Supplementary Material II

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Colony Size

```r
poci_size <- read.csv('coral_size.csv')
```

```r
poci_size.gg <- read_csv("poci_size_main.csv")
```

```
Rows: 3639 Columns: 10
-- Column specification ----------------------------------------------------------
Delimiter: ","
chr (3): level, Site, cover
dbl (7): layer, class, id, area, enn, para, size_cm

i Use `spec()` to retrieve the full column specification for this data.
i Specify the column types or set `show_col_types = FALSE` to quiet this message.
```
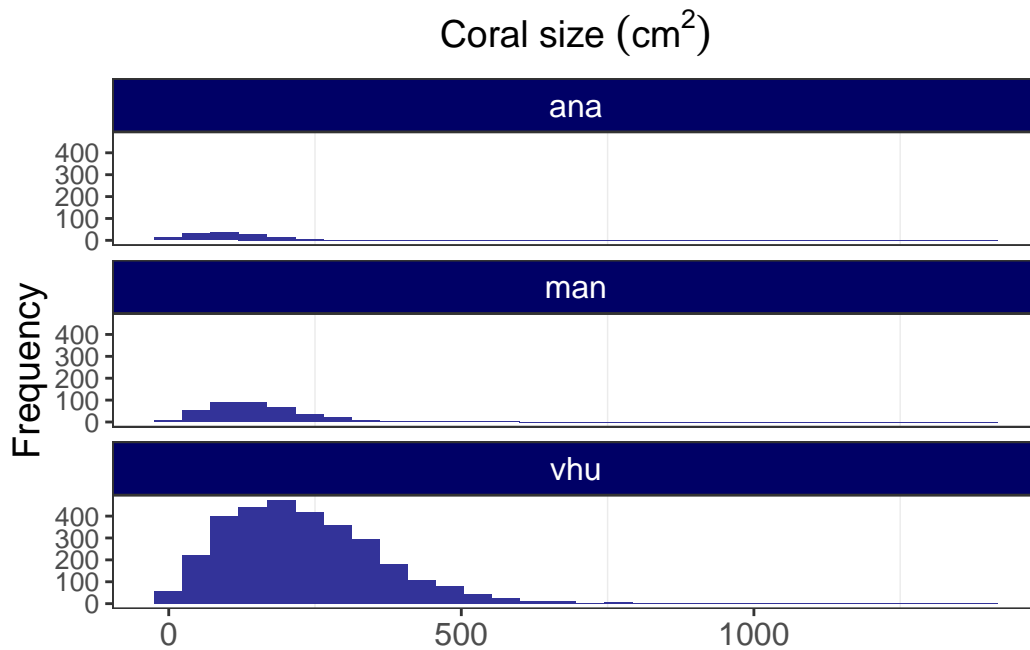
```r
ggplot(poci_size.gg, aes(x = size_cm)) +
  geom_histogram(fill = "#333399") +
  #below here is ylabel, xlabel, and main title
  ylab("Frequency") +
  xlab(NULL) +
  ggtitle(expression("Coral size " (cm**2))) +
  theme_bw() +
  facet_wrap(~ Site, ncol = 1) +
  #theme sets sizes, text, etc
  theme(axis.title.x = element_text(size = 14),
        axis.title.y = element_text(size = 14),
        axis.text.y  = element_text(size= 10),
        axis.text.x  = element_text(size = 12),
```

```
        legend.text = element_text(size = 12),
        legend.title = element_text(size = 12),
        plot.title = element_text(hjust = 0.5, size = 14),
        # change plot background, grid lines, etc (just examples so you can see)
        panel.background = element_rect(fill = "white"),
        panel.grid.minor.y = element_blank(),
        panel.grid.major = element_blank(),
        plot.background = element_rect(fill = "white"),
        legend.background = element_rect(fill = "white"),
        strip.text.x = element_text(size = 12, colour = "#FFFFFF"),
        strip.background = element_rect(fill = '#000066')
  )
```

`stat_bin()` using `bins = 30`. Pick better value with `binwidth`.

Coral size (cm^2)

```
poci_size2 <-
poci_size %>%
  as_tibble() %>%
  mutate(size_cm = area*10000) %>%
  group_by(Site) %>%
```

```
  dplyr::summarize(mean = mean(size_cm),
                  sd = sd(size_cm),
                  n = n(),
                  se = sd/sqrt(n)
  ) %>%
  mutate(se = sd / sqrt(n),
         lower.ci = mean - qt(1 - (0.05 / 2), n - 1) * se,
         upper.ci = mean + qt(1 - (0.05 / 2), n - 1) * se) %>%
  mutate_at(vars(Site), factor) %>%
  add_column(
         location = c('Anakena', 'Manavai', 'Southeast')
         ) %>%
  mutate_at(vars(location), factor)

poci_size2
```

```
# A tibble: 3 x 8
  Site   mean    sd     n    se lower.ci upper.ci location
  <fct> <dbl> <dbl> <int> <dbl>    <dbl>    <dbl> <fct>
1 ana    111.  73.8   136  6.33     98.2     123. Anakena
2 man    151.  82.7   372  4.29    142.      159. Manavai
3 vhu    231. 137.   3131  2.44    227.      236. Southeast
```

```
poci_size.gg <-
  poci_size %>%
  mutate(size_cm = area*10000) %>%
  as_tibble() %>%
  mutate_at(vars(Site), factor)

poci_size.gg
```

```
# A tibble: 3,639 x 10
  layer level class    id Site  cover      area     enn  para size_cm
  <int> <chr> <int> <int> <fct> <chr>     <dbl>   <dbl> <dbl>   <dbl>
1     1 patch     1     2 ana   coral 0.0165   0.111    42.0    165.
2     1 patch     1     3 ana   coral 0.0261   0.111    32.1    261.
3     1 patch     1     4 ana   coral 0.0162   0.0598   44.3    162.
4     1 patch     1     5 ana   coral 0.0149   0.230    38.6    149.
5     1 patch     1     6 ana   coral 0.00788  0.535    61.5     78.8
6     1 patch     1     7 ana   coral 0.0148   0.532    41.1    148.
```

```
7     1 patch     1     8 ana    coral 0.0109  0.0598  50.6   109.
8     1 patch     1     9 ana    coral 0.0101  0.346   52.6   101.
9     1 patch     1    10 ana    coral 0.0262  0.192   38.4   262.
10    1 patch     1    11 ana    coral 0.00620 0.137   71.6    62.0
# i 3,629 more rows
```

```
model_1.lm <- lm(size_cm ~ Site, data = poci_size.gg)
```

```
model_1.lm
```

```
Call:
lm(formula = size_cm ~ Site, data = poci_size.gg)

Coefficients:
(Intercept)        Siteman        Sitevhu
     110.67          40.18         120.81
```

```
summary(model_1.lm)
```

```
Call:
lm(formula = size_cm ~ Site, data = poci_size.gg)

Residuals:
    Min      1Q  Median      3Q      Max
-231.46  -91.09  -16.44   70.33 1160.47

Coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept)   110.67      11.18   9.896  < 2e-16 ***
Siteman        40.18      13.07   3.074  0.00212 **
Sitevhu       120.81      11.42  10.575  < 2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 130.4 on 3636 degrees of freedom
Multiple R-squared:  0.05804,   Adjusted R-squared:  0.05752
F-statistic:   112 on 2 and 3636 DF,  p-value: < 2.2e-16
```
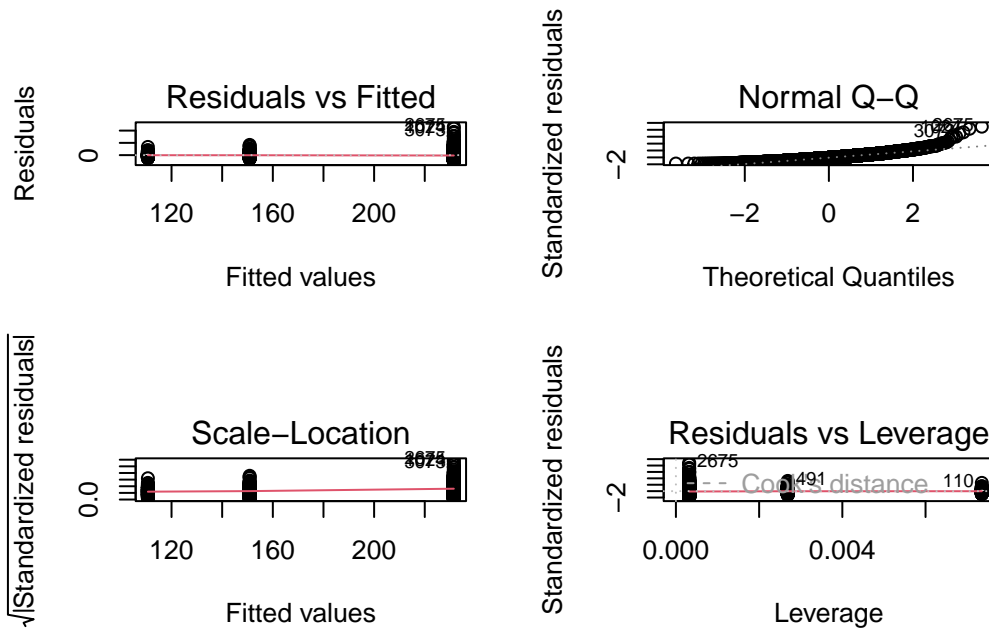
```r
par(mfrow = c(2, 2))
plot(model_1.lm)
```



```r
Anova(model_1.lm, type = "III")
```

```
Anova Table (Type III tests)

Response: size_cm
             Sum Sq   Df F value    Pr(>F)
(Intercept)  1665764    1  97.933 < 2.2e-16 ***
Site         3810826    2 112.022 < 2.2e-16 ***
Residuals   61845547 3636
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```r
model_1.aov <- Anova(model_1.lm, type = "III")
```

```r
as.data.frame(model_1.aov)
```

```
             Sum Sq  Df  F value      Pr(>F)
(Intercept)  1665764   1  97.93297 8.382392e-23
Site         3810826   2 112.02231 6.156818e-48
Residuals   61845547 3636      NA          NA
```

```
flextable(model_1.aov)
```

Warning in raw_block(x, "latex", ...): raw_block() requires Pandoc >= 2.0.0

Sum Sq	Df	F value	Pr(>F)
1,665,764	1	97.932970.0000000000000000000000083823920979013643663544!
3,810,826	2	112.022310.00000000000000000000000000000000000000000000000
61,845,547	3,636		

```
post_hoc.model_1.lm <- glht(model_1.lm, linfct = mcp(Site = 'Tukey'))
```

```
model_1.aov <- aov(size_cm ~ Site, data = poci_size.gg)
```

```
# Tukey's test
tukey <- TukeyHSD(model_1.aov)
```

```
# compact letter display
cld <- multcompLetters4(model_1.aov, tukey)
```

```
cld
```

```
$Site
vhu man ana
"a" "b" "c"
```

```
poci_size3 <-
poci_size2 %>%
  add_column(
        cld = c('a', 'b', 'c')
        ) %>%
```

```
  mutate_at(vars(cld), factor)

  poci_size3
```

```
# A tibble: 3 x 9
  Site   mean    sd     n    se lower.ci upper.ci location  cld
  <fct> <dbl> <dbl> <int> <dbl>    <dbl>    <dbl> <fct>     <fct>
1 ana    111.  73.8   136  6.33     98.2     123. Anakena   a
2 man    151.  82.7   372  4.29    142.      159. Manavai   b
3 vhu    231. 137.   3131  2.44    227.      236. Southeast c
```

Percent Cover

From **Damgaard & Irvine (2019)** Using the beta distribution to analyse plant cover data *Journal of Ecology. 107:2747-2759*

```
  p_cover = read_csv('rpn_percent_cover.csv') %>%
    group_by(Site) %>%
    mutate(
      pland_decimal = pland*0.01
    ) %>%
    mutate_at(vars(Site, cover, plot_id), factor)
```

```
Rows: 750 Columns: 12
-- Column specification -----------------------------------------------------
Delimiter: ","
chr (3): Site, cover, level
dbl (7): plot_id, class, layer, percentage_inside, clumpy, pd, pland
lgl (2): id, NA

i Use `spec()` to retrieve the full column specification for this data.
i Specify the column types or set `show_col_types = FALSE` to quiet this message.
```

```
  p_cover
```

```
# A tibble: 750 x 13
# Groups:   Site [3]
   plot_id class Site  cover level layer id    percentage_inside clumpy    pd
```

```
      <fct>     <dbl> <fct> <fct> <chr> <dbl> <lgl>              <dbl>  <dbl> <dbl>
 1 1            1 ana   coral class     1 NA                 100.   0.992  2.00
 2 1            0 man   coral class    NA NA                  NA    NA     NA
 3 1            0 vhu   coral class     1 NA                 100.   0.987 19.0
 4 2            1 ana   coral class     1 NA                  99.9  0.990  8.01
 5 2            0 man   coral class    NA NA                  NA    NA     NA
 6 2            0 vhu   coral class     1 NA                  99.9  0.987 20.0
 7 3            1 ana   coral class     1 NA                 100.   0.995  4.00
 8 3            0 man   coral class    NA NA                  NA    NA     NA
 9 3            0 vhu   coral class     1 NA                 100.   0.989 16.0
10 4            1 ana   coral class     1 NA                 100.   0.995  3.00
# i 740 more rows
# i 3 more variables: pland <dbl>, `NA` <lgl>, pland_decimal <dbl>
```

```
head(p_cover)
```

```
# A tibble: 6 x 13
# Groups:   Site [3]
  plot_id class Site  cover level layer id    percentage_inside clumpy    pd
  <fct>     <dbl> <fct> <fct> <chr> <dbl> <lgl>             <dbl>  <dbl> <dbl>
1 1            1 ana   coral class     1 NA                100.   0.992  2.00
2 1            0 man   coral class    NA NA                 NA    NA     NA
3 1            0 vhu   coral class     1 NA                100.   0.987 19.0
4 2            1 ana   coral class     1 NA                 99.9  0.990  8.01
5 2            0 man   coral class    NA NA                 NA    NA     NA
6 2            0 vhu   coral class     1 NA                 99.9  0.987 20.0
# i 3 more variables: pland <dbl>, `NA` <lgl>, pland_decimal <dbl>
```

```r
ggplot(p_cover, aes(x = pland_decimal)) +
  geom_histogram(fill = "#333399") +
  #below here is ylabel, xlabel, and main title
  ylab("Frequency") +
  xlab(NULL) +
  ggtitle(expression("Coral Cover (%)")) +
  theme_bw() +
  facet_wrap(~ Site, ncol = 1) +
  #theme sets sizes, text, etc
  theme(axis.title.x = element_text(size = 14),
        axis.title.y = element_text(size = 14),
        axis.text.y  = element_text(size= 10),
```
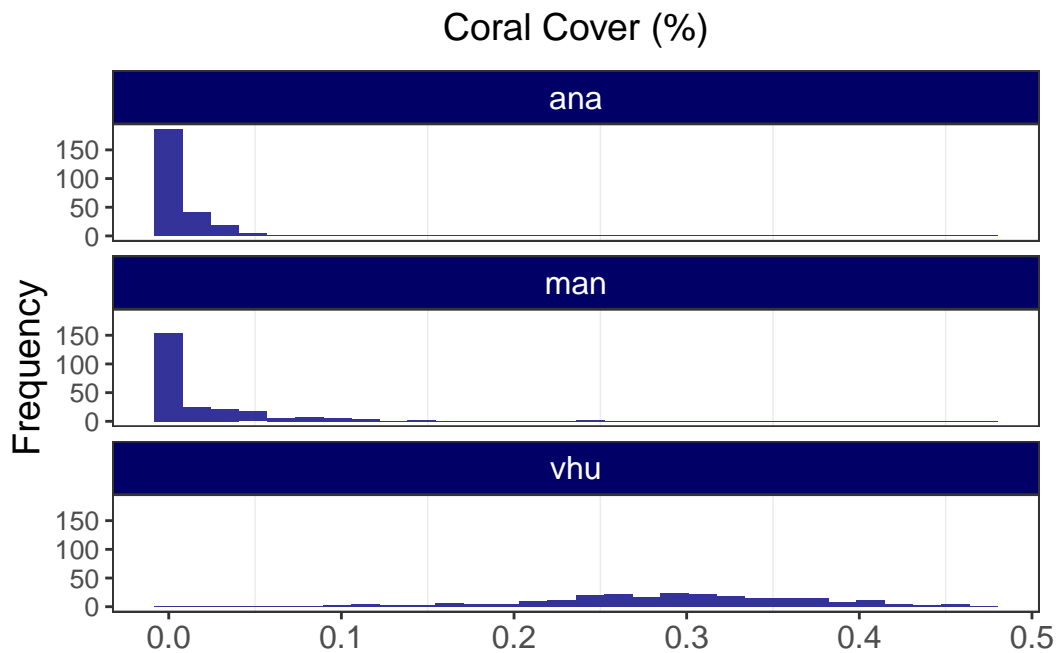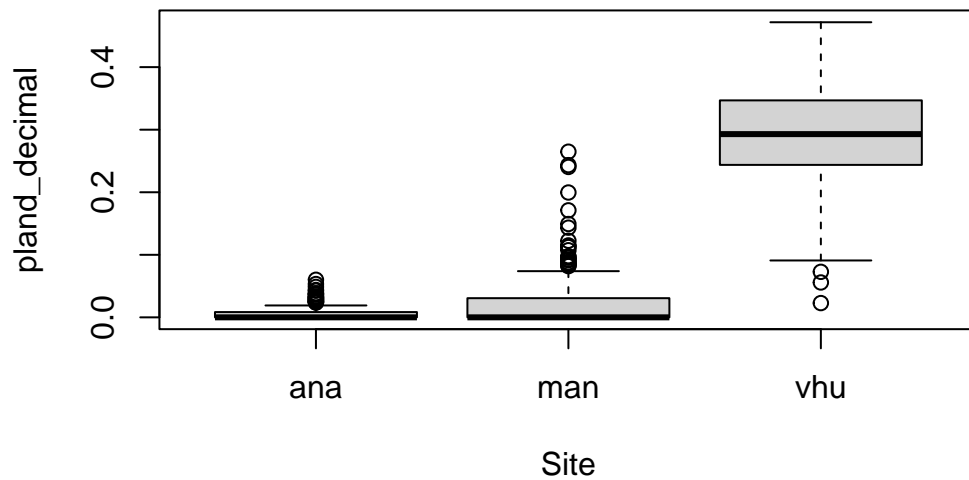
```
        axis.text.x   = element_text(size = 12),
        legend.text = element_text(size = 12),
        legend.title = element_text(size = 12),
        plot.title = element_text(hjust = 0.5, size = 14),
        # change plot background, grid lines, etc (just examples so you can see)
        panel.background = element_rect(fill = "white"),
        panel.grid.minor.y = element_blank(),
        panel.grid.major = element_blank(),
        plot.background = element_rect(fill = "white"),
        legend.background = element_rect(fill = "white"),
        strip.text.x = element_text(size = 12, colour = "#FFFFFF"),
        strip.background = element_rect(fill = '#000066')
    )
```

`stat_bin()` using `bins = 30`. Pick better value with `binwidth`.

Coral Cover (%)

```
plot(pland_decimal ~ Site, data = p_cover)
```

```
p_cover.mean <-
  p_cover %>%
  group_by(Site) %>%
  dplyr::summarise(mean = mean(pland_decimal))

p_cover.mean
```

```
# A tibble: 3 x 2
  Site      mean
  <fct>    <dbl>
1 ana    0.00602
2 man    0.0224
3 vhu    0.290
```

Methods for analyzing percent cover of pocilloporid coral

One option for dealing with the 0 and 1 values is to transform them to be slightly less than one or more than zero. This approach assumes that the data are consistent with a common beta distribution. We fit five models to the data: three variations on the beta model and two linear model approaches.

A beta regression assuming a common spatial aggregation δ or precision parameter (ϕ) (object named: mod.beta1). Notice that $\delta = \frac{1}{1+\phi}$ and $\phi = \frac{(1-\delta)}{\delta}$. A beta regression assuming each reef location had a different ϕ parameter.

Other options based on assuming that the residuals are normally distributed is to use a linear model with a logit-transformed response or a linear model with response untransformed proportions.

For comparison this applies a logit-transformation to the empirical proportions and then uses a standard linear regression model.

Raw data - no transformation

```
p_cover_mod.aov1 <- aov(pland_decimal ~ Site, data = p_cover)
summary(p_cover_mod.aov1)
```

```
            Df Sum Sq Mean Sq F value Pr(>F)
Site         2 12.699   6.350    2203 <2e-16 ***
Residuals  747  2.153   0.003
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
p_cover_mod.lm1 <- lm(pland_decimal ~ Site, data = p_cover)
summary(p_cover_mod.lm1)
```

```
Call:
lm(formula = pland_decimal ~ Site, data = p_cover)

Residuals:
     Min        1Q    Median        3Q       Max
-0.267087 -0.022444 -0.006021  0.015304  0.242376

Coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept) 0.006021   0.003395   1.773  0.07656 .
Siteman     0.016423   0.004802   3.420  0.00066 ***
Sitevhu     0.283878   0.004802  59.122  < 2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.05368 on 747 degrees of freedom
```
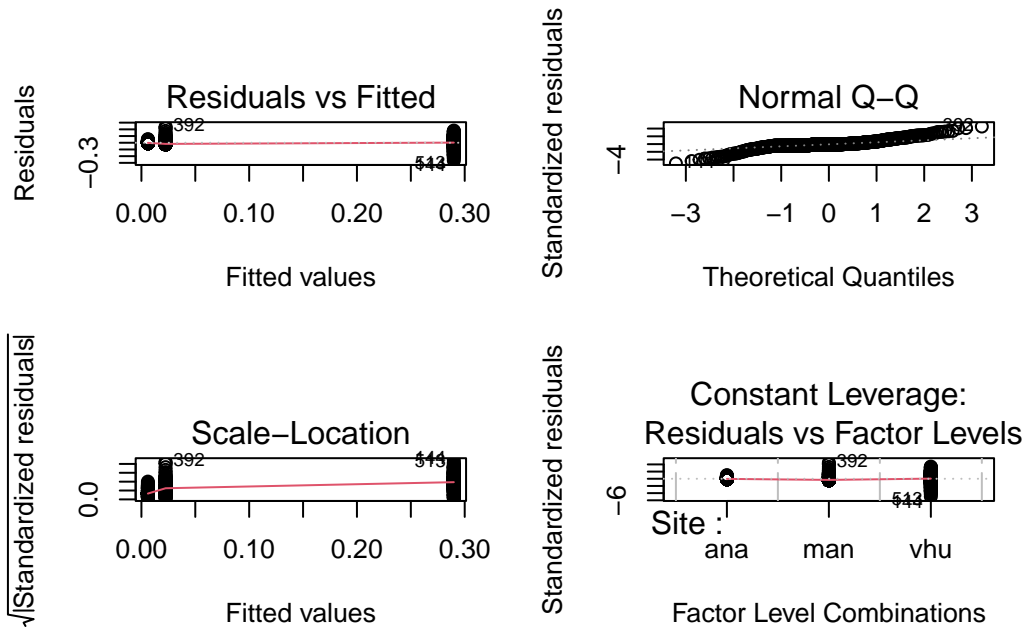
```
Multiple R-squared:  0.8551,    Adjusted R-squared:  0.8547
F-statistic:  2203 on 2 and 747 DF,  p-value: < 2.2e-16
```

```
par(mfrow = c(2, 2))
plot(p_cover_mod.lm1)
```



```
Anova(p_cover_mod.lm1, type = "III")
```

```
Anova Table (Type III tests)

Response: pland_decimal
            Sum Sq  Df   F value   Pr(>F)
(Intercept)  0.0091   1    3.1451  0.07656 .
Site        12.6991   2 2203.2548  < 2e-16 ***
Residuals    2.1528 747
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

One option to deal with 0 and 100 percent cover is to add and subtract a small amount to those values

```r
transform01 <- function(x) {
  (x * (length(x) - 1) + 0.5) / (length(x))
}

p_cover$pland_decimal_scaled <- transform01(p_cover$pland_decimal)
```

Logit-transformation

```r
p_cover_mod.lm2 <- lm(logit(pland_decimal_scaled) ~ Site, data = p_cover)

summary(p_cover_mod.lm2)
```

```
Call:
lm(formula = logit(pland_decimal_scaled) ~ Site, data = p_cover)

Residuals:
    Min      1Q  Median      3Q     Max
-2.7875 -1.0925 -0.1617  0.7543  4.5854

Coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept) -6.22005    0.09621 -64.654  < 2e-16 ***
Siteman      0.61521    0.13606   4.522 7.13e-06 ***
Sitevhu      5.27828    0.13606  38.795  < 2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 1.521 on 747 degrees of freedom
Multiple R-squared:  0.7067,    Adjusted R-squared:  0.7059
F-statistic: 900.1 on 2 and 747 DF,  p-value: < 2.2e-16
```
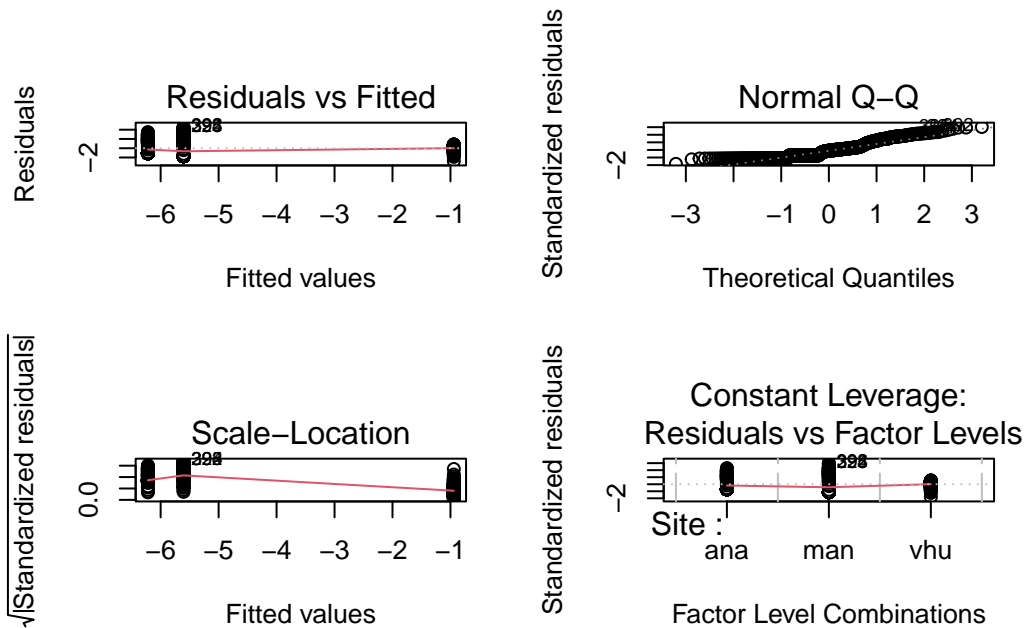
```r
par(mfrow = c(2, 2))
plot(p_cover_mod.lm2)
```

```
Anova(p_cover_mod.lm2, type = "III")
```

```
Anova Table (Type III tests)

Response: logit(pland_decimal_scaled)
            Sum Sq  Df F value     Pr(>F)
(Intercept) 9672.3   1 4180.11 < 2.2e-16 ***
Site        4165.2   2  900.06 < 2.2e-16 ***
Residuals   1728.5 747
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Generalized-linear model

```
p_cover_mod.glm1 <- glm(pland_decimal ~ Site, family = binomial, data = p_cover)
```

```
Warning in eval(family$initialize): non-integer #successes in a binomial glm!
```

```
summary(p_cover_mod.glm1)
```

```
Call:
glm(formula = pland_decimal ~ Site, family = binomial, data = p_cover)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-0.71274  -0.15856  -0.10518   0.07292   0.94245

Coefficients:
            Estimate Std. Error z value Pr(>|z|)
(Intercept)  -5.1064     0.8175  -6.246 4.21e-10 ***
Siteman       1.3324     0.9223   1.445    0.149
Sitevhu       4.2106     0.8293   5.077 3.83e-07 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for binomial family taken to be 1)

    Null deviance: 161.289  on 749  degrees of freedom
Residual deviance:  26.922  on 747  degrees of freedom
AIC: 191.54

Number of Fisher Scoring iterations: 8
```
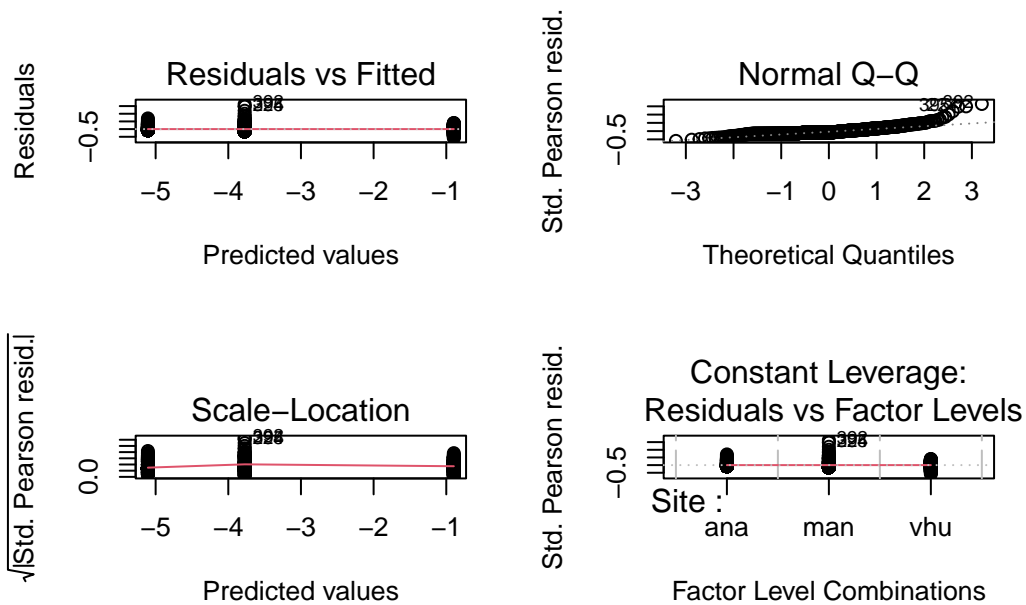
```
par(mfrow = c(2, 2))
plot(p_cover_mod.glm1)
```

```r
Anova(p_cover_mod.glm1, type = "III")
```

```
Warning in eval(family$initialize): non-integer #successes in a binomial glm!
```

```
Analysis of Deviance Table (Type III tests)

Response: pland_decimal
     LR Chisq Df Pr(>Chisq)
Site   134.37  2  < 2.2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Beta Regression I: ϕ does not vary

```r
p_cover_mod.beta1 <- betareg(pland_decimal_scaled ~ Site, data = p_cover, link = c("logit"
```

```r
summary(p_cover_mod.beta1)
```

```
Call:
```

```
betareg(formula = pland_decimal_scaled ~ Site, data = p_cover, link = c("logit"),
    link.phi = NULL, type = c("ML"))
```

Standardized weighted residuals 2:
```
    Min      1Q  Median      3Q     Max
-6.1915 -0.6623 -0.3219  0.6315  1.8412
```

Coefficients (mean model with logit link):
```
            Estimate Std. Error z value Pr(>|z|)
(Intercept) -4.28350    0.07391 -57.953   <2e-16 ***
Siteman      0.20537    0.08442   2.433    0.015 *
Sitevhu      3.38355    0.07733  43.754   <2e-16 ***
```

Phi coefficients (precision model with identity link):
```
       Estimate Std. Error z value Pr(>|z|)
(phi)    25.321      1.561   16.22   <2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
Type of estimator: ML (maximum likelihood)
Log-likelihood:  2094 on 4 Df
Pseudo R-squared: 0.7048
Number of iterations: 19 (BFGS) + 2 (Fisher scoring)
```

Beta Regression II: ϕ does vary (by **Site**)

```
p_cover_mod.beta2 <- betareg(pland_decimal_scaled ~ Site | Site, data = p_cover, link = c(
```

Extract AIC from beta regression models

```
p_cover_mod.beta1_aic <- AIC(p_cover_mod.beta1)
p_cover_mod.beta2_aic <- AIC(p_cover_mod.beta2)
```

```
p_cover_mod.beta1_aic
```

```
[1] -4179.365
```

```
p_cover_mod.beta2_aic
```

```
[1] -4259.399
```