R14 - Interactions in regression

HCI/PSYCH 522
Iowa State University

April 28, 2022

Interactions

Independent variables

- Categorical-continuous
- Categorical-categorical
- Continuous-continuous

Effects of Light on Meadowfoam Flowering - Descriptive Statistics

```
case0901 <- Sleuth3::case0901 %>%
  mutate(Start = recode(Time, `1` = "Late", `2` = "Early"),
         Start = factor(Start, levels = c("Early","Late")))
head(case0901)
```

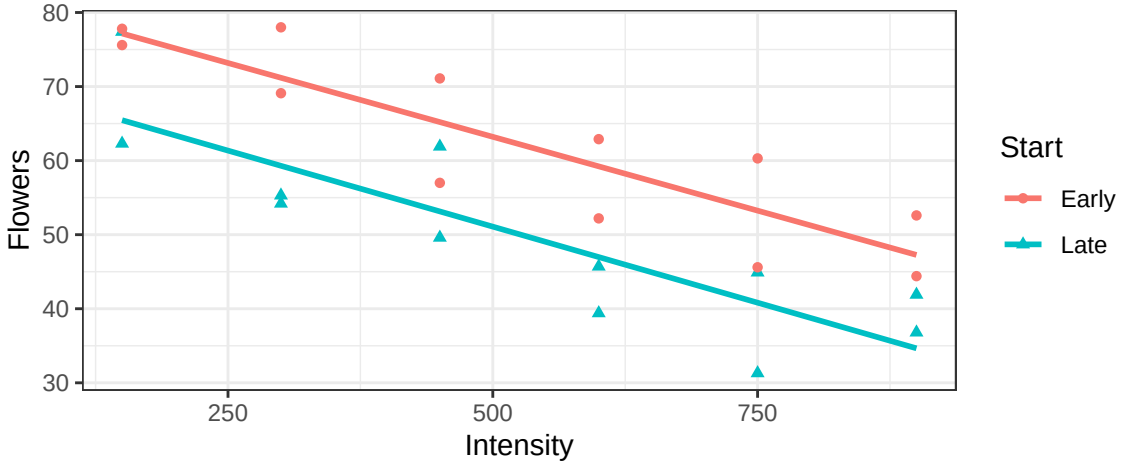
```
##   Flowers Time Intensity Start
## 1    62.3    1       150  Late
## 2    77.4    1       150  Late
## 3    55.3    1       300  Late
## 4    54.2    1       300  Late
## 5    49.6    1       450  Late
## 6    61.9    1       450  Late
```

```
summary(case0901)
```

```
##     Flowers           Time       Intensity     Start
##  Min.   :31.30   Min.   :1.0   Min.   :150   Early:12
##  1st Qu.:45.42   1st Qu.:1.0   1st Qu.:300   Late :12
##  Median :54.75   Median :1.5   Median :525
##  Mean   :56.14   Mean   :1.5   Mean   :525
##  3rd Qu.:64.45   3rd Qu.:2.0   3rd Qu.:750
##  Max.   :78.00   Max.   :2.0   Max.   :900
```

Effects of Light on Meadowfoam Flowering - Graphical Statistics

```
g <- ggplot(case0901, aes(x = Intensity, y = Flowers, color = Start, shape = Start)) +
  geom_point()
g + geom_smooth(method="lm", se = FALSE)
```



Effects of Light on Meadowfoam Flowering - Models

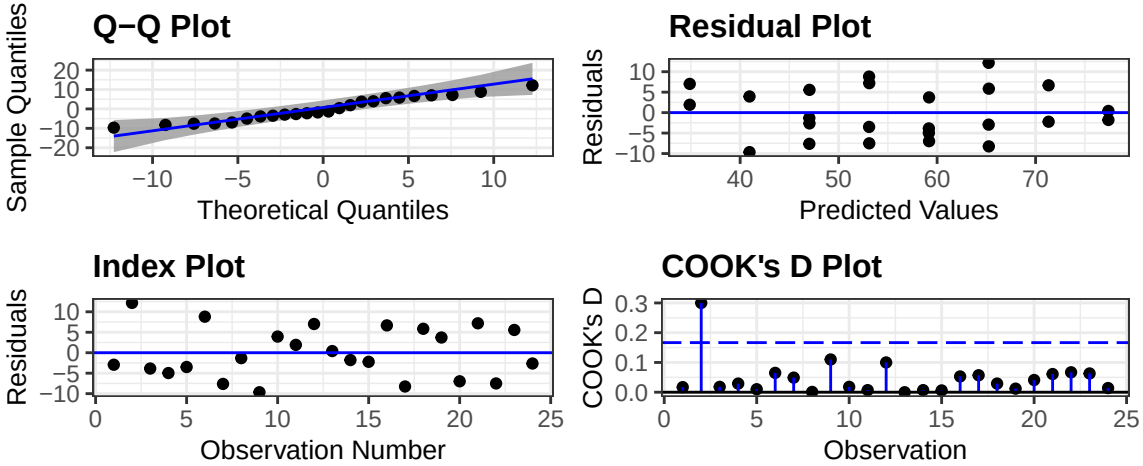
```
mM <- lm(Flowers ~ Start + Intensity, data = case0901) # Main effects model
mI <- lm(Flowers ~ Start * Intensity, data = case0901) # Interaction model

drop1(mI, test="F")


## Single term deletions
##
## Model:
## Flowers ~ Start * Intensity
##                 Df Sum of Sq    RSS    AIC F value Pr(>F)
## <none>                       870.66 94.189
## Start:Intensity  1   0.57604 871.24 92.205  0.0132 0.9096
```

Effects of Light on Meadowfoam Flowering - Diagnostics

```
resid_panel(mM, plots = c("qq", "resid", "index", "cookd"), qqbands = TRUE)
```



Effects of Light on Meadowfoam Flowering - Main effects model

```
summary(mM)


##
## Call:
## lm(formula = Flowers ~ Start + Intensity, data = case0901)
##
## Residuals:
##    Min     1Q Median     3Q    Max
## -9.652 -4.139 -1.558  5.632 12.165
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)  83.464167   3.273772  25.495  < 2e-16 ***
## StartLate   -12.158333   2.629557  -4.624 0.000146 ***
## Intensity    -0.040471   0.005132  -7.886 1.04e-07 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 6.441 on 21 degrees of freedom
## Multiple R-squared:  0.7992,Adjusted R-squared:   0.78
## F-statistic: 41.78 on 2 and 21 DF,  p-value: 4.786e-08
```

Effects of Light on Meadowfoam Flowering - Main effects model

```
em <- emmeans(mM, pairwise ~ Start | Intensity, at = list(Intensity = c(150,500,900)))
(cm <- confint(em, type = "response"))
```

```
## $emmeans
## Intensity = 150:
##  Start emmean   SE df lower.CL upper.CL
##  Early   77.4 2.68 21     71.8     83.0
##  Late    65.2 2.68 21     59.7     70.8
##
## Intensity = 500:
##  Start emmean   SE df lower.CL upper.CL
##  Early   63.2 1.86 21     59.4     67.1
##  Late    51.1 1.86 21     47.2     54.9
##
## Intensity = 900:
##  Start emmean   SE df lower.CL upper.CL
##  Early   47.0 2.68 21     41.5     52.6
##  Late    34.9 2.68 21     29.3     40.4
##
## Confidence level used: 0.95
##
## $contrasts
## Intensity = 150:
##  contrast     estimate   SE df lower.CL upper.CL
##  Early - Late     12.2 2.63 21     6.69     17.6
##
## Intensity = 500:
##  contrast     estimate   SE df lower.CL upper.CL
##  Early - Late     12.2 2.63 21     6.69     17.6
```

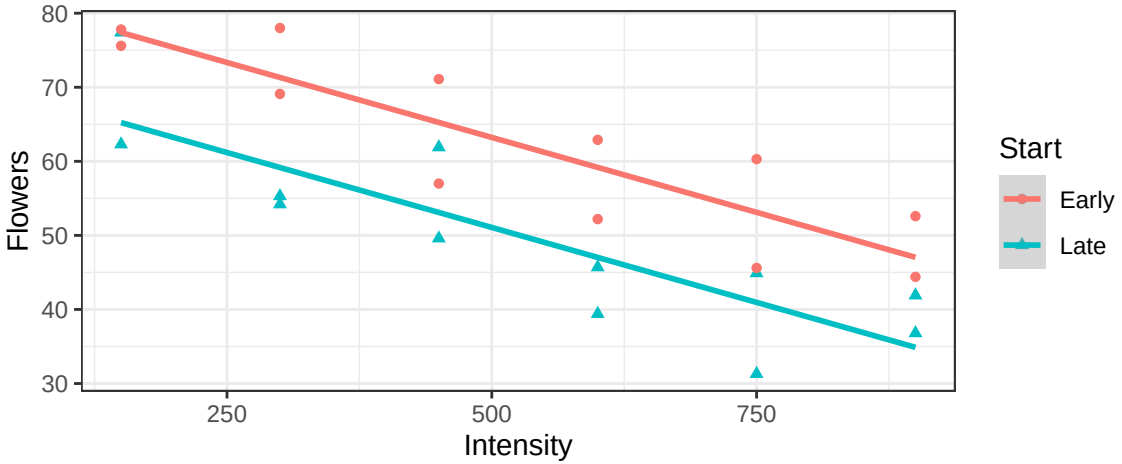
Effects of Light on Meadowfoam Flowering - Main effects model

```
et <- emtrends(mM, pairwise ~ Start, var = "Intensity")
(ct <- confint(et, type = "response"))


## $emtrends
##  Start Intensity.trend      SE df lower.CL upper.CL
##  Early         -0.0405 0.00513 21  -0.0511  -0.0298
##  Late          -0.0405 0.00513 21  -0.0511  -0.0298
##
## Confidence level used: 0.95
##
## $contrasts
##  contrast     estimate SE df lower.CL upper.CL
##  Early - Late        0  0 21        0        0
##
## Confidence level used: 0.95
```

Effects of Light on Meadowfoam Flowering - Main effects model

```
g + geom_smooth(method = "lm", mapping=aes(y=predict(mM, case0901)))
```



Effects of Light on Meadowfoam Flowering - Interaction model

```
summary(mI)
```

```
##
## Call:
## lm(formula = Flowers ~ Start * Intensity, data = case0901)
##
## Residuals:
##    Min     1Q Median     3Q    Max
## -9.516 -4.276 -1.422  5.473 11.938
##
## Coefficients:
##                       Estimate Std. Error t value Pr(>|t|)
## (Intercept)          83.146667   4.343305  19.144 2.49e-14 ***
## StartLate           -11.523333   6.142360  -1.876   0.0753 .
## Intensity            -0.039867   0.007435  -5.362 3.01e-05 ***
## StartLate:Intensity  -0.001210   0.010515  -0.115   0.9096
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 6.598 on 20 degrees of freedom
## Multiple R-squared:  0.7993,Adjusted R-squared:  0.7692
## F-statistic: 26.55 on 3 and 20 DF,  p-value: 3.549e-07
```

Effects of Light on Meadowfoam Flowering - Interaction model

```
em <- emmeans(mI, pairwise ~ Start | Intensity, at = list(Intensity = c(150,500,900)))
(cm <- confint(em, type = "response"))
```

```
## $emmeans
## Intensity = 150:
##  Start emmean   SE df lower.CL upper.CL
##  Early   77.2 3.38 20     70.1     84.2
##  Late    65.5 3.38 20     58.4     72.5
##
## Intensity = 500:
##  Start emmean   SE df lower.CL upper.CL
##  Early   63.2 1.91 20     59.2     67.2
##  Late    51.1 1.91 20     47.1     55.1
##
## Intensity = 900:
##  Start emmean   SE df lower.CL upper.CL
##  Early   47.3 3.38 20     40.2     54.3
##  Late    34.7 3.38 20     27.6     41.7
##
## Confidence level used: 0.95
##
## $contrasts
## Intensity = 150:
##  contrast     estimate   SE df lower.CL upper.CL
##  Early - Late     11.7 4.78 20     1.74     21.7
##
## Intensity = 500:
##  contrast     estimate   SE df lower.CL upper.CL
##  Early - Late     12.1 2.71 20     6.48     17.8
```

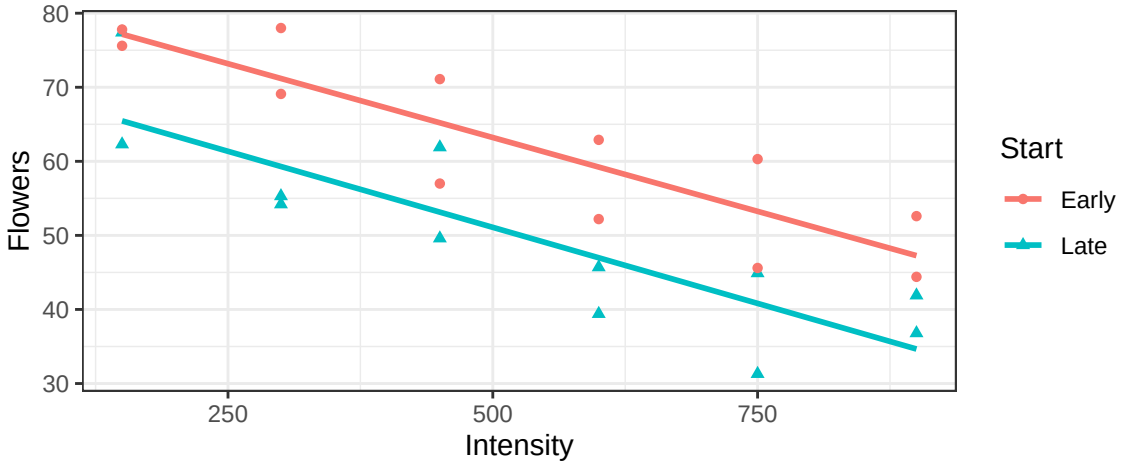
Effects of Light on Meadowfoam Flowering - Interaction model

```
et <- emtrends(mI, pairwise ~ Start, var = "Intensity")
(ct <- confint(et, type = "response"))


## $emtrends
##  Start Intensity.trend      SE df lower.CL upper.CL
##  Early         -0.0399 0.00744 20  -0.0554  -0.0244
##  Late          -0.0411 0.00744 20  -0.0566  -0.0256
##
## Confidence level used: 0.95
##
## $contrasts
##  contrast     estimate     SE df lower.CL upper.CL
##  Early - Late  0.00121 0.0105 20  -0.0207   0.0231
##
## Confidence level used: 0.95
```

Effects of Light on Meadowfoam Flowering - Interaction model

```
g + geom_smooth(method = "lm", se=FALSE)
```



Effects of Seaweed Grazers - Descriptive Statistics

```
case1301 <- Sleuth3::case1301 %>%
  filter(Treat %in% c("C","L","f","Lf"), Block %in% c("B1","B2","B3"))
head(case1301)
```

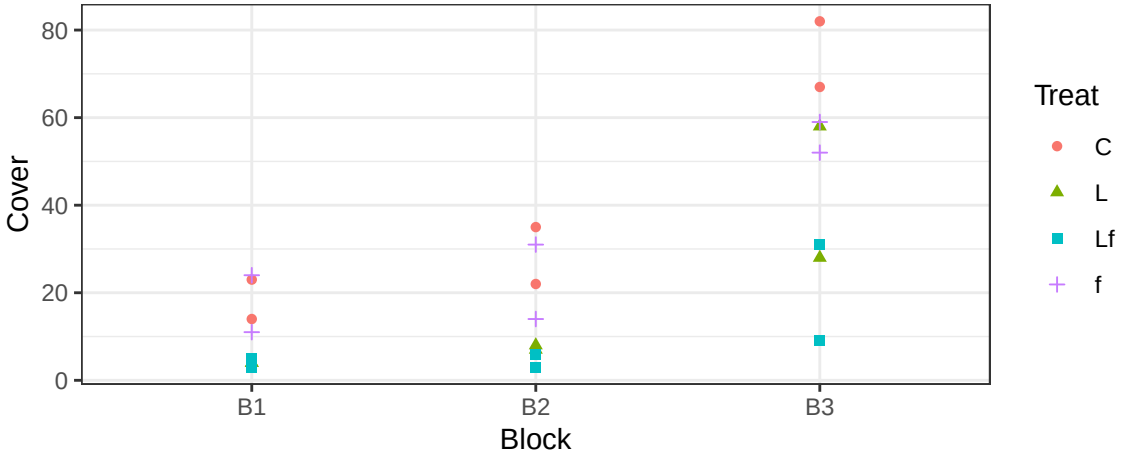
```
##   Cover Block Treat
## 1    14    B1     C
## 2    23    B1     C
## 3    22    B2     C
## 4    35    B2     C
## 5    67    B3     C
## 6    82    B3     C
```

```
summary(case1301)
```

```
##      Cover           Block   Treat
##  Min.   : 3.00   B1     :8   C  :6
##  1st Qu.: 6.75   B2     :8   L  :6
##  Median :18.00   B3     :8   Lf :6
##  Mean   :25.00   B4     :0   LfF:0
##  3rd Qu.:32.00   B5     :0   f  :6
##  Max.   :82.00   B6     :0   fF :0
##                  (Other):0
```

Effects of Seaweed Grazers - Graphical Statistics

```
g <- ggplot(case1301, aes(x = Block, y = Cover, color = Treat, shape = Treat)) +
  geom_point()
g
```



Effects of Seaweed Grazers - Models

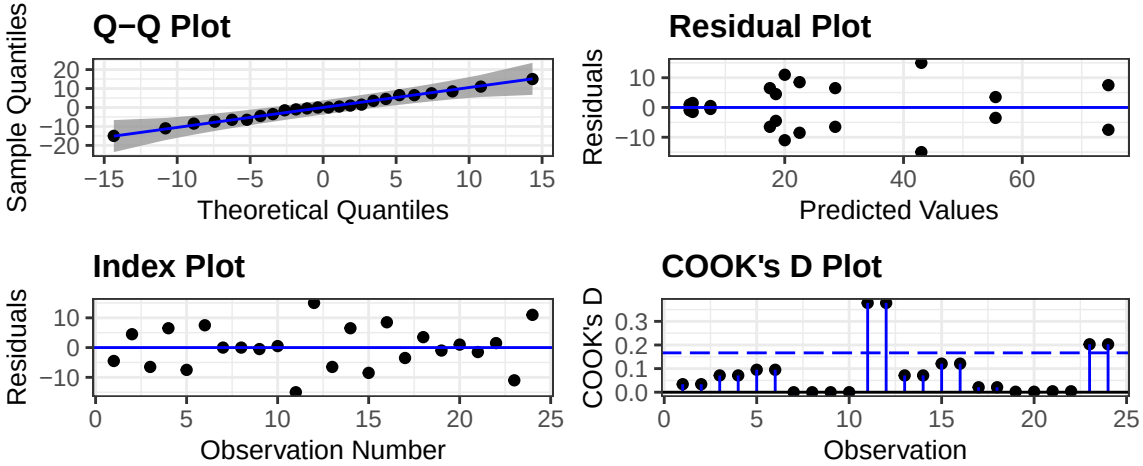
```
mM <- lm(Cover ~ Treat + Block, data = case1301) # Main effects model
mI <- lm(Cover ~ Treat * Block, data = case1301) # Interaction model

drop1(mI, test="F")


## Single term deletions
##
## Model:
## Cover ~ Treat * Block
##             Df Sum of Sq    RSS    AIC F value Pr(>F)
## <none>                   1190.0 117.69
## Treat:Block  6    889.67 2079.7 119.09  1.4952 0.2601
```

Effects of Seaweed Grazers - Diagnostics

```
resid_panel(mI, plots = c("qq", "resid", "index", "cookd"), qqbands = TRUE)
```



Effects of Seaweed Grazers - Main effects model

```
summary(mM)


##
## Call:
## lm(formula = Cover ~ Treat + Block, data = case1301)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -23.7500  -4.3333  -0.1667   5.8542  18.2500
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept)   26.500      5.374   4.931 0.000108 ***
## TreatL       -22.333      6.206  -3.599 0.002053 **
## TreatLf      -31.000      6.206  -4.995 9.38e-05 ***
## Treatf        -8.667      6.206  -1.397 0.179537
## BlockB2        4.750      5.374   0.884 0.388447
## BlockB3       37.250      5.374   6.931 1.77e-06 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 10.75 on 18 degrees of freedom
## Multiple R-squared:  0.8281,Adjusted R-squared:  0.7804
## F-statistic: 17.35 on 5 and 18 DF,  p-value: 2.509e-06
```

Effects of Seaweed Grazers - Main effects model

```
em <- emmeans(mM, trt.vs.ctrl ~ Treat)
(cm <- confint(em, type = "response"))


## $emmeans
##  Treat emmean   SE df lower.CL upper.CL
##  C       40.5 4.39 18   31.281     49.7
##  L       18.2 4.39 18    8.947     27.4
##  Lf       9.5 4.39 18    0.281     18.7
##  f       31.8 4.39 18   22.614     41.1
##
## Results are averaged over the levels of: Block
## Confidence level used: 0.95
##
## $contrasts
##  contrast estimate   SE df lower.CL upper.CL
##  L - C      -22.33 6.21 18    -38.3    -6.32
##  Lf - C     -31.00 6.21 18    -47.0   -14.98
##  f - C       -8.67 6.21 18    -24.7     7.35
##
## Results are averaged over the levels of: Block
## Confidence level used: 0.95
## Conf-level adjustment: dunnettx method for 3 estimates
```

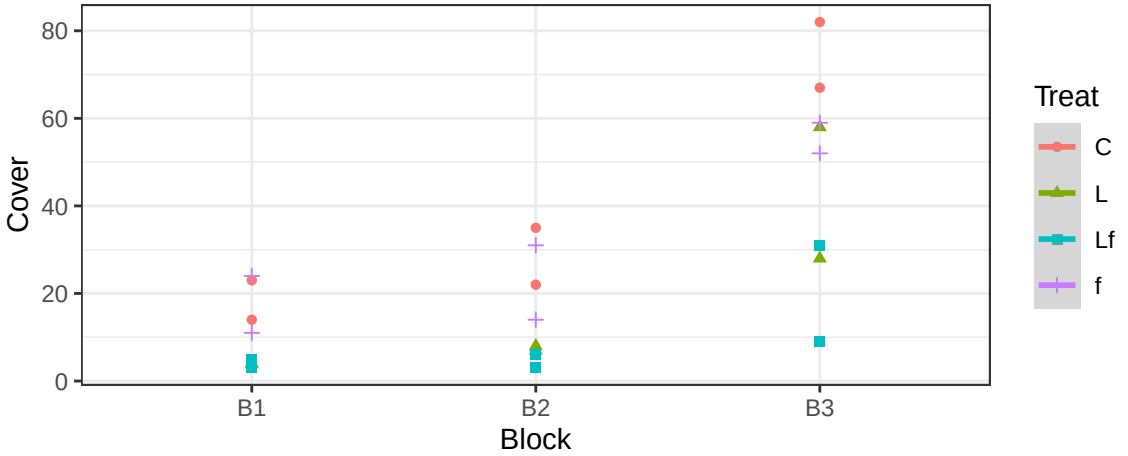
Effects of Seaweed Grazers - Main effects model

```
et <- emmeans(mM, pairwise ~ Block)
(ct <- confint(et, type = "response"))


## $emmeans
##  Block emmean  SE df lower.CL upper.CL
##  B1      11.0 3.8 18     3.02     19.0
##  B2      15.8 3.8 18     7.77     23.7
##  B3      48.2 3.8 18    40.27     56.2
##
## Results are averaged over the levels of: Treat
## Confidence level used: 0.95
##
## $contrasts
##  contrast estimate   SE df lower.CL upper.CL
##  B1 - B2     -4.75 5.37 18    -18.5     8.97
##  B1 - B3    -37.25 5.37 18    -51.0   -23.53
##  B2 - B3    -32.50 5.37 18    -46.2   -18.78
##
## Results are averaged over the levels of: Treat
## Confidence level used: 0.95
## Conf-level adjustment: tukey method for comparing a family of 3 estimates
```

Effects of Seaweed Grazers - Main effects model

```
g + geom_smooth(method = "lm", mapping=aes(y=predict(mM, case1301)))
```



Effects of Seaweed Grazers - Interaction model

```
summary(mI)


##
## Call:
## lm(formula = Cover ~ Treat * Block, data = case1301)
##
## Residuals:
##    Min     1Q Median     3Q    Max
##    -15     -5      0      5     15
##
## Coefficients:
##                 Estimate Std. Error t value Pr(>|t|)
## (Intercept)       18.500      7.042   2.627 0.022087 *
## TreatL           -14.500      9.958  -1.456 0.171031
## TreatLf          -14.500      9.958  -1.456 0.171031
## Treatf            -1.000      9.958  -0.100 0.921670
## BlockB2           10.000      9.958   1.004 0.335106
## BlockB3           56.000      9.958   5.623 0.000112 ***
## TreatL:BlockB2    -6.500     14.083  -0.462 0.652661
## TreatLf:BlockB2   -9.500     14.083  -0.675 0.512737
## Treatf:BlockB2    -5.000     14.083  -0.355 0.728725
## TreatL:BlockB3   -17.000     14.083  -1.207 0.250642
## TreatLf:BlockB3  -40.000     14.083  -2.840 0.014889 *
## Treatf:BlockB3   -18.000     14.083  -1.278 0.225374
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 9.958 on 12 degrees of freedom
## Multiple R-squared:  0.9017,Adjusted R-squared:  0.8115
```

Effects of Seaweed Grazers - Interaction model

```
em <- emmeans(mI, pairwise ~ Treat | Block)
(cm <- confint(em, type = "response"))


## $emmeans
## Block = B1:
##  Treat emmean   SE df lower.CL upper.CL
##  C       18.5 7.04 12     3.16     33.8
##  L        4.0 7.04 12   -11.34     19.3
##  Lf       4.0 7.04 12   -11.34     19.3
##  f       17.5 7.04 12     2.16     32.8
##
## Block = B2:
##  Treat emmean   SE df lower.CL upper.CL
##  C       28.5 7.04 12    13.16     43.8
##  L        7.5 7.04 12    -7.84     22.8
##  Lf       4.5 7.04 12   -10.84     19.8
##  f       22.5 7.04 12     7.16     37.8
##
## Block = B3:
##  Treat emmean   SE df lower.CL upper.CL
##  C       74.5 7.04 12    59.16     89.8
##  L       43.0 7.04 12    27.66     58.3
##  Lf      20.0 7.04 12     4.66     35.3
##  f       55.5 7.04 12    40.16     70.8
##
## Confidence level used: 0.95
##
## $contrasts
## Block = B1:
```

Effects of Seaweed Grazers - Interaction model

```
et <- emtrends(mI, pairwise ~ Treat, var = "Block")

## Error in Summary.factor(structure(c(1L, 1L, 2L, 2L, 3L, 3L, 1L, 1L, 2L, :  'range' not meaningful for factors

(ct <- confint(et, type = "response"))

## $emmeans
##  Block emmean  SE df lower.CL upper.CL
##  B1      11.0 3.8 18     3.02     19.0
##  B2      15.8 3.8 18     7.77     23.7
##  B3      48.2 3.8 18    40.27     56.2
##
## Results are averaged over the levels of: Treat
## Confidence level used: 0.95
##
## $contrasts
##  contrast estimate   SE df lower.CL upper.CL
##  B1 - B2     -4.75 5.37 18    -18.5     8.97
##  B1 - B3    -37.25 5.37 18    -51.0   -23.53
##  B2 - B3    -32.50 5.37 18    -46.2   -18.78
##
## Results are averaged over the levels of: Treat
## Confidence level used: 0.95
## Conf-level adjustment: tukey method for comparing a family of 3 estimates
```

Effects of Seaweed Grazers - Interaction model

```
g
```