Individual Project

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Project Title:

The effects of seasonal fish assemblages on eelgrass (Zostera marina) bed health within the impacted San Francisco Bay Estuary

Introduction:

Global seagrass habitat has declined by 19% since 1880 (Dunic et al., 2021). In San Francisco Bay (SFB), the native seagrass commonly known as eelgrass (*Zostera marina*) faces harmful eutrophication-induced microalgal blooms, along with intense mechanical damage, biological invasion, and pollution (Kelly et al., 2019; Cohen & Carlton, 1998; Fonseca et al., 2017). The high ecological value of eelgrass beds combined with their dwindling coverage has prompted scientists to investigate how rapidly changing environmental conditions will affect the suite of organisms that benefit from and contribute to the health of eelgrass.

Local studies have demonstrated that fishes can improve eelgrass performance (Best & Stachowicz, 2012; Carr & Boyer, 2014) via a trophic cascade in which a fish predator directly consumes or alters the grazing behavior of an epifaunal invertebrate that consumes eelgrass leaves, such as *Ampithoe valida* (Harper et al., 2022; Lewis & Boyer, 2014; Reynolds et al., 2012; Ayala, 2021). Current studies are investigating the effects of climate change-induced carbon dioxide increases in baywater predicted by 2100 on the herbivorous feeding preferences of common epifauna like *A. valida*. And while the community composition of epifauna in eelgrass beds in SFB has recently been examined (Ayala, 2021), informing researchers about present day conditions, the same cannot be said about the community composition of fish, as the last monitoring of fish in littoral areas occurred in 1987 (Baxter et al., 1999).

As climate change continues to alter baywater conditions, community fish assemblages and trophic interactions must be evaluated to establish a baseline of the top-down effects of fish on the eelgrass habitat. Therefore, my study will pair environmental DNA (eDNA) and beach seining to assess the composition of fish communities within eelgrass beds. The community survey phase will also be intertwined with a feeding experiment phase that will elucidate trophic interactions between fishes and epifauna throughout changing seasonal conditions. My study will give coastal managers insight into the role that water conditions, food availability, and nursery fish communities play in determining the performance of crucial eelgrass habitat now and under conditions brought about by climate change.

Guiding Question:

What is the composition of the fish communities in eelgrass beds over a seasonal cycle and how are they involved in the food web of the eelgrass system in SFB?

Aims:

1. Ascertain how fish assemblages and epifaunal invertebrate communities compare in eelgrass beds over a seasonal cycle and across SFB.

2. Determine the relative seasonal consumption rates of epifauna among some of the most common fishes in eelgrass beds across SFB.

Statistical Analysis

For my statistical analysis assignment, I will focus on my second aim.

H0: There is no difference in consumption rates of epifauna among seasons and fish individuals per species. HA: In general, there will be higher consumption rates of epifauna during summer and fall when higher water temperatures increase metabolic rates and larger prey abundances create an environment for reduced resource partitioning, which allow fishes to have more generalized feeding preferences. The species and number of individuals per tank will demonstrate variable epifaunal consumption rates depending on the species-specific prey capture strategies.

I determined relatively early on that a generalized linear model would be the best type of model to analyze my data given the bounded counts that my experiments entail. Using a GLM under Poisson assumptions, I created a model for each epifaunal consumption variable under several predictor variables, such as fish_mass_tot, tank, season, and of course treatment. I noticed that AIC scores dropped as I included the interaction of more variables. Ultimately, after re-reading my hypothesis for this project, I decided to settle on a model that describes the interaction between season and treatment on the consumption of epifauna without much focus on the magnitude of the AIC score since these predictors fell more in line with my scientific question. While analyzing the model output, I noticed that solo P. ornata individuals consumed, on average, many more gammarid amphipods during summer relative to other seasons for the same treatment and the overall control. In order to showcase this finding, I envisioned a boxplot demonstrating consumption counts for gammarid amphipods subset by season, with the summer P. ornata box and whisker plot not overlapping with the control treatment and the other seasons of P. ornata treatments. Given that this worked for gammarid amphipods and to maintain consistency, I figured I would also apply the same figure outline for both caprellid amphipod and Pentidotea resecata loss.

Below the references is some of the work I have completed to simulate the data values that I can expect during my experiments. More information on my experiments and simulated dataset is available in the dataset card available here: https://github.com/AngeloLCS/EpifaunaExperimentBIOL710/blob/070cc3c0aeba8b0e9b3f4680e01527374d516e12/RCode/Input/DatasetCard.md

```r
library(tidyverse)
```

```
## Warning: package 'ggplot2' was built under R version 4.4.3

## Warning: package 'purrr' was built under R version 4.4.3

## -- Attaching core tidyverse packages ------------------------ tidyverse 2.0.0 --
## v dplyr     1.1.4     v readr     2.1.5
## v forcats   1.0.0     v stringr   1.5.1
## v ggplot2   3.5.2     v tibble    3.2.1
## v lubridate 1.9.4     v tidyr     1.3.1
## v purrr     1.0.4
## -- Conflicts ------------------------------------------ tidyverse_conflicts() --
## x dplyr::filter() masks stats::filter()
## x dplyr::lag()    masks stats::lag()
## i Use the conflicted package (<http://conflicted.r-lib.org/>) to force all conflicts to become errors
```

```r
getwd()
```

```
## [1] "C:/Users/Angelo L/Documents/GitHub/EpifaunaExperimentBIOL710/RCode/Input"
```

```r
# Importing Data
epifauna <- read.csv('epifauna.csv', stringsAsFactors = TRUE )
str(epifauna)
```

```
## 'data.frame':    243 obs. of  11 variables:
##  $ season       : Factor w/ 3 levels "fall","spring",..: 2 2 2 2 2 2 2 2 2 2 ...
##  $ day          : int  1 1 1 1 1 1 1 1 1 1 ...
##  $ tank         : Factor w/ 27 levels "\xd1","A","B",..: 4 15 22 20 11 8 10 23 3 27 ...
##  $ treatment    : Factor w/ 11 levels "2_C. aggregata",..: 7 7 7 6 6 6 1 1 1 9 ...
##  $ gamm_loss    : int  5 4 4 27 6 1 18 7 11 11 ...
##  $ capr_loss    : int  9 0 10 27 26 32 46 33 17 11 ...
##  $ pent_loss    : int  3 0 0 1 2 3 1 2 2 5 ...
##  $ fish1_mass   : num  NA NA NA 9.39 8.51 8.37 4.67 3.87 3.54 9.17 ...
##  $ fish2_mass   : num  NA NA NA NA NA NA 4.42 4 3.86 NA ...
##  $ fish_mass_tot: num  NA NA NA 9.39 8.51 8.37 9.09 7.87 7.4 9.17 ...
##  $ tank_vol     : num  0.04 0.04 0.04 0.04 0.04 0.04 0.04 0.04 0.04 0.04 ...
```

```r
# Exploring distribution of data of interest (fish biomass and epifaunal consumption)
gamm_f <- ggplot(epifauna, aes(x=gamm_loss))+
  geom_histogram()
#gamm_f

capr_f <- ggplot(epifauna, aes(x=capr_loss))+
  geom_histogram()
#capr_f

pent_f <- ggplot(epifauna, aes(x=pent_loss))+
  geom_histogram()
#pent_f

fishbm_f <- ggplot(epifauna, aes(x=fish_mass_tot))+
  geom_histogram()
#fishbm_f
```

```r
# Releveling variables for simpler model output interpretation
epifauna$season <- fct_relevel(epifauna$season, 'spring', 'summer')
epifauna$treatment <- relevel(epifauna$treatment, 'Control')
```

```r
#Statistical tests gammarid amphipods
#GLM with Poisson family due to count data and right skewness of the data
gamm_glm <- glm(gamm_loss ~ treatment*season, family = "poisson", data = epifauna)
summary(gamm_glm)
```

```
##
## Call:
## glm(formula = gamm_loss ~ treatment * season, family = "poisson",
##     data = epifauna)
##
## Coefficients: (6 not defined because of singularities)
##                                          Estimate Std. Error z value Pr(>|z|)
## (Intercept)                               1.09861    0.19245   5.709 1.14e-08
## treatment2_C. aggregata                   1.81615    0.20751   8.752  < 2e-16
```

```
## treatment2_H. guttulata                 2.04170    0.20456   9.981  < 2e-16
## treatment2_L. armatus                   1.92452    0.20602   9.342  < 2e-16
## treatment2_P. californicus              2.19722    0.19920  11.030  < 2e-16
## treatment2_P. ornata                    2.15090    0.20334  10.578  < 2e-16
## treatmentC. aggregata                   1.77307    0.20815   8.518  < 2e-16
## treatmentH. guttulata                   2.20133    0.20282  10.854  < 2e-16
## treatmentL. armatus                     1.99243    0.20515   9.712  < 2e-16
## treatmentP. californicus                1.75539    0.20466   8.577  < 2e-16
## treatmentP. ornata                      1.69460    0.20938   8.093 5.80e-16
## seasonsummer                           -0.07696    0.27756  -0.277   0.7816
## seasonfall                              0.03637    0.26972   0.135   0.8927
## treatment2_C. aggregata:seasonsummer    0.26329    0.29675   0.887   0.3749
## treatment2_H. guttulata:seasonsummer    0.26488    0.29297   0.904   0.3659
## treatment2_L. armatus:seasonsummer      0.16487    0.29562   0.558   0.5770
## treatment2_P. californicus:seasonsummer      NA         NA      NA       NA
## treatment2_P. ornata:seasonsummer       0.06395    0.29277   0.218   0.8271
## treatmentC. aggregata:seasonsummer      0.23380    0.29783   0.785   0.4324
## treatmentH. guttulata:seasonsummer     -0.01753    0.29264  -0.060   0.9522
## treatmentL. armatus:seasonsummer       -0.06964    0.29654  -0.235   0.8143
## treatmentP. californicus:seasonsummer        NA         NA      NA       NA
## treatmentP. ornata:seasonsummer         0.69233    0.29583   2.340   0.0193
## treatment2_C. aggregata:seasonfall      0.01070    0.29073   0.037   0.9706
## treatment2_H. guttulata:seasonfall           NA         NA      NA       NA
## treatment2_L. armatus:seasonfall        0.12777    0.28765   0.444   0.6569
## treatment2_P. californicus:seasonfall        NA         NA      NA       NA
## treatment2_P. ornata:seasonfall         0.09662    0.28432   0.340   0.7340
## treatmentC. aggregata:seasonfall        0.10966    0.29065   0.377   0.7059
## treatmentH. guttulata:seasonfall             NA         NA      NA       NA
## treatmentL. armatus:seasonfall          0.19683    0.28601   0.688   0.4913
## treatmentP. californicus:seasonfall          NA         NA      NA       NA
## treatmentP. ornata:seasonfall           0.18269    0.29158   0.627   0.5310
##
## (Intercept)                            ***
## treatment2_C. aggregata                ***
## treatment2_H. guttulata                ***
## treatment2_L. armatus                  ***
## treatment2_P. californicus             ***
## treatment2_P. ornata                   ***
## treatmentC. aggregata                  ***
## treatmentH. guttulata                  ***
## treatmentL. armatus                    ***
## treatmentP. californicus               ***
## treatmentP. ornata                     ***
## seasonsummer
## seasonfall
## treatment2_C. aggregata:seasonsummer
## treatment2_H. guttulata:seasonsummer
## treatment2_L. armatus:seasonsummer
## treatment2_P. californicus:seasonsummer
## treatment2_P. ornata:seasonsummer
## treatmentC. aggregata:seasonsummer
## treatmentH. guttulata:seasonsummer
## treatmentL. armatus:seasonsummer
## treatmentP. californicus:seasonsummer
```

```
## treatmentP. ornata:seasonsummer          *
## treatment2_C. aggregata:seasonfall
## treatment2_H. guttulata:seasonfall
## treatment2_L. armatus:seasonfall
## treatment2_P. californicus:seasonfall
## treatment2_P. ornata:seasonfall
## treatmentC. aggregata:seasonfall
## treatmentH. guttulata:seasonfall
## treatmentL. armatus:seasonfall
## treatmentP. californicus:seasonfall
## treatmentP. ornata:seasonfall
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## (Dispersion parameter for poisson family taken to be 1)
##
##     Null deviance: 2992.2  on 242  degrees of freedom
## Residual deviance: 2147.0  on 216  degrees of freedom
## AIC: 3281.4
##
## Number of Fisher Scoring iterations: 5
```

```
#Statistical tests caprellid amphipods
capr_glm <- glm(capr_loss ~ treatment*season, family = "poisson", data = epifauna)
summary(capr_glm)
```

```
##
## Call:
## glm(formula = capr_loss ~ treatment * season, family = "poisson",
##     data = epifauna)
##
## Coefficients: (6 not defined because of singularities)
##                                       Estimate Std. Error z value Pr(>|z|)
## (Intercept)                            1.79176    0.13608  13.167  < 2e-16
## treatment2_C. aggregata                1.52444    0.15017  10.152  < 2e-16
## treatment2_H. guttulata                1.43155    0.15147   9.451  < 2e-16
## treatment2_L. armatus                  1.37231    0.15236   9.007  < 2e-16
## treatment2_P. californicus             1.65694    0.17939   9.236  < 2e-16
## treatment2_P. ornata                   1.12300    0.15666   7.168 7.59e-13
## treatmentC. aggregata                  1.69119    0.14809  11.420  < 2e-16
## treatmentH. guttulata                  1.33403    0.15296   8.721  < 2e-16
## treatmentL. armatus                    1.61313    0.14903  10.825  < 2e-16
## treatmentP. californicus               1.82280    0.17718  10.288  < 2e-16
## treatmentP. ornata                     1.57554    0.14950  10.539  < 2e-16
## seasonsummer                          -0.37807    0.21341  -1.772 0.076475
## seasonfall                            -0.37807    0.21341  -1.772 0.076475
## treatment2_C. aggregata:seasonsummer   0.04079    0.23501   0.174 0.862213
## treatment2_H. guttulata:seasonsummer   0.32817    0.23371   1.404 0.160272
## treatment2_L. armatus:seasonsummer     0.55804    0.23273   2.398 0.016493
## treatment2_P. californicus:seasonsummer     NA         NA      NA       NA
## treatment2_P. ornata:seasonsummer      0.59395    0.23754   2.500 0.012403
## treatmentC. aggregata:seasonsummer    -0.19012    0.23448  -0.811 0.417482
## treatmentH. guttulata:seasonsummer     0.51464    0.23384   2.201 0.027745
## treatmentL. armatus:seasonsummer       0.06421    0.23299   0.276 0.782851
```

```
## treatmentP. californicus:seasonsummer          NA         NA      NA       NA
## treatmentP. ornata:seasonsummer           0.10181    0.23330   0.436 0.662540
## treatment2_C. aggregata:seasonfall        0.52063    0.23038   2.260 0.023828
## treatment2_H. guttulata:seasonfall             NA         NA      NA       NA
## treatment2_L. armatus:seasonfall          0.35431    0.23462   1.510 0.131010
## treatment2_P. californicus:seasonfall          NA         NA      NA       NA
## treatment2_P. ornata:seasonfall           0.88285    0.23496   3.757 0.000172
## treatmentC. aggregata:seasonfall          0.04023    0.23183   0.174 0.862238
## treatmentH. guttulata:seasonfall               NA         NA      NA       NA
## treatmentL. armatus:seasonfall            0.32112    0.23052   1.393 0.163615
## treatmentP. californicus:seasonfall            NA         NA      NA       NA
## treatmentP. ornata:seasonfall            -0.21664    0.23732  -0.913 0.361316
##
## (Intercept)                              ***
## treatment2_C. aggregata                  ***
## treatment2_H. guttulata                  ***
## treatment2_L. armatus                    ***
## treatment2_P. californicus               ***
## treatment2_P. ornata                     ***
## treatmentC. aggregata                    ***
## treatmentH. guttulata                    ***
## treatmentL. armatus                      ***
## treatmentP. californicus                 ***
## treatmentP. ornata                       ***
## seasonsummer                             .
## seasonfall                               .
## treatment2_C. aggregata:seasonsummer
## treatment2_H. guttulata:seasonsummer
## treatment2_L. armatus:seasonsummer       *
## treatment2_P. californicus:seasonsummer
## treatment2_P. ornata:seasonsummer        *
## treatmentC. aggregata:seasonsummer
## treatmentH. guttulata:seasonsummer       *
## treatmentL. armatus:seasonsummer
## treatmentP. californicus:seasonsummer
## treatmentP. ornata:seasonsummer
## treatment2_C. aggregata:seasonfall       *
## treatment2_H. guttulata:seasonfall
## treatment2_L. armatus:seasonfall
## treatment2_P. californicus:seasonfall
## treatment2_P. ornata:seasonfall          ***
## treatmentC. aggregata:seasonfall
## treatmentH. guttulata:seasonfall
## treatmentL. armatus:seasonfall
## treatmentP. californicus:seasonfall
## treatmentP. ornata:seasonfall
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## (Dispersion parameter for poisson family taken to be 1)
##
##     Null deviance: 2675.9  on 242  degrees of freedom
## Residual deviance: 1901.0  on 216  degrees of freedom
## AIC: 3066.5
```

```
##
## Number of Fisher Scoring iterations: 5
```

```r
#Statistical tests pentidotea isopods
pent_glm <- glm(pent_loss ~ treatment*season, family = "poisson", data = epifauna)
summary(pent_glm)
```

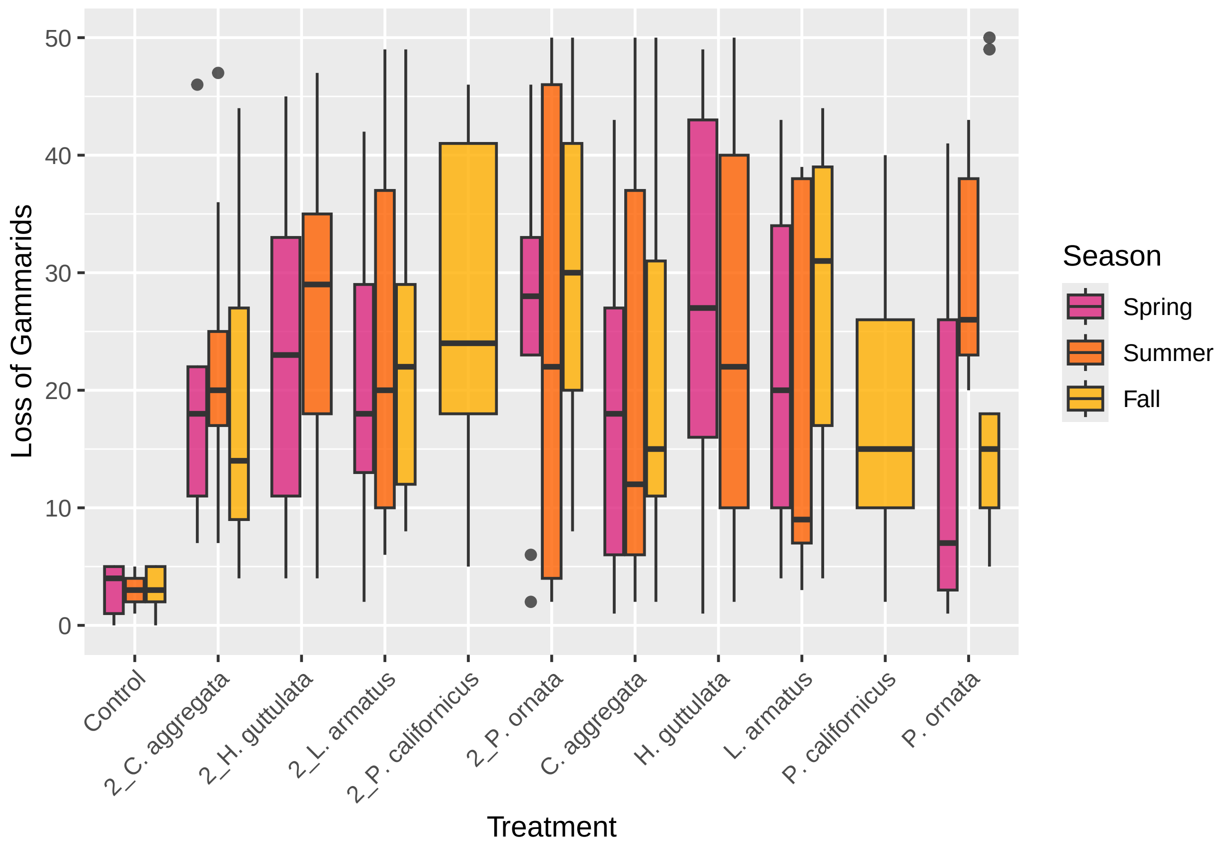
```
##
## Call:
## glm(formula = pent_loss ~ treatment * season, family = "poisson",
##     data = epifauna)
##
## Coefficients: (6 not defined because of singularities)
##                                         Estimate Std. Error z value Pr(>|z|)
## (Intercept)                              0.28768    0.28867   0.997  0.31898
## treatment2_C. aggregata                  0.45953    0.36873   1.246  0.21267
## treatment2_H. guttulata                  0.60614    0.35887   1.689  0.09122
## treatment2_L. armatus                    1.15268    0.33113   3.481  0.00050
## treatment2_P. californicus               0.96141    0.32609   2.948  0.00320
## treatment2_P. ornata                     1.27629    0.32648   3.909 9.26e-05
## treatmentC. aggregata                    0.60614    0.35887   1.689  0.09122
## treatmentH. guttulata                    0.60614    0.35887   1.689  0.09122
## treatmentL. armatus                      1.36524    0.32343   4.221 2.43e-05
## treatmentP. californicus                 1.01857    0.32357   3.148  0.00164
## treatmentP. ornata                       0.65059    0.35611   1.827  0.06771
## seasonsummer                             0.51083    0.36515   1.399  0.16183
## seasonfall                               0.08004    0.40032   0.200  0.84152
## treatment2_C. aggregata:seasonsummer     0.18232    0.46074   0.396  0.69231
## treatment2_H. guttulata:seasonsummer     0.26933    0.44679   0.603  0.54663
## treatment2_L. armatus:seasonsummer      -0.27721    0.42483  -0.653  0.51407
## treatment2_P. californicus:seasonsummer       NA         NA      NA       NA
## treatment2_P. ornata:seasonsummer       -0.58315    0.42613  -1.368  0.17117
## treatmentC. aggregata:seasonsummer       0.06169    0.45214   0.136  0.89147
## treatmentH. guttulata:seasonsummer       0.31015    0.44586   0.696  0.48665
## treatmentL. armatus:seasonsummer        -0.48977    0.41886  -1.169  0.24228
## treatmentP. californicus:seasonsummer         NA         NA      NA       NA
## treatmentP. ornata:seasonsummer          0.20383    0.44507   0.458  0.64698
## treatment2_C. aggregata:seasonfall       0.98285    0.48070   2.045  0.04089
## treatment2_H. guttulata:seasonfall            NA         NA      NA       NA
## treatment2_L. armatus:seasonfall         0.28970    0.45250   0.640  0.52202
## treatment2_P. californicus:seasonfall         NA         NA      NA       NA
## treatment2_P. ornata:seasonfall         -0.23032    0.45884  -0.502  0.61569
## treatmentC. aggregata:seasonfall         0.72074    0.47552   1.516  0.12960
## treatmentH. guttulata:seasonfall              NA         NA      NA       NA
## treatmentL. armatus:seasonfall          -0.01817    0.44892  -0.040  0.96772
## treatmentP. californicus:seasonfall           NA         NA      NA       NA
## treatmentP. ornata:seasonfall            0.42205    0.47963   0.880  0.37889
##
## (Intercept)
## treatment2_C. aggregata
## treatment2_H. guttulata                 .
## treatment2_L. armatus                   ***
## treatment2_P. californicus              **
## treatment2_P. ornata                    ***
```

```
## treatmentC. aggregata                    .
## treatmentH. guttulata                    .
## treatmentL. armatus                      ***
## treatmentP. californicus                 **
## treatmentP. ornata                       .
## seasonsummer
## seasonfall
## treatment2_C. aggregata:seasonsummer
## treatment2_H. guttulata:seasonsummer
## treatment2_L. armatus:seasonsummer
## treatment2_P. californicus:seasonsummer
## treatment2_P. ornata:seasonsummer
## treatmentC. aggregata:seasonsummer
## treatmentH. guttulata:seasonsummer
## treatmentL. armatus:seasonsummer
## treatmentP. californicus:seasonsummer
## treatmentP. ornata:seasonsummer
## treatment2_C. aggregata:seasonfall      *
## treatment2_H. guttulata:seasonfall
## treatment2_L. armatus:seasonfall
## treatment2_P. californicus:seasonfall
## treatment2_P. ornata:seasonfall
## treatmentC. aggregata:seasonfall
## treatmentH. guttulata:seasonfall
## treatmentL. armatus:seasonfall
## treatmentP. californicus:seasonfall
## treatmentP. ornata:seasonfall
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## (Dispersion parameter for poisson family taken to be 1)
##
##     Null deviance: 594.11  on 242  degrees of freedom
## Residual deviance: 460.27  on 216  degrees of freedom
## AIC: 1207.7
##
## Number of Fisher Scoring iterations: 5
```

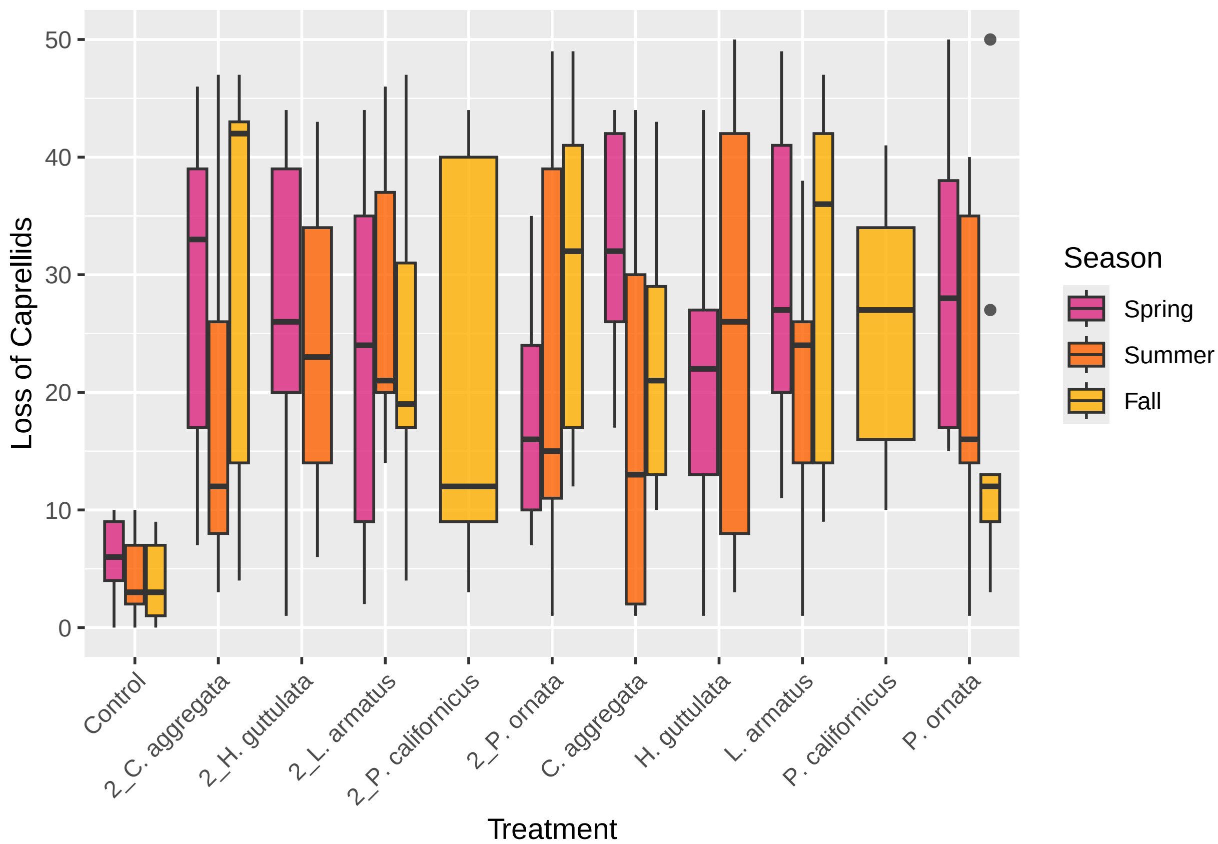
```r
#Property plots
# plot(gamm_glm)
# plot(capr_glm)
# plot(pent_glm)
```

```r
#Figures
gamm_f2 <- ggplot(epifauna, aes(x = treatment, y = gamm_loss, fill=season)) +
  geom_boxplot(alpha = 0.8) +
  scale_fill_manual(
    values=c('#DC267F', '#FE6100', '#FFB000'),
    label =c('Spring', 'Summer', 'Fall')
  )+
  labs(
    x = "Treatment",
    y = "Loss of Gammarids",
    fill = 'Season') +
```

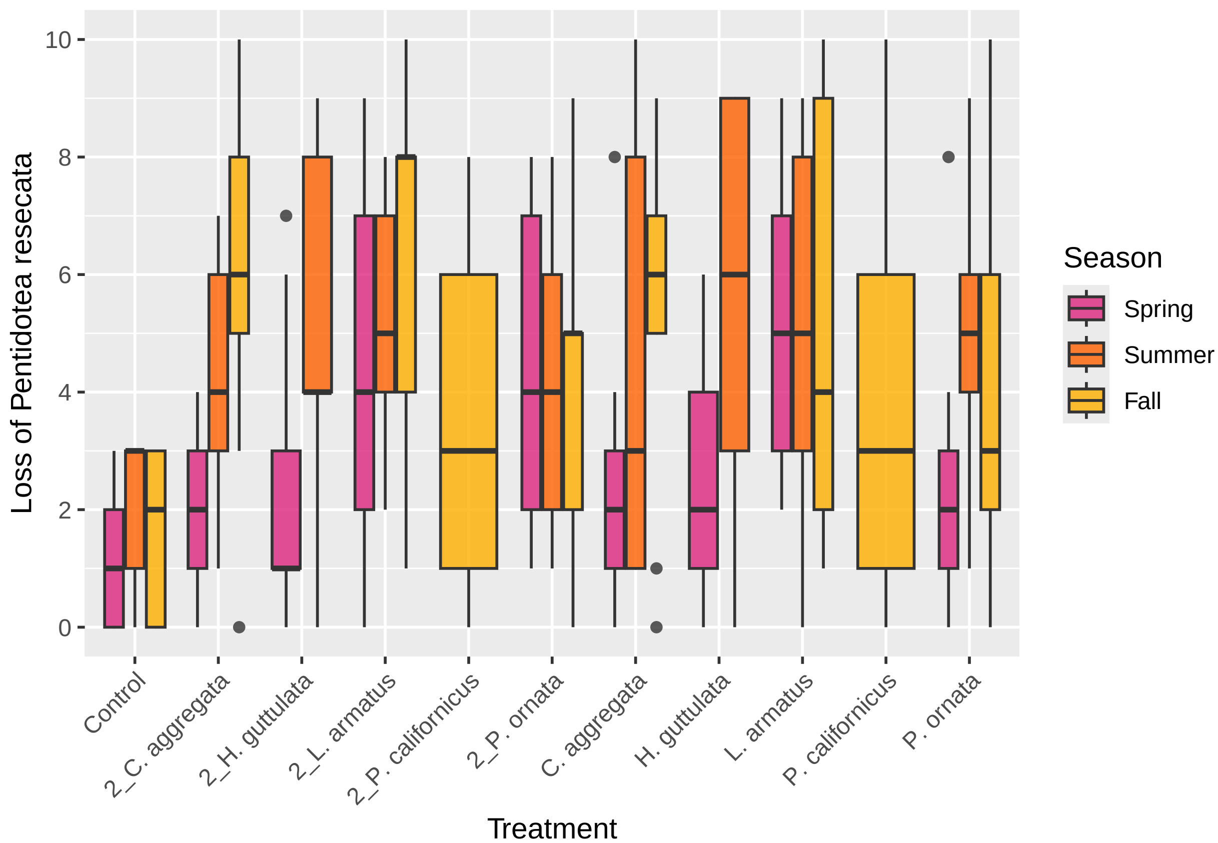
```
  theme(axis.text.x = element_text(angle = 45, vjust = 1, hjust = 1))
gamm_f2
```




```
capr_f2 <- ggplot(epifauna, aes(x = treatment, y = capr_loss, fill=season)) +
  geom_boxplot(alpha = 0.8) +
  scale_fill_manual(
    values=c('#DC267F', '#FE6100', '#FFB000'),
    label =c('Spring', 'Summer', 'Fall')
  )+
  labs(
    x = "Treatment",
    y = "Loss of Caprellids",
    fill = 'Season') +
  theme(axis.text.x = element_text(angle = 45, vjust = 1, hjust = 1))
capr_f2
```




```
pent_f2 <- ggplot(epifauna, aes(x = treatment, y = pent_loss, fill=season)) +
  geom_boxplot(alpha = 0.8) +
  scale_fill_manual(
    values=c('#DC267F', '#FE6100', '#FFB000'),
    label =c('Spring', 'Summer', 'Fall')
  )+
  labs(
    x = "Treatment",
    y = "Loss of Pentidotea resecata",
    fill = 'Season') +
  theme(axis.text.x = element_text(angle = 45, vjust = 1, hjust = 1))+
  scale_y_continuous(breaks=c(0, 2, 4, 6, 8, 10))
pent_f2
```



References:

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Data Simulation Methods:

```
#vector <- rnorm(100, mean = 1.5, sd = 0.7)
#vector

# ctrl_gamm <- sample(0:5, 27, replace = TRUE)
# ctrl_capr <- sample(0:10, 27, replace = TRUE)
# ctrl_pent <- sample(0:3, 27, replace = TRUE)
#
# ctrl_gamm <- as.matrix(ctrl_gamm)
# ctrl_capr <- as.matrix(ctrl_capr)
# ctrl_pent <- as.matrix(ctrl_pent)
```

```
# tank <- c("A", "B", "C", "D", "E", "F", "G", "H", "I", "J", "K", "L", "M", "N", "Ñ", "O", "P", "Q", "
#
# tank_rand1 <- sample(tank, 27)
# tank_rand1
# tank_rand2 <- sample(tank, 27)
# tank_rand3 <- sample(tank, 27)
# tank_rand4 <- sample(tank, 27)
# tank_rand5 <- sample(tank, 27)
# tank_rand6 <- sample(tank, 27)
# tank_rand7 <- sample(tank, 27)
# tank_rand8 <- sample(tank, 27)
# tank_rand9 <- sample(tank, 27)
#
# tank_rand <- rbind(tank_rand1, tank_rand2, tank_rand3, tank_rand4, tank_rand5, tank_rand6, tank_rand7
# tank_rand
# tank_rand <- as.matrix(c(apply(tank_rand, 1, c)))
#for (i in tank) {
#  print(sample(tank, 27))
#}
```

```
# gamm <- sample(1:50, 243, replace = TRUE)
# capr <- sample(1:50, 243, replace = TRUE)
# pent <- sample(0:10, 243, replace = TRUE)
#
# gamm <- as.matrix(gamm)
# capr <- as.matrix(capr)
# pent <- as.matrix(pent)
```

```
# sp_cym <- runif(n=230, min=3.5, max=10)
# sp_lept <- runif(n=27, min=3.7, max=11.4)
# sp_hyps <- runif(n=27, min=3.3, max=9.3)
# sp_pho <- runif(n=27, min=1.4, max=5.9)
#
# sp_cym <- as.matrix(sp_cym)
# sp_lept <- as.matrix(sp_lept)
# sp_hyps <- as.matrix(sp_hyps)
# sp_pho <- as.matrix(sp_pho)
```

```
# rec.list <- function(len){
#   if(length(len) == 1){
#     vector("list", len)
#   } else {
#     lapply(1:len[1], function(...) rec.list(len[-1]))
#   }
# }
```

```
# set.seed(5094)
#
# season <- c('spring', 'summer', 'fall')
# tank <- c("A", "B", "C", "D", "E", "F", "G", "H", "I", "J", "K", "L", "M", "N", "Ñ", "O", "P", "Q", "
# treatment <- c("control", "control","control","C_aggregata", "C_aggregata","C_aggregata","2C_aggregat
#
# Data_full <- rec.list(c(length(season), 3, length(tank)))
#
# for (x in 1:length(season)) {
#   for (u in 1:3){#day
#     for (t in 1:length(tank)){
#
#  pent_loss <- sample(1:10, 1, replace=TRUE)
#  gamm_loss <- sample(1:50, 1, replace=TRUE)
#  capr_loss <- sample(1:50, 1, replace=TRUE)
#  treat <- sample(treatment, 1, replace=FALSE)
#  # fish1_mass<-
#  #   if (treat == 'control'){
#  #   NA
#  #   } else if (season == 'spring' & treat == 'C_aggregata' ){
#  #     runif(n=1, min=3.5, max=10)
#  #   } else {
#  #     10
#  #   }
#
#  Data_full[[x]][[u]][[t]] <- data_frame(
#                                'pent_loss'=pent_loss,
#                                'gamm_loss'=gamm_loss,
#                                'capr_loss'= capr_loss,
#                                'treatment' = treat)#,
#                               # 'fish1_mass' = fish1_mass)
#       } #tank
#     names(Data_full[[x]][[u]]) <- tank
#     } #day
#   } #season
```

```r
# names(Data_full) <- season
#
#
#
# Test <- unlist(Data_full)
#
# Test2 <- data.frame(Reduce(rbind, Data_full))
#
# Test3 <- ldply(Data_full, data_frame())
```