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)
```

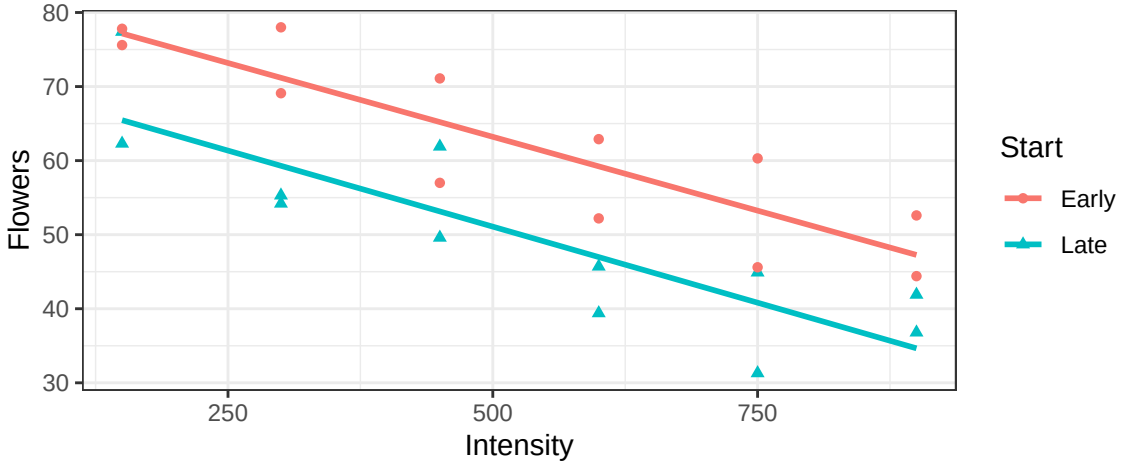
```
##   Flowers Time Intensity Start
## 1    62.3    1       150  Late
## 2    77.4    1       150  Late
## 3    55.3    1       300  Late
## 4    54.2    1       300  Late
## 5    49.6    1       450  Late
## 6    61.9    1       450  Late
```

```
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

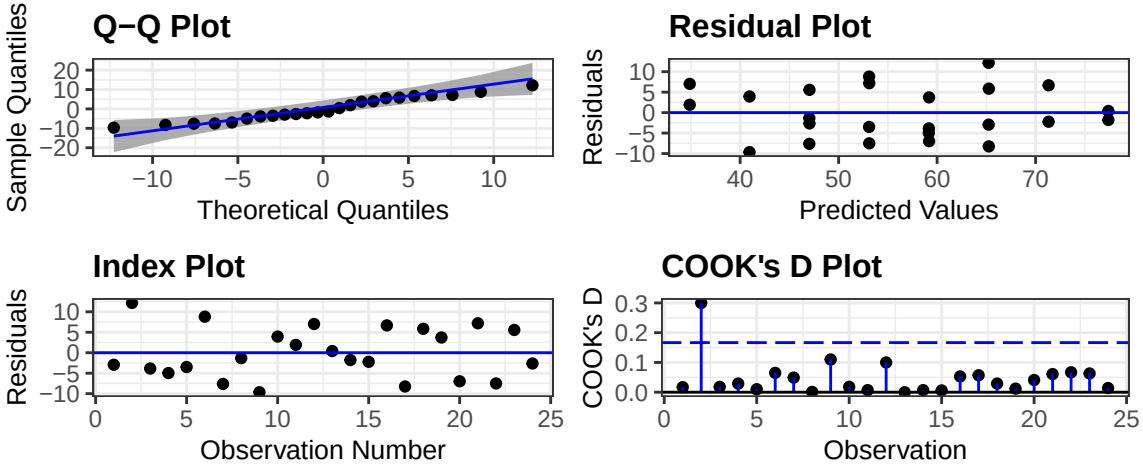
```
mM <- lm(Flowers ~ Start + Intensity, data = case0901) # Main effects model
mI <- lm(Flowers ~ Start * Intensity, data = case0901) # Interaction model

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"); cm
```

```
## $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
```

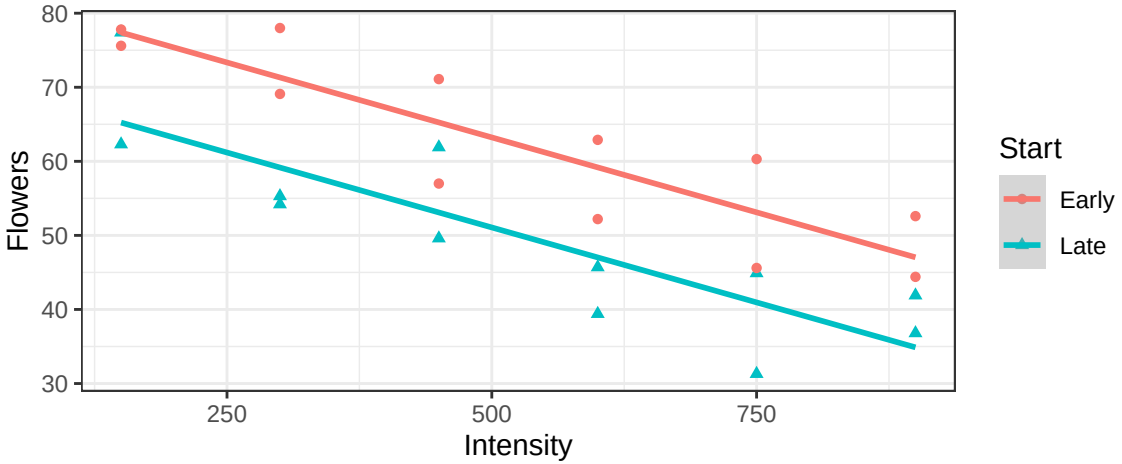
Effects of Light on Meadowfoam Flowering - Main effects model

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


## $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"); cm
```

```
## $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
```

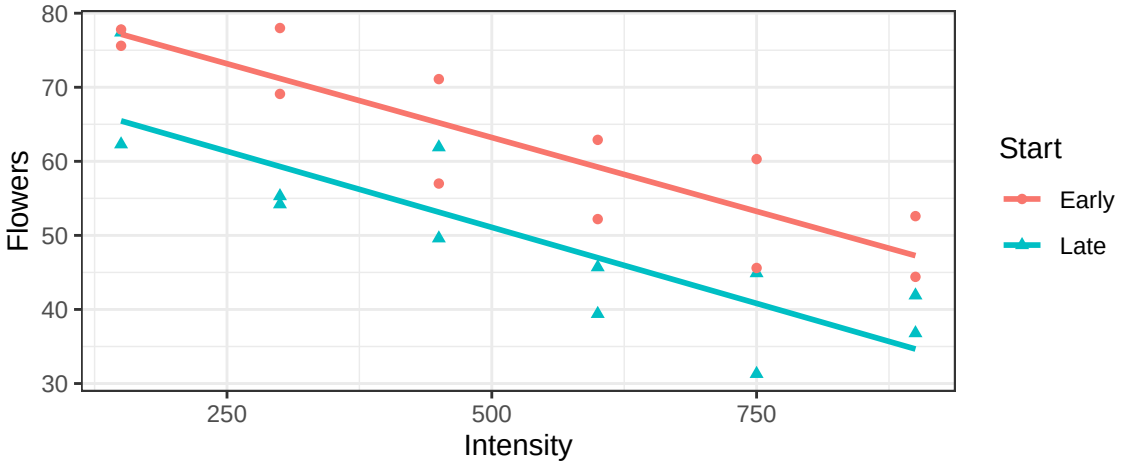
Effects of Light on Meadowfoam Flowering - Interaction model

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


## $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)
```

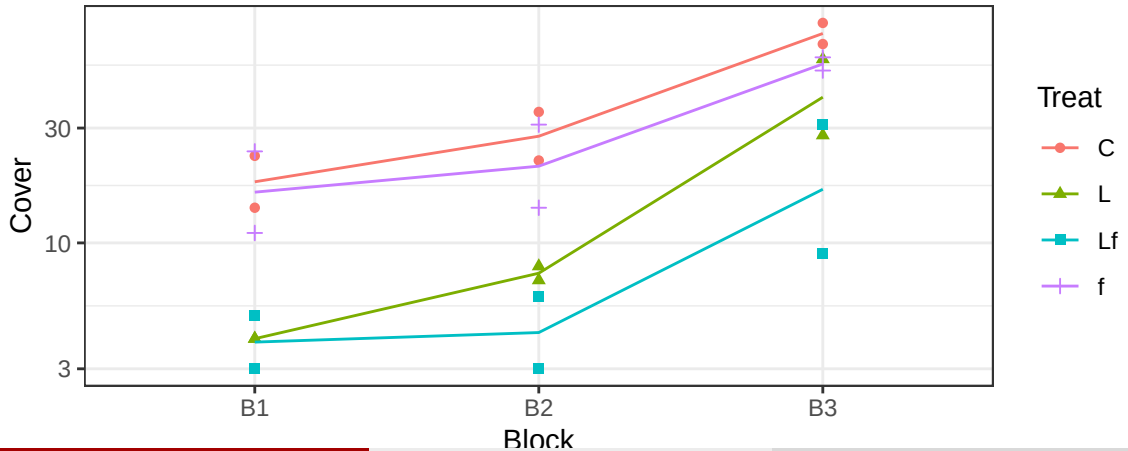
```
##   Cover Block Treat
## 1    14    B1     C
## 2    23    B1     C
## 3    22    B2     C
## 4    35    B2     C
## 5    67    B3     C
## 6    82    B3     C
```

```
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, group = Treat)) +
  geom_point() + scale_y_log10()
g + stat_summary(fun = mean, geom = "line")
```



Effects of Seaweed Grazers - Models

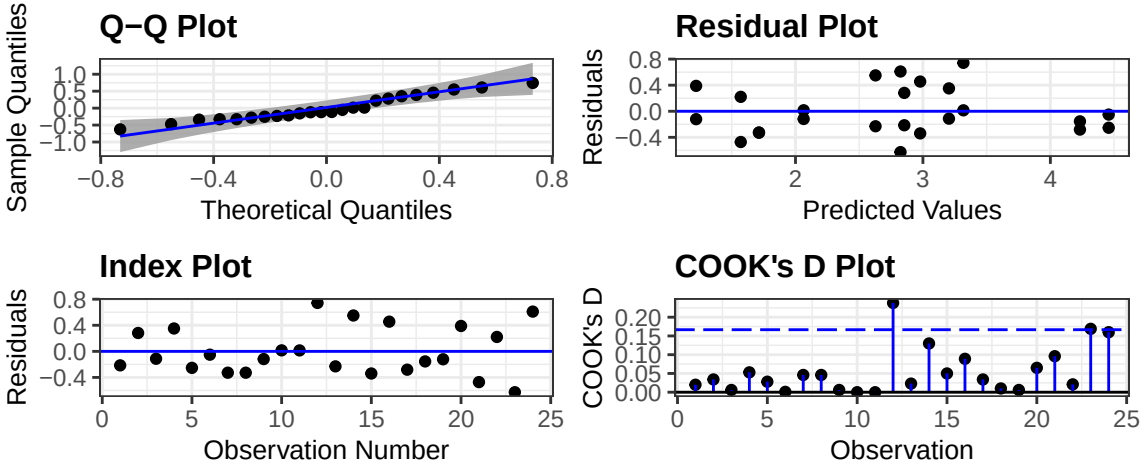
```
mM <- lm(log(Cover) ~ Treat + Block, data = case1301) # Main effects model
mI <- lm(log(Cover) ~ Treat * Block, data = case1301) # Interaction model

drop1(mI, test="F")


## Single term deletions
##
## Model:
## log(Cover) ~ Treat * Block
##            Df Sum of Sq    RSS     AIC F value Pr(>F)
## <none>                  2.2893 -32.396
## Treat:Block  6   0.80329 3.0925 -37.178  0.7018 0.6541
```

Effects of Seaweed Grazers - Diagnostics

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



Effects of Seaweed Grazers - Main effects model

```
summary(mM)


##
## Call:
## lm(formula = log(Cover) ~ Treat + Block, data = case1301)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -0.6270 -0.2602 -0.1157  0.2990  0.7428
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept)   2.8539     0.2072  13.770 5.35e-11 ***
## TreatL       -1.1403     0.2393  -4.765 0.000155 ***
## TreatLf      -1.6338     0.2393  -6.827 2.17e-06 ***
## Treatf       -0.2258     0.2393  -0.943 0.357971
## BlockB2       0.3505     0.2072   1.691 0.108036
## BlockB3       1.6041     0.2072   7.740 3.91e-07 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.4145 on 18 degrees of freedom
## Multiple R-squared:  0.8768,Adjusted R-squared:  0.8425
## F-statistic: 25.62 on 5 and 18 DF,  p-value: 1.355e-07
```

Effects of Seaweed Grazers - Main effects model

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


## $emmeans
##  Treat response   SE df lower.CL upper.CL
##  C          33.3 5.63 18    23.33    47.51
##  L          10.6 1.80 18     7.46    15.19
##  Lf          6.5 1.10 18     4.55     9.27
##  f          26.6 4.50 18    18.62    37.91
##
## Results are averaged over the levels of: Block
## Confidence level used: 0.95
## Intervals are back-transformed from the log scale
##
## $contrasts
##  contrast ratio     SE df lower.CL upper.CL
##  L / C    0.320 0.0765 18    0.172    0.593
##  Lf / C   0.195 0.0467 18    0.105    0.362
##  f / C    0.798 0.1909 18    0.430    1.480
##
## Results are averaged over the levels of: Block
## Confidence level used: 0.95
## Conf-level adjustment: dunnettx method for 3 estimates
## Intervals are back-transformed from the log scale
```

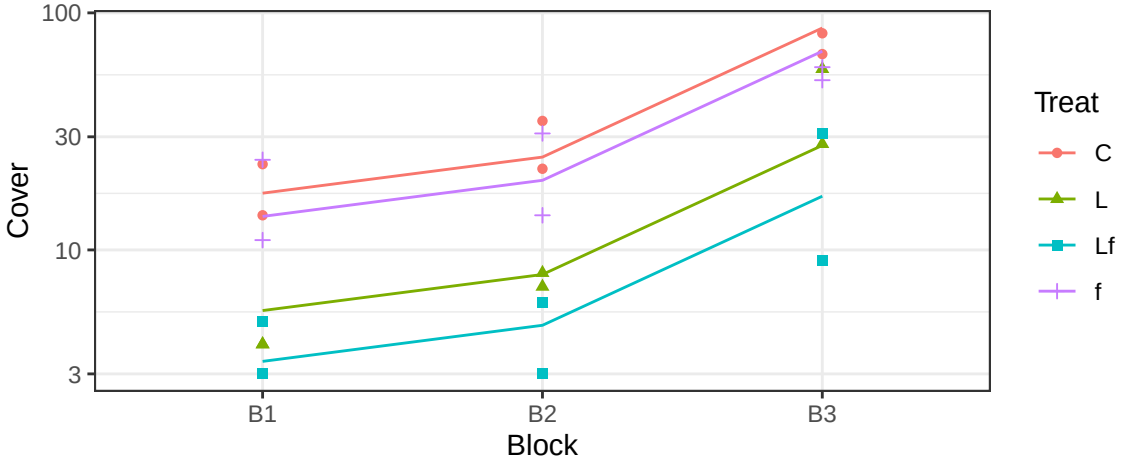
Effects of Seaweed Grazers - Main effects model

```
et <- emmeans(mM, trt.vs.ctrl ~ Block)
ct <- confint(et, type = "response"); ct


## $emmeans
##  Block response   SE df lower.CL upper.CL
##  B1         8.2 1.20 18     6.03     11.2
##  B2        11.6 1.71 18     8.55     15.8
##  B3        40.8 5.98 18    29.97     55.5
##
## Results are averaged over the levels of: Treat
## Confidence level used: 0.95
## Intervals are back-transformed from the log scale
##
## $contrasts
##  contrast ratio    SE df lower.CL upper.CL
##  B2 / B1   1.42 0.294 18    0.861     2.34
##  B3 / B1   4.97 1.031 18    3.015     8.20
##
## Results are averaged over the levels of: Treat
## Confidence level used: 0.95
## Conf-level adjustment: dunnettx method for 2 estimates
## Intervals are back-transformed from the log scale
```

Effects of Seaweed Grazers - Main effects model

```
g + geom_line(mapping=aes(y=exp(predict(mM, case1301))))
```



Effects of Seaweed Grazers - Interaction model

```
summary(mI)
```

```
##
## Call:
## lm(formula = log(Cover) ~ Treat * Block, data = case1301)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -0.6184 -0.2500  0.0000  0.2500  0.6184
##
## Coefficients:
##                 Estimate Std. Error t value Pr(>|t|)
## (Intercept)      2.88728    0.30885   9.349 7.38e-07 ***
## TreatL          -1.50098    0.43677  -3.437  0.00493 **
## TreatLf         -1.53325    0.43677  -3.510  0.00430 **
## Treatf          -0.09930    0.43677  -0.227  0.82398
## BlockB2          0.43592    0.43677   0.998  0.33796
## BlockB3          1.41843    0.43677   3.248  0.00699 **
## TreatL:BlockB2   0.19046    0.61769   0.308  0.76311
## TreatLf:BlockB2 -0.34476    0.61769  -0.558  0.58701
## Treatf:BlockB2  -0.18737    0.61769  -0.303  0.76682
## TreatL:BlockB3   0.89160    0.61769   1.443  0.17449
## TreatLf:BlockB3  0.04315    0.61769   0.070  0.94546
## Treatf:BlockB3  -0.19201    0.61769  -0.311  0.76124
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.4368 on 12 degrees of freedom
## Multiple R-squared:  0.9088,Adjusted R-squared:  0.8252
```

Effects of Seaweed Grazers - Interaction model

```
em <- emmeans(mI, trt.vs.ctrl ~ Treat | Block)
cm <- confint(em, type = "response"); cm$contrasts


## Block = B1:
##  contrast ratio     SE df lower.CL upper.CL
##  L / C    0.223 0.0974 12   0.0684    0.726
##  Lf / C   0.216 0.0943 12   0.0662    0.703
##  f / C    0.905 0.3955 12   0.2778    2.951
##
## Block = B2:
##  contrast ratio     SE df lower.CL upper.CL
##  L / C    0.270 0.1178 12   0.0827    0.879
##  Lf / C   0.153 0.0668 12   0.0469    0.498
##  f / C    0.751 0.3279 12   0.2304    2.447
##
## Block = B3:
##  contrast ratio     SE df lower.CL upper.CL
##  L / C    0.544 0.2375 12   0.1668    1.772
##  Lf / C   0.225 0.0984 12   0.0691    0.734
##  f / C    0.747 0.3264 12   0.2293    2.435
##
## Confidence level used: 0.95
## Conf-level adjustment: dunnettx method for 3 estimates
## Intervals are back-transformed from the log scale
```

Effects of Seaweed Grazers - Interaction model

```
et <- emmeans(mI, trt.vs.ctrl ~ Block | Treat)
ct <- confint(et, type = "response"); ct$contrasts


## Treat = C:
##  contrast ratio    SE df lower.CL upper.CL
##  B2 / B1   1.55 0.675 12    0.514     4.65
##  B3 / B1   4.13 1.804 12    1.373    12.43
##
## Treat = L:
##  contrast ratio    SE df lower.CL upper.CL
##  B2 / B1   1.87 0.817 12    0.622     5.63
##  B3 / B1  10.07 4.400 12    3.348    30.32
##
## Treat = Lf:
##  contrast ratio    SE df lower.CL upper.CL
##  B2 / B1   1.10 0.478 12    0.364     3.30
##  B3 / B1   4.31 1.884 12    1.433    12.98
##
## Treat = f:
##  contrast ratio    SE df lower.CL upper.CL
##  B2 / B1   1.28 0.560 12    0.426     3.86
##  B3 / B1   3.41 1.489 12    1.133    10.26
##
## Confidence level used: 0.95
## Conf-level adjustment: dunnettx method for 2 estimates
## Intervals are back-transformed from the log scale
```

Effects of Seaweed Grazers - Interaction model

```
g + stat_summary(fun = mean, geom = "line")
```