**	-0.168
June_Flow	0.034	-0.233	**-0.534**	0.228	-0.350	0.034	-0.233	**-0.534**	**0.581**	-0.350
July_Flow	0.367	0.040	-0.118	-0.252	-0.157	0.367	0.040	-0.118	0.064	-0.157
Aug_Flow	0.311	-0.098	-0.252	-0.098	-0.267	0.311	-0.098	-0.252	0.154	-0.267
Sept_Flow	0.232	-0.173	-0.108	**0.580**	-0.331	0.241	-0.168	-0.120	0.055	-0.325
Avg_Sum_Temp	**-0.546**	-0.197	-0.071	0.378	0.237	**-0.546**	-0.197	-0.071	-0.055	0.237
Avg_Max_Daily.Sum_Temp	**-0.764**	-0.439	-0.361	-0.021	0.073	**-0.764**	-0.439	-0.361	-0.023	0.073
DaysGT70F	**-0.769**	**-0.488**	-0.378	**0.524**	0.005	**-0.769**	**-0.488**	-0.378	-0.028	0.005
Days.GT67F	**-0.759**	-0.437	-0.272	**0.581**	-0.005	**-0.759**	-0.437	-0.272	-0.104	-0.005
Days_Ideal_Temp	**0.756**	**0.523**	0.389	0.064	0.106	**0.756**	**0.523**	0.389	0.078	0.106
GrantMean	0.418	0.439	0.280	0.154	0.189	0.418	0.439	0.279	-0.273	0.189
GrantMin	0.323	0.411	0.408	0.055	0.215	0.323	0.411	0.408	-0.408	0.215
GrantMax	0.425	0.432	0.324	-0.055	0.191	0.425	0.432	0.324	-0.322	0.191

Table J4. Best regression for fish condition and flow and temperature.

WITHOUT 5-siphon flows

```
Call:
lm(formula = K ~ MinAnnFlow + Mean6_9Flow + Days_Ideal_Temp)

Residuals:
       Min         1Q     Median         3Q        Max 
-0.0590311 -0.0175278  0.0004966  0.0149587  0.0654143 

Coefficients:
                  Estimate Std. Error t value Pr(>|t|)    
(Intercept)      0.8776870  0.0290990  30.162 1.58e-15 ***
MinAnnFlow       0.0024826  0.0007571   3.279 0.004722 ** 
Mean6_9Flow     -0.0002837  0.0001224  -2.317 0.034058 *  
Days_Ideal_Temp  0.0010746  0.0002173   4.946 0.000146 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.03377 on 16 degrees of freedom
Multiple R-squared: 0.6954,     Adjusted R-squared: 0.6382 
F-statistic: 12.17 on 3 and 16 DF,  p-value: 0.0002114
```

WITH 5-siphon flows

```
Call:
lm(formula = K ~ MinAnnFlow + Mean6_9Flow + Days_Ideal_Temp)

Residuals:
       Min         1Q     Median         3Q        Max 
-0.0589030 -0.0179307  0.0003649  0.0147702  0.0657284 

Coefficients:
                  Estimate Std. Error t value Pr(>|t|)    
(Intercept)      0.8788979  0.0291416  30.160 1.58e-15 ***
MinAnnFlow       0.0024433  0.0007539   3.241 0.005119 ** 
Mean6_9Flow     -0.0002790  0.0001208  -2.309 0.034642 *  
Days_Ideal_Temp  0.0010759  0.0002179   4.938 0.000148 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.03382 on 16 degrees of freedom
Multiple R-squared: 0.6945,     Adjusted R-squared: 0.6372 
F-statistic: 12.12 on 3 and 16 DF,  p-value: 0.0002163
```

Table J5. Biomass versus flow only

Without 5-siphon flows

```
Call:
lm(formula = Biom ~ GrantMean + SumDays.50)

Residuals:
    Min      1Q  Median      3Q     Max 
-43.923 -21.156  -6.301  14.592  76.665 

Coefficients:
              Estimate Std. Error t value Pr(>|t|)    
(Intercept) -2.058e+01  2.711e+01  -0.759 0.454733    
GrantMean    3.140e-03  6.735e-04   4.662 8.95e-05 ***
SumDays.50   7.441e-01  1.822e-01   4.085 0.000398 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1 

Residual standard error: 29.13 on 25 degrees of freedom
Multiple R-squared: 0.5136,     Adjusted R-squared: 0.4747 
F-statistic:  13.2 on 2 and 25 DF,  p-value: 0.0001224
```

With 5-siphon flows

```
> summary(reg.Biom.Flow.2)

Call:
lm(formula = Biom ~ GrantMean + SumDays.50)

Residuals:
   Min     1Q Median     3Q    Max 
-43.92 -21.16  -6.30  14.59  76.66 

Coefficients:
              Estimate Std. Error t value Pr(>|t|)    
(Intercept) -2.058e+01  2.711e+01  -0.759 0.454733    
GrantMean    3.140e-03  6.735e-04   4.662 8.95e-05 ***
SumDays.50   7.441e-01  1.822e-01   4.085 0.000398 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1 

Residual standard error: 29.13 on 25 degrees of freedom
Multiple R-squared: 0.5136,     Adjusted R-squared: 0.4747 
F-statistic:  13.2 on 2 and 25 DF,  p-value: 0.0001224
```

Table J6. Biomass with flow and temperature.

Without 5-siphon flows

```
Call:
lm(formula = Biom ~ Days_Ideal_Temp + MinAnnFlow + MaxAnnFlow +
    MinAnnFlow:MaxAnnFlow)

Residuals:
    Min      1Q  Median      3Q     Max
-40.241 -10.154   3.784  12.518  16.303

Coefficients:
                        Estimate Std. Error t value Pr(>|t|)
(Intercept)           226.768004  30.750667   7.374 2.31e-06 ***
Days_Ideal_Temp         1.072019   0.114697   9.347 1.21e-07 ***
MinAnnFlow             -3.935786   0.827895  -4.754 0.000256 ***
MaxAnnFlow             -0.491855   0.118072  -4.166 0.000828 ***
MinAnnFlow:MaxAnnFlow   0.010042   0.002869   3.501 0.003218 **
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 17.62 on 15 degrees of freedom
Multiple R-squared: 0.8705,     Adjusted R-squared: 0.8359
F-statistic:  25.2 on 4 and 15 DF,  p-value: 1.658e-06
```

With 5-siphon flows

```
> summary(reg.Biom.FlowTemp.4int)

Call:
lm(formula = Biom ~ Days_Ideal_Temp + MinAnnFlow + MaxAnnFlow +
    MinAnnFlow:MaxAnnFlow)

Residuals:
    Min      1Q  Median      3Q     Max
-45.235  -9.039   4.922  13.099  16.958

Coefficients:
                        Estimate Std. Error t value Pr(>|t|)
(Intercept)           219.937256  30.185731   7.286 2.67e-06 ***
Days_Ideal_Temp         1.038933   0.114421   9.080 1.75e-07 ***
MinAnnFlow             -3.775623   0.817988  -4.616 0.000336 ***
MaxAnnFlow             -0.379532   0.096462  -3.935 0.001325 **
MinAnnFlow:MaxAnnFlow   0.007680   0.002472   3.107 0.007213 **
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 17.9 on 15 degrees of freedom
Multiple R-squared: 0.8662,     Adjusted R-squared: 0.8305
F-statistic: 24.28 on 4 and 15 DF,  p-value: 2.105e-06
```

Table J7. Multiple regression models for flow variables and densities of age-0 brown trout with and without 5-siphon flows.

BEST FLOW MULTIPLE REGRESSION

```
> summary(reg.Dens0.Flow.2)

Call:
lm(formula = log(Dens0) ~ SumDays.150 + +MinAnnFlow + GrantMin)

Residuals:
      Min        1Q    Median        3Q       Max 
-0.782329 -0.281420 -0.009826  0.226416  0.678394 

Coefficients:
              Estimate Std. Error t value Pr(>|t|)    
(Intercept)  8.084e+00  3.383e-01  23.899  < 2e-16 ***
SumDays.150 -1.488e-02  3.736e-03  -3.983 0.000587 ***
MinAnnFlow  -2.482e-02  9.627e-03  -2.579 0.016794 *  
GrantMin     4.925e-05  1.059e-05   4.649 0.000112 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1 

Residual standard error: 0.409 on 23 degrees of freedom
Multiple R-squared: 0.5534,     Adjusted R-squared: 0.4952 
F-statistic:   9.5 on 3 and 23 DF,  p-value: 0.0002854
```

WITH 5-siphon flows

```
> summary(reg.Dens0.Flow.2)

Call:
lm(formula = log(Dens0) ~ SumDays.150 + +MinWinFlow + GrantMin)

Residuals:
     Min       1Q   Median       3Q      Max 
-0.86340 -0.25861 -0.07903  0.34481  0.66938 

Coefficients:
              Estimate Std. Error t value Pr(>|t|)    
(Intercept)  8.284e+00  3.997e-01  20.724 2.22e-16 ***
SumDays.150 -1.492e-02  3.760e-03  -3.967 0.000611 ***
MinWinFlow  -2.757e-02  1.102e-02  -2.502 0.019921 *  
GrantMin     4.964e-05  1.092e-05   4.546 0.000144 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1 

Residual standard error: 0.4146 on 23 degrees of freedom
Multiple R-squared: 0.5411,     Adjusted R-squared: 0.4813 
F-statistic: 9.041 on 3 and 23 DF,  p-value: 0.0003861
```

Table J8. Multiple regression models for flow and temperature variables and densities of age-0 brown trout with and without 5-siphon flows.

BEST Flow and Temperature Regression Model

```
> reg.Dens0.FlowTemp1<-lm(log(Dens0) ~ MinAnnFlow + SumDays.150 +
Days_Ideal_Temp + GrantMin)
> summary(reg.Dens0.FlowTemp1)

Call:
lm(formula = log(Dens0) ~ MinAnnFlow + SumDays.150 + Days_Ideal_Temp +
    GrantMin)

Residuals:
     Min       1Q   Median       3Q      Max
-0.74337 -0.11574 -0.01169  0.13914  0.56022

Coefficients:
                  Estimate Std. Error t value Pr(>|t|)
(Intercept)      7.885e+00  2.796e-01  28.201 2.07e-14 ***
MinAnnFlow      -2.425e-02  7.621e-03  -3.182 0.006189 **
SumDays.150     -1.710e-02  3.573e-03  -4.788 0.000240 ***
Days_Ideal_Temp  8.513e-03  2.145e-03   3.969 0.001234 **
GrantMin         4.075e-05  1.016e-05   4.010 0.001136 **
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.3023 on 15 degrees of freedom
Multiple R-squared: 0.771,      Adjusted R-squared: 0.7099
F-statistic: 12.62 on 4 and 15 DF,  p-value: 0.0001073


WITH 5-siphon flows

Call:
lm(formula = log(Dens0) ~ MinAnnFlow + SumDays.150 + Days_Ideal_Temp +
    GrantMin)

Residuals:
      Min        1Q    Median        3Q       Max
-0.740695 -0.096023 -0.007383  0.133312  0.565137

Coefficients:
                  Estimate Std. Error t value Pr(>|t|)
(Intercept)      7.900e+00  2.781e-01  28.409 1.86e-14 ***
MinAnnFlow      -2.469e-02  7.594e-03  -3.251 0.005369 **
SumDays.150     -1.697e-02  3.520e-03  -4.822 0.000224 ***
Days_Ideal_Temp  8.622e-03  2.143e-03   4.024 0.001105 **
GrantMin         4.062e-05  1.011e-05   4.018 0.001118 **
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.301 on 15 degrees of freedom
Multiple R-squared: 0.773,      Adjusted R-squared: 0.7124
F-statistic: 12.77 on 4 and 15 DF,  p-value: 0.0001007
```