Impact of food availability and light on A. lixula larval growth - data analysis - model visualization

```r
library('dplyr')
library('readr')
library('ggplot2')
library('knitr')
library('tidyr')
library('emmeans')
library('rstan')
rstan::rstan_options(auto_write = TRUE)
library('brms')
options(mc.cores = parallel::detectCores())  # run all cores
library('bayesplot')
library('marginaleffects')
library('ggdist')
```

```r
unscale_outcome <- function(x){
  x = (x * sdL) + meanL
}
```

1. Data overview

Making a data set containing only the data pertaining to *A. lixula* at 6 dpf.

```r
Al_df <-  read_delim("larval_morphology.csv", delim = ",",
                 col_types = "fffnfiffffffiniif")
Al_df = drop_na(Al_df, length)
Al_df[Al_df$length < 0,]
```

```
## # A tibble: 0 x 15
## # i 15 variables: larva <fct>, side <fct>, rod <fct>, length <dbl>, ate <fct>,
## #   Food_conc <int>, Food_species <fct>, fed <fct>, lit <fct>, condition <fct>,
## #   larvae_per_well <int>, lar_ml <dbl>, hpf <int>, dpf <int>, species <fct>
```

```r
# make Al_df$larva by concatenating Al_df$species with Al_df$larva
Al_df$larva <- as.factor(paste0(Al_df$species, Al_df$larva))
Al_df <- Al_df[Al_df$species == "Al",]
Al_df <- Al_df[Al_df$dpf == "6",]
#ensure correct order for levels
Al_df<-Al_df %>% mutate(lit = factor(lit, levels = c("DD", "LD", "LL")))
Al_df<-Al_df %>% mutate(rod = factor(rod, levels = c("BR", "PO", "ALA")))

print(paste0('There are ', dim(Al_df)[1], ' measures from ', length(unique(Al_df$larva)), ' individual l
```

```
## [1] "There are 604 measures from 130 individual larvae."
```

```r
meanL <- mean(Al_df$length)
sdL <- sd(Al_df$length)
```

```
Al_df$L  <- as.numeric(scale(Al_df$length))

Al_df <- droplevels(Al_df) # drop factor levels which are absent
head(Al_df)
```

```
## # A tibble: 6 x 16
##   larva side  rod   length ate   Food_conc Food_species fed     lit   condition
##   <fct> <fct> <fct>  <dbl> <fct>     <int> <fct>        <fct>   <fct> <fct>
## 1 Al42  R     PO     237.  NO            0 NO           Starved LD    FSW
## 2 Al42  L     BR      85.8 NO            0 NO           Starved LD    FSW
## 3 Al42  L     PO     233.  NO            0 NO           Starved LD    FSW
## 4 Al43  R     BR     101.  NO            0 NO           Starved LD    FSW
## 5 Al43  R     PO     227.  NO            0 NO           Starved LD    FSW
## 6 Al43  R     ALA    141.  NO            0 NO           Starved LD    FSW
## # i 6 more variables: larvae_per_well <int>, lar_ml <dbl>, hpf <int>,
## #   dpf <int>, species <fct>, L <dbl>
```

3. Load best model

```
dir.create("model_objects", showWarnings = FALSE)

url <- "https://github.com/MariaCoc/Urchin_phenotypic_plasticity/releases/download/v1.0.0/Al_rod_fed_li

local_file <- file.path("model_objects", "Al_rod_fed_lit_mod.rds")

if (!file.exists(local_file)) {
  download.file(url, local_file, mode = "wb")
}

Al_rod_fed_lit_mod <- readRDS('model_objects/Al_rod_fed_lit_mod.rds')
Al_rod_fed_lit_mod
```

```
##  Family: gaussian
##   Links: mu = identity; sigma = log
## Formula: L ~ rod * fed * lit + (1 | larva)
##          sigma ~ rod * fed * lit
##    Data: Al_df (Number of observations: 604)
##   Draws: 4 chains, each with iter = 2500; warmup = 1250; thin = 1;
##          total post-warmup draws = 5000
##
## Multilevel Hyperparameters:
## ~larva (Number of levels: 130)
##               Estimate Est.Error l-95% CI u-95% CI Rhat Bulk_ESS Tail_ESS
## sd(Intercept)     0.07      0.01     0.05     0.08 1.00     1214     1805
##
## Regression Coefficients:
##                         Estimate Est.Error l-95% CI u-95% CI Rhat
## Intercept                  -0.90      0.02    -0.94    -0.86 1.00
## sigma_Intercept            -2.14      0.11    -2.34    -1.93 1.00
## rodPO                       1.92      0.06     1.80     2.04 1.00
## rodALA                      0.37      0.04     0.29     0.44 1.00
## fedStarved                 -0.06      0.03    -0.12    -0.00 1.00
## litLD                       0.05      0.03    -0.01     0.10 1.00
```

```
## litLL                              -0.01    0.03   -0.07    0.04 1.00
## rodPO:fedStarved                    0.21    0.10    0.01    0.41 1.00
## rodALA:fedStarved                   0.17    0.06    0.04    0.29 1.00
## rodPO:litLD                        -0.29    0.08   -0.45   -0.12 1.00
## rodALA:litLD                       -0.07    0.09   -0.24    0.09 1.00
## rodPO:litLL                         0.04    0.10   -0.15    0.24 1.00
## rodALA:litLL                       -0.07    0.05   -0.18    0.03 1.00
## fedStarved:litLD                   -0.03    0.04   -0.11    0.06 1.00
## fedStarved:litLL                    0.01    0.04   -0.07    0.10 1.00
## rodPO:fedStarved:litLD              0.40    0.13    0.15    0.67 1.00
## rodALA:fedStarved:litLD             0.39    0.11    0.18    0.60 1.00
## rodPO:fedStarved:litLL              0.11    0.20   -0.27    0.52 1.00
## rodALA:fedStarved:litLL             0.36    0.15    0.07    0.66 1.00
## sigma_rodPO                         1.26    0.14    0.98    1.54 1.00
## sigma_rodALA                        0.51    0.17    0.19    0.86 1.00
## sigma_fedStarved                   -0.36    0.17   -0.69   -0.02 1.00
## sigma_litLD                        -0.32    0.18   -0.66    0.04 1.00
## sigma_litLL                        -0.22    0.16   -0.54    0.11 1.00
## sigma_rodPO:fedStarved              0.58    0.22    0.15    1.00 1.00
## sigma_rodALA:fedStarved             0.23    0.29   -0.33    0.79 1.00
## sigma_rodPO:litLD                   0.18    0.23   -0.27    0.62 1.00
## sigma_rodALA:litLD                  0.78    0.27    0.25    1.31 1.00
## sigma_rodPO:litLL                   0.46    0.21    0.05    0.87 1.00
## sigma_rodALA:litLL                 -0.13    0.29   -0.71    0.43 1.00
## sigma_fedStarved:litLD              0.48    0.25   -0.00    0.97 1.00
## sigma_fedStarved:litLL              0.43    0.26   -0.09    0.95 1.00
## sigma_rodPO:fedStarved:litLD       -0.64    0.32   -1.28   -0.02 1.00
## sigma_rodALA:fedStarved:litLD      -1.50    0.46   -2.42   -0.57 1.00
## sigma_rodPO:fedStarved:litLL       -0.29    0.33   -0.94    0.35 1.00
## sigma_rodALA:fedStarved:litLL       0.96    0.42    0.19    1.79 1.00
##                                  Bulk_ESS Tail_ESS
## Intercept                           1589     2940
## sigma_Intercept                     1619     3043
## rodPO                               2259     2668
## rodALA                              2380     3184
## fedStarved                          1498     2012
## litLD                               1680     2970
## litLL                               1735     3073
## rodPO:fedStarved                    2383     3286
## rodALA:fedStarved                   2566     3174
## rodPO:litLD                         2657     3300
## rodALA:litLD                        2802     3428
## rodPO:litLL                         3329     3652
## rodALA:litLL                        2641     3273
## fedStarved:litLD                    1799     2906
## fedStarved:litLL                    1748     2834
## rodPO:fedStarved:litLD              2445     3594
## rodALA:fedStarved:litLD             2648     3276
## rodPO:fedStarved:litLL              3484     3574
## rodALA:fedStarved:litLL             3741     4101
## sigma_rodPO                         1777     3042
## sigma_rodALA                        1882     3102
## sigma_fedStarved                    1519     2859
## sigma_litLD                         1401     2183
```

```
## sigma_litLL                             1536    2734
## sigma_rodPO:fedStarved                  1688    2975
## sigma_rodALA:fedStarved                 1995    3095
## sigma_rodPO:litLD                       1678    2768
## sigma_rodALA:litLD                      1815    2747
## sigma_rodPO:litLL                       1691    3192
## sigma_rodALA:litLL                      1811    2699
## sigma_fedStarved:litLD                  1338    2569
## sigma_fedStarved:litLL                  1679    2854
## sigma_rodPO:fedStarved:litLD            1697    2863
## sigma_rodALA:fedStarved:litLD           2163    3111
## sigma_rodPO:fedStarved:litLL            1813    2836
## sigma_rodALA:fedStarved:litLL           2023    3248
##
## Draws were sampled using sampling(NUTS). For each parameter, Bulk_ESS
## and Tail_ESS are effective sample size measures, and Rhat is the potential
## scale reduction factor on split chains (at convergence, Rhat = 1).
```

4. Marginaleffects plot with avg_predictions

```r
preds_df <- marginaleffects::avg_predictions(Al_rod_fed_lit_mod,
                newdata = datagrid(fed = unique(Al_df$fed),
                            lit = unique(Al_df$lit),
                            rod = unique(Al_df$rod)
                            ),
                by = c("lit","fed","rod"),
                transform = unscale_outcome,
                re_formula = NA
                )

preds_df
```

```
##
## lit     fed rod Estimate 2.5 % 97.5 %
##   DD Fed     BR      95.3  93.1   97.4
##   DD Fed     PO     201.6 195.0  208.2
##   DD Fed     ALA    115.5 111.6  119.5
##   DD Starved BR      92.0  89.8   94.0
##   DD Starved PO     209.8 200.6  219.0
##   DD Starved ALA    121.4 115.6  127.1
##   LD Fed     BR      98.0  95.9  100.1
##   LD Fed     PO     188.4 182.1  194.6
##   LD Fed     ALA    114.1 105.7  122.6
##   LD Starved BR      93.1  90.7   95.7
##   LD Starved PO     217.2 210.4  224.3
##   LD Starved ALA    139.9 135.5  144.6
##   LL Fed     BR      94.5  92.4   96.6
##   LL Fed     PO     203.1 194.5  211.6
##   LL Fed     ALA    110.7 106.8  114.8
##   LL Starved BR      91.9  89.1   94.8
##   LL Starved PO     218.4 202.6  234.4
##   LL Starved ALA    137.2 123.3  151.8
##
```

```
## Type:  response
## Columns: rowid, lit, fed, rod, estimate, conf.low, conf.high, larva, rowid_dedup
```

We plot model predictions of the mean alongside the original data. The scaling and centering in the model has been reversed to show the predictions in the original scale.

```r
ggplot() +
  # Add original data points
  geom_jitter(data = Al_df, aes(x = rod, y = length, color = fed),
              position = position_jitterdodge(jitter.width = 0.25, dodge.width = 0.5),
              size = 1, alpha = 0.4) +
  scale_colour_manual(values = c("#00BBC1", "#F86D63"), name = "Individual measures") +

  # Add the avg_predictions and error bars (95% CI)
  geom_point(data = preds_df, aes(x = rod, y = estimate, fill = fed),  # Use "response" column
             size = 2, position = position_dodge(width = 0.5)) +
  geom_errorbar(data = preds_df, aes(x = rod, ymin = conf.low, ymax = conf.high, fill = fed),
                width = 0.2, size = 0.7, position = position_dodge(width = 0.5)) + #, position = positi
  scale_fill_manual(values = c("black", "black"), name = "avg_predictions") +

  # Facet by specific variables of interest
  facet_grid(~lit) +

  # Customize plot
  labs(title = "Average predictions for fed, conditioned on lit and rod",
       y = "Length in um", x = "Skeletal rod") +
  theme_bw() +
  theme(axis.text = element_text(size = 11),
        axis.title = element_text(size = 13),
        legend.title = element_text(size = 13),
        strip.text = element_text(size = 13),
        plot.title = element_text(size = 17, face = "bold"))
```

```
## Warning: Using `size` aesthetic for lines was deprecated in ggplot2 3.4.0.
## i Please use `linewidth` instead.
## This warning is displayed once every 8 hours.
## Call `lifecycle::last_lifecycle_warnings()` to see where this warning was
## generated.
```

```
## Warning in geom_errorbar(data = preds_df, aes(x = rod, ymin = conf.low, :
## Ignoring unknown aesthetics: fill
```

Average predictions for fed, conditioned on lit and rod
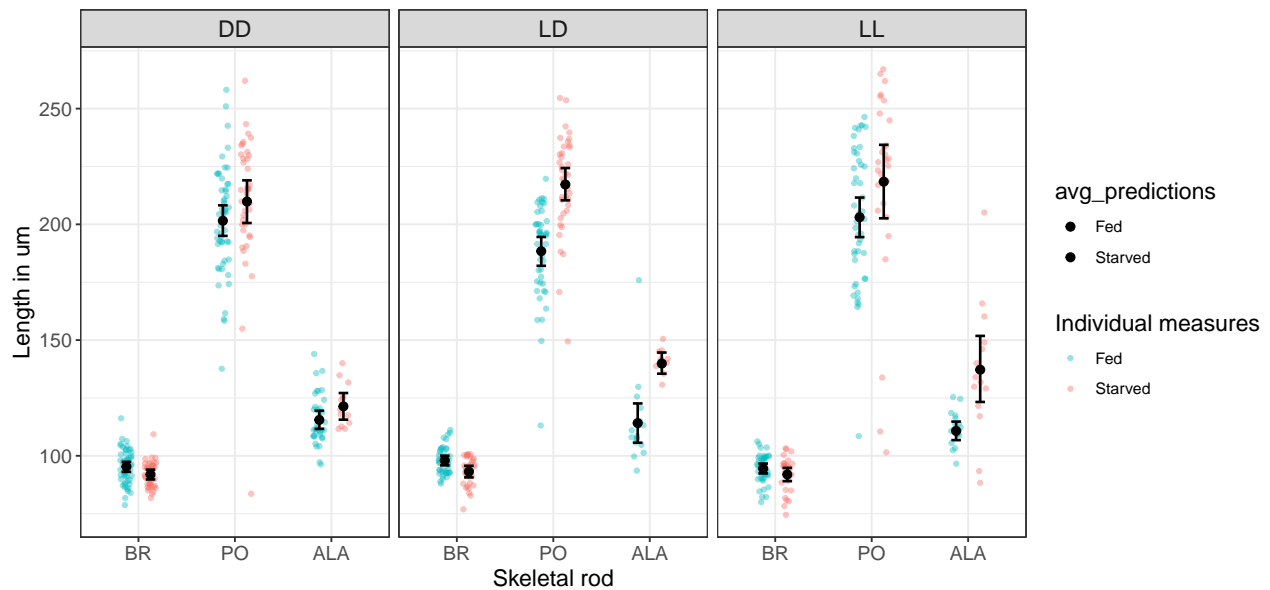

```r
ggplot() +
  # Add original data points with jittering
  geom_jitter(data = Al_df, aes(x = rod, y = length, color = lit),
              position = position_jitterdodge(jitter.width = 0.25, dodge.width = 0.5),
              size = 1, alpha = 0.6) +
  scale_colour_manual(values = c("#7473d1", "#f5b905","#d62222"), name= "Individual measures") +

  # Add the avg_predictions and error bars (95% CI)
  geom_point(data = preds_df, aes(x = rod, y = estimate, fill = lit),
             size = 2, position = position_dodge(width = 0.5)) +
  geom_errorbar(data = preds_df, aes(x = rod, ymin = conf.low, ymax = conf.high, fill=lit),
                width = 0.2, size = 0.7, position = position_dodge(width = 0.5)) +
  scale_fill_manual(values = c("black", "black", "black"), name="avg_predictions") +

  # Facet by specific variables of interest
  facet_grid(~ fed) +

  # Customize plot
  labs(title = "Average predictions for lit, conditioned on lit and rod",
       y = "Length um", x = "rod") +
  theme_bw() +
  theme(axis.text = element_text(size = 11),
        axis.title = element_text(size = 13),
        legend.title = element_text(size = 13),
        strip.text = element_text(size = 13),
        plot.title = element_text(size = 17, face = "bold"))
```

```
## Warning in geom_errorbar(data = preds_df, aes(x = rod, ymin = conf.low, :
## Ignoring unknown aesthetics: fill
```

Average predictions for lit, conditioned on lit and rod