

# Supplementary Material II

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## Colony Size

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

```
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.

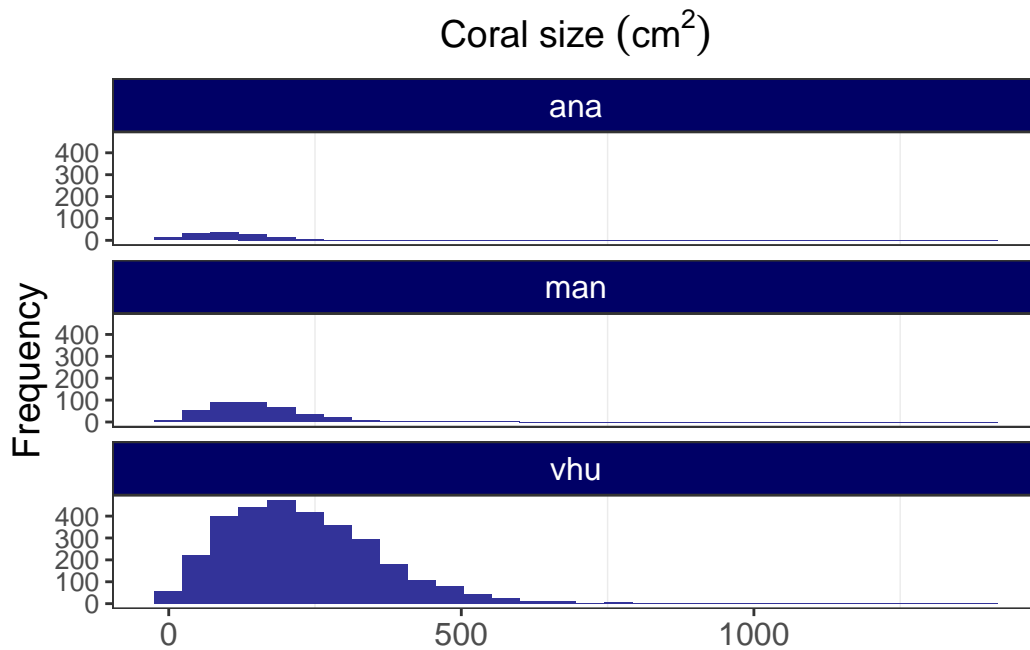
```
ggplot(poci_size.gg, aes(x = size_cm)) +  
  geom_histogram(fill = "#333399") +  
  #below here is ylabel, xlabel, and main title  
  ylab("Frequency") +  
  xlab(NULL) +  
  ggtitle(expression("Coral size " (cm**2))) +  
  theme_bw() +  
  facet_wrap(~ Site, ncol = 1) +  
  #theme sets sizes, text, 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`.



```

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 ***

---

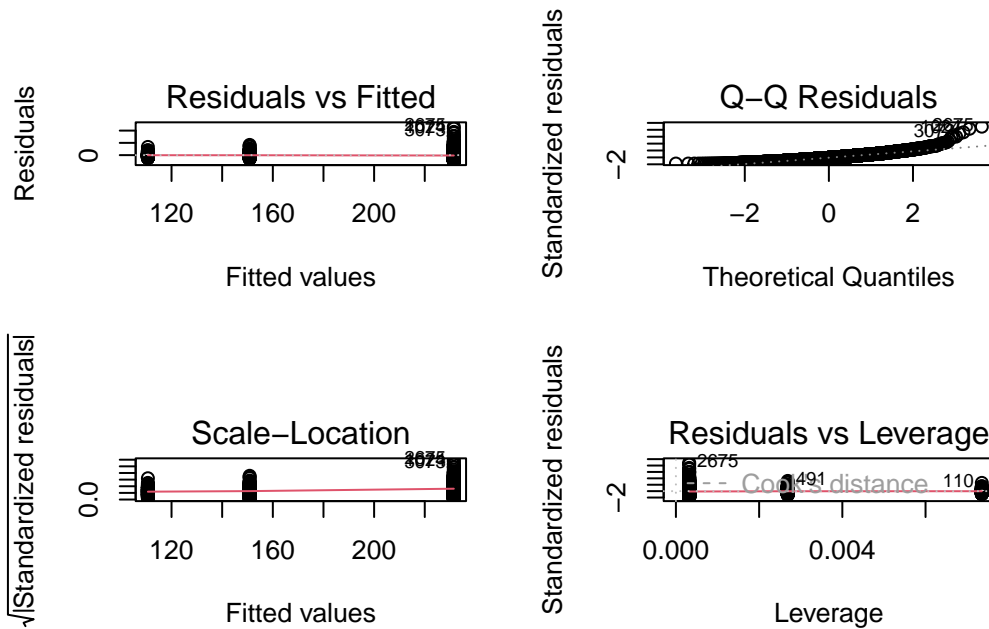
Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1

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

```
par(mfrow = c(2, 2))
plot(model_1.lm)
```



```
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

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

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

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

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

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

```
cld
```

```
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>

```

```

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),

```

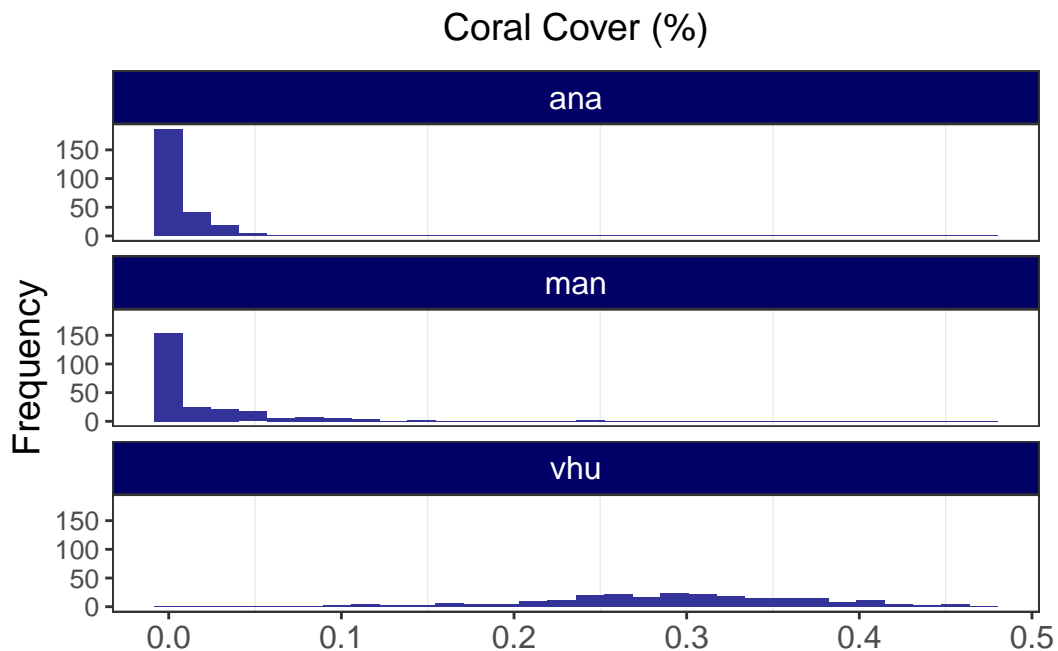


```

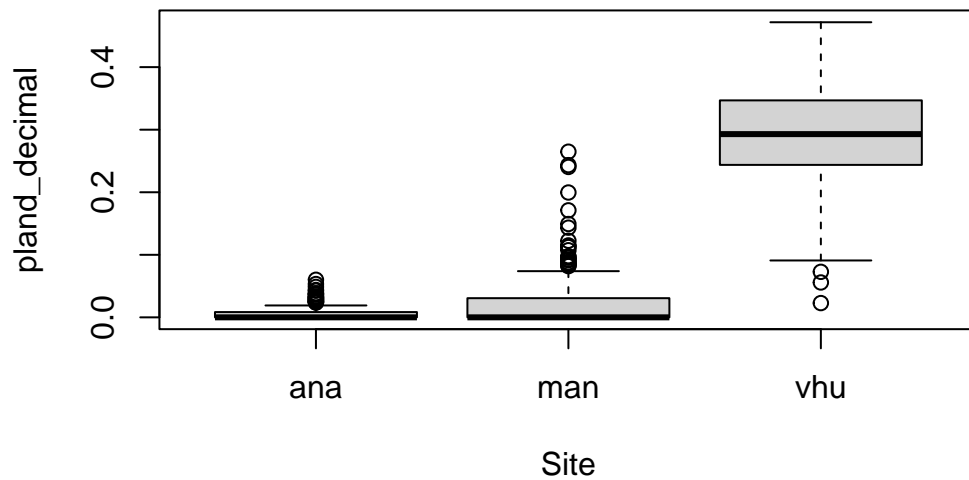
axis.text.x = element_text(size = 12),
legend.text = element_text(size = 12),
legend.title = element_text(size = 12),
plot.title = element_text(hjust = 0.5, size = 14),
# change plot background, grid lines, etc (just examples so you can see)
panel.background = element_rect(fill = "white"),
panel.grid.minor.y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



```
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  $\delta$  or precision parameter ( $\phi$ ) (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  $\phi$  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 ***
---

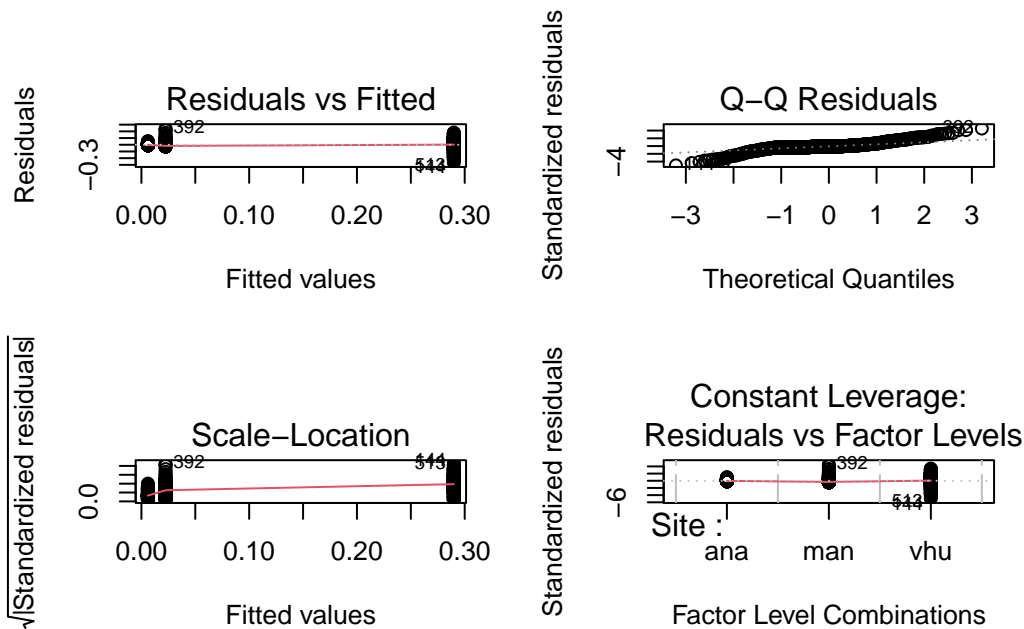
```

```
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

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

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

### Logit-transformation

```
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 ***

---

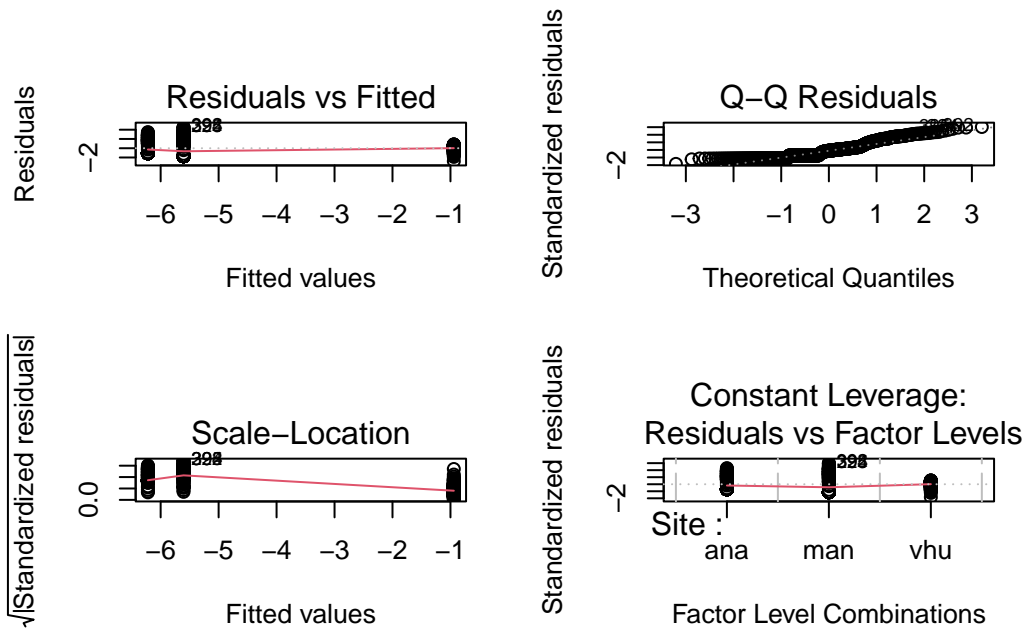
Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1

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

```
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)
```

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 ***

---

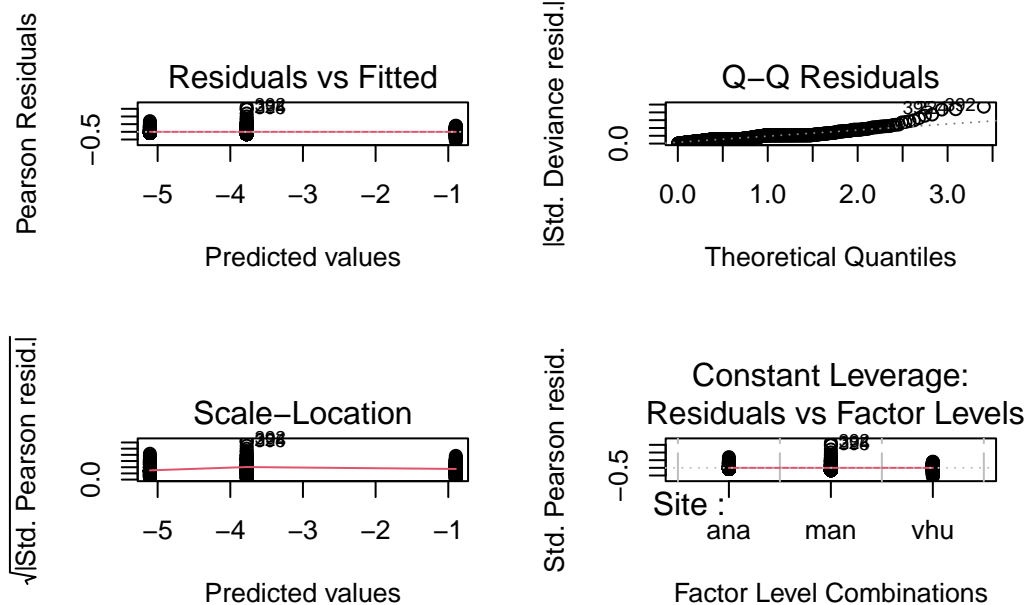
Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1

(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)
```



```
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:**  $\phi$  does not vary

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

```
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:**  $\phi$  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
```