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# 1. Versions

All analyses were conducted in R version 4.0.3 on a MacBook Air running macOS Catalina 10.15.7. Key statistical packages used are nlme 3.1-149 (Pinheiro et al. 2020) and emmeans 1.5.4 (Lenth 2021).

# 2. Energetic compensation GLS

Compensation is calculated as (SmallGranivoreEnergy\_Exclosures - SmallGranivoreEnergy\_Controls) / KangarooRatEnergy\_Controls for each census period.

Model formula:

smgran\_comp ~ era, correlation = corCAR1(form = ~ period)

**Significance of terms**

Following <https://stats.stackexchange.com/questions/13859/finding-overall-p-value-for-gls-model>, we compare a version of the model with no fixed effect to the above model. The two models are separated by 1 degree of freedom. Likelihood ratio 38.18461; p = 6.435788e-10.

**Contrasts**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| contrast | estimate | SE | df | t.ratio | p.value |
| a\_pre\_pb - b\_pre\_reorg | -0.3596238 | 0.0644233 | 60.44042 | -5.5822045 | 0.0000018 |
| a\_pre\_pb - c\_post\_reorg | -0.0296368 | 0.0691495 | 57.97849 | -0.4285901 | 0.9038819 |
| b\_pre\_reorg - c\_post\_reorg | 0.3299870 | 0.0650229 | 62.66119 | 5.0749352 | 0.0000110 |

**Estimates**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| era | emmean | SE | df | lower.CL | upper.CL |
| a\_pre\_pb | 0.1887873 | 0.0484923 | 56.08128 | 0.0916487 | 0.2859260 |
| b\_pre\_reorg | 0.5484112 | 0.0432238 | 60.40971 | 0.4619628 | 0.6348595 |
| c\_post\_reorg | 0.2184241 | 0.0493101 | 59.73403 | 0.1197802 | 0.3170680 |

# 

# 3. Total energy ratio GLS

The ratio of total energy use on exclosure plots relative to controls, calculated for each census period.

Model formula:

total\_e\_rat ~ era, correlation = corCAR1(form = ~ period)

**Significance of effects**

Compared to an autocorrelation + intercept model, likelihood ratio: 40.28898; p = 2.190414e-10.

**Contrasts**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| contrast | estimate | SE | df | t.ratio | p.value |
| a\_pre\_pb - b\_pre\_reorg | -0.3881293 | 0.0605211 | 40.83178 | -6.413128 | 0.0000003 |
| a\_pre\_pb - c\_post\_reorg | -0.1666183 | 0.0655510 | 37.48394 | -2.541812 | 0.0396518 |
| b\_pre\_reorg - c\_post\_reorg | 0.2215110 | 0.0608245 | 41.78673 | 3.641807 | 0.0020966 |

**Estimates**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| era | emmean | SE | df | lower.CL | upper.CL |
| a\_pre\_pb | 0.2955610 | 0.0461672 | 36.54729 | 0.2019781 | 0.3891438 |
| b\_pre\_reorg | 0.6836903 | 0.0407429 | 38.89409 | 0.6012729 | 0.7661077 |
| c\_post\_reorg | 0.4621793 | 0.0465896 | 38.01610 | 0.3678648 | 0.5564937 |

# 

# 4. Small granivore proportional energy use GLM

Energy use by small granivores as a proportion of treatment-level energy use in each census period.

Model formula:

smgran\_prop ~ oera \* oplottype, family = quasibinomial()

oera is the time period, and oplottype is treatment.

summary(smgran\_glm)

##   
## Call:  
## glm(formula = smgran\_prop ~ oera \* oplottype, family = quasibinomial(),   
## data = smgran\_dat)  
##   
## Deviance Residuals:   
## Min 1Q Median 3Q Max   
## -1.43532 -0.24132 0.08354 0.39955 1.04138   
##   
## Coefficients:  
## Estimate Std. Error t value Pr(>|t|)   
## (Intercept) 0.56734 0.05530 10.260 < 2e-16 \*\*\*  
## oera.L 0.60675 0.09777 6.206 9.47e-10 \*\*\*  
## oera.Q -0.45238 0.09375 -4.826 1.73e-06 \*\*\*  
## oplottype.L 2.78683 0.07820 35.636 < 2e-16 \*\*\*  
## oera.L:oplottype.L -0.69768 0.13827 -5.046 5.80e-07 \*\*\*  
## oera.Q:oplottype.L 0.18833 0.13258 1.421 0.156   
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## (Dispersion parameter for quasibinomial family taken to be 0.1838797)  
##   
## Null deviance: 537.12 on 682 degrees of freedom  
## Residual deviance: 121.81 on 677 degrees of freedom  
## (1 observation deleted due to missingness)  
## AIC: NA  
##   
## Number of Fisher Scoring iterations: 5

Contrasts

smgran\_emmeans <- (emmeans(smgran\_glm, specs = ~ oera | oplottype))  
  
smgran\_contrasts <- as.data.frame(pairs(smgran\_emmeans))  
smgran\_contrasts

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| contrast | oplottype | estimate | SE | df | z.ratio | p.value |
| a\_pre\_pb - b\_pre\_reorg | CC | -1.4950249 | 0.1690498 | Inf | -8.8436974 | 0.0000000 |
| a\_pre\_pb - c\_post\_reorg | CC | -1.5557527 | 0.1741513 | Inf | -8.9333383 | 0.0000000 |
| b\_pre\_reorg - c\_post\_reorg | CC | -0.0607279 | 0.1260275 | Inf | -0.4818620 | 0.8798965 |
| a\_pre\_pb - b\_pre\_reorg | EE | -0.4711439 | 0.2155610 | Inf | -2.1856643 | 0.0736226 |
| a\_pre\_pb - c\_post\_reorg | EE | -0.1603938 | 0.2148034 | Inf | -0.7467004 | 0.7356211 |
| b\_pre\_reorg - c\_post\_reorg | EE | 0.3107501 | 0.2297173 | Inf | 1.3527498 | 0.3660145 |

Estimates

Estimates from emmeans differ numerically (in the far decimals) from estimates obtained via predict() and back transformation. Below are estimates from emmeans, because those are what are used for contrasts. Estimates given on the response (not link) scale.

smgran\_estimates <- as.data.frame(regrid(smgran\_emmeans))  
  
smgran\_estimates

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| oera | oplottype | prob | SE | df | asymp.LCL | asymp.UCL |
| a\_pre\_pb | CC | 0.0816472 | 0.0109974 | Inf | 0.0600928 | 0.1032017 |
| b\_pre\_reorg | CC | 0.2839099 | 0.0170898 | Inf | 0.2504146 | 0.3174052 |
| c\_post\_reorg | CC | 0.2964165 | 0.0195829 | Inf | 0.2580348 | 0.3347982 |
| a\_pre\_pb | EE | 0.9111217 | 0.0114288 | Inf | 0.8887217 | 0.9335218 |
| b\_pre\_reorg | EE | 0.9425976 | 0.0088160 | Inf | 0.9253185 | 0.9598767 |
| c\_post\_reorg | EE | 0.9232823 | 0.0114700 | Inf | 0.9008015 | 0.9457631 |

Estimates from predict:

smgran\_glm\_se <- est\_glm\_ilink(smgran\_glm, smgran\_dat) %>%  
 dplyr::select(-period, -censusdate) %>%  
 dplyr::distinct()

## Joining, by = c("period", "oplottype")

smgran\_glm\_se

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| fit | se.fit | residual.scale | est | lower | upper | oplottype | oera |
| -2.4201739 | 0.1466690 | 0.428812 | 0.0816472 | 0.0621807 | 0.1065157 | CC | a\_pre\_pb |
| 2.3274089 | 0.1411329 | 0.428812 | 0.9111217 | 0.8854559 | 0.9314816 | EE | a\_pre\_pb |
| -0.9251490 | 0.0840597 | 0.428812 | 0.2839099 | 0.2510033 | 0.3192915 | CC | b\_pre\_reorg |
| 2.7985528 | 0.1629357 | 0.428812 | 0.9425976 | 0.9222044 | 0.9578890 | EE | b\_pre\_reorg |
| -0.8644212 | 0.0938983 | 0.428812 | 0.2964165 | 0.2587994 | 0.3370151 | CC | c\_post\_reorg |
| 2.4878027 | 0.1619321 | 0.428812 | 0.9232823 | 0.8969641 | 0.9433030 | EE | c\_post\_reorg |

# 5. C baileyi proportional abundance GLM

Energy use by *C. baileyi* as a proportion of treatment-level energy use in each census period. Because *C. baileyi* was absent from 1977-1996, restricted to the second two time periods (July 1997-2020)

Model call:

pb\_glm <- glm(pb\_prop ~ oera \* oplottype, family = quasibinomial(), data= pb\_nozero)

oera is the time period, and oplottype is treatment.

summary(pb\_glm)

##   
## Call:  
## glm(formula = pb\_prop ~ oera \* oplottype, family = quasibinomial(),   
## data = pb\_nozero)  
##   
## Deviance Residuals:   
## Min 1Q Median 3Q Max   
## -0.77785 -0.23751 -0.07486 0.18362 1.66203   
##   
## Coefficients:  
## Estimate Std. Error t value Pr(>|t|)   
## (Intercept) -2.0044 0.1601 -12.523 < 2e-16 \*\*\*  
## oera.L -2.0922 0.2263 -9.243 < 2e-16 \*\*\*  
## oplottype.L 2.7474 0.2263 12.138 < 2e-16 \*\*\*  
## oera.L:oplottype.L 0.8987 0.3201 2.807 0.00521 \*\*   
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## (Dispersion parameter for quasibinomial family taken to be 0.1092629)  
##   
## Null deviance: 242.507 on 454 degrees of freedom  
## Residual deviance: 51.407 on 451 degrees of freedom  
## (1 observation deleted due to missingness)  
## AIC: NA  
##   
## Number of Fisher Scoring iterations: 8

Contrasts

pb\_emmeans <- (emmeans(pb\_glm, specs = ~ oera | oplottype))  
  
pb\_contrasts <- as.data.frame(pairs(pb\_emmeans))  
pb\_contrasts

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| contrast | oplottype | estimate | SE | df | z.ratio | p.value |
| b\_pre\_reorg - c\_post\_reorg | CC | 3.857543 | 0.6322409 | Inf | 6.101382 | 0 |
| b\_pre\_reorg - c\_post\_reorg | EE | 2.060214 | 0.1007264 | Inf | 20.453577 | 0 |

Estimates

Estimates from emmeans differ numerically (in the far decimals) from estimates obtained via predict() and back transformation. Below are estimates from emmeans, because those are what are used for contrasts. Estimates given on the response (not link) scale.

pb\_estimates <- as.data.frame(regrid(pb\_emmeans))  
  
pb\_estimates

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| oera | oplottype | prob | SE | df | asymp.LCL | asymp.UCL |
| b\_pre\_reorg | CC | 0.1172888 | 0.0094009 | Inf | 0.0988634 | 0.1357142 |
| c\_post\_reorg | CC | 0.0027984 | 0.0017460 | Inf | -0.0006237 | 0.0062206 |
| b\_pre\_reorg | EE | 0.7248069 | 0.0130485 | Inf | 0.6992323 | 0.7503815 |
| c\_post\_reorg | EE | 0.2512829 | 0.0144098 | Inf | 0.2230401 | 0.2795256 |

Estimates from predict:

pb\_glm\_se <- est\_glm\_ilink(pb\_glm, pb\_nozero) %>%  
 dplyr::select(-period, -censusdate) %>%  
 dplyr::distinct()

## Joining, by = c("period", "oplottype")

pb\_glm\_se

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| fit | se.fit | residual.scale | est | lower | upper | oplottype | oera |
| -2.0183586 | 0.0908017 | 0.3305494 | 0.1172888 | 0.0997539 | 0.1374355 | CC | b\_pre\_reorg |
| 0.9684323 | 0.0654186 | 0.3305494 | 0.7248069 | 0.6979585 | 0.7501232 | EE | b\_pre\_reorg |
| -5.8759020 | 0.6256866 | 0.3305494 | 0.0027984 | 0.0008023 | 0.0097130 | CC | c\_post\_reorg |
| -1.0917821 | 0.0765911 | 0.3305494 | 0.2512829 | 0.2235731 | 0.2811833 | EE | c\_post\_reorg |

# 6. E. ciculatum proportional abundance GLM

*E. ciculatum* abundance as a proportion of total plant abundance for each winter census.

Model call - note that an interaction between plot type and era is not significant, so we drop it:

erod\_glm <- glm(erod\_treatment\_prop\_abundance ~ oplottype \* oera, data = erodium\_treatments\_noz, family = quasibinomial())  
  
summary(erod\_glm)

##   
## Call:  
## glm(formula = erod\_treatment\_prop\_abundance ~ oplottype \* oera,   
## family = quasibinomial(), data = erodium\_treatments\_noz)  
##   
## Deviance Residuals:   
## Min 1Q Median 3Q Max   
## -1.0510 -0.2145 -0.1153 0.2447 0.8881   
##   
## Coefficients:  
## Estimate Std. Error t value Pr(>|t|)   
## (Intercept) -1.8645 0.2778 -6.711 1.86e-08 \*\*\*  
## oplottype.L 1.1271 0.3929 2.869 0.00607 \*\*   
## oera.L 0.9523 0.5746 1.657 0.10384   
## oera.Q -2.4553 0.3647 -6.732 1.72e-08 \*\*\*  
## oplottype.L:oera.L -0.1200 0.8126 -0.148 0.88321   
## oplottype.L:oera.Q 0.6096 0.5158 1.182 0.24292   
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## (Dispersion parameter for quasibinomial family taken to be 0.1630108)  
##   
## Null deviance: 26.0828 on 54 degrees of freedom  
## Residual deviance: 8.8253 on 49 degrees of freedom  
## AIC: NA  
##   
## Number of Fisher Scoring iterations: 7

erod\_glm\_nointeraction <- glm(erod\_treatment\_prop\_abundance ~ oplottype + oera, data = erodium\_treatments\_noz, family = quasibinomial())  
  
(anova(erod\_glm, erod\_glm\_nointeraction, test = "Chisq"))

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Resid. Df | Resid. Dev | Df | Deviance | Pr(>Chi) |
| 49 | 8.825256 | NA | NA | NA |
| 51 | 9.125314 | -2 | -0.3000576 | 0.3983751 |

summary(erod\_glm\_nointeraction)

##   
## Call:  
## glm(formula = erod\_treatment\_prop\_abundance ~ oplottype + oera,   
## family = quasibinomial(), data = erodium\_treatments\_noz)  
##   
## Deviance Residuals:   
## Min 1Q Median 3Q Max   
## -0.9996 -0.2698 -0.1459 0.1637 0.9504   
##   
## Coefficients:  
## Estimate Std. Error t value Pr(>|t|)   
## (Intercept) -1.7058 0.1990 -8.574 1.86e-11 \*\*\*  
## oplottype.L 0.8185 0.2233 3.666 0.000587 \*\*\*  
## oera.L 0.8626 0.3876 2.225 0.030516 \*   
## oera.Q -2.2667 0.2798 -8.100 1.01e-10 \*\*\*  
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## (Dispersion parameter for quasibinomial family taken to be 0.1646958)  
##   
## Null deviance: 26.0828 on 54 degrees of freedom  
## Residual deviance: 9.1253 on 51 degrees of freedom  
## AIC: NA  
##   
## Number of Fisher Scoring iterations: 6

Contrasts

erod\_emmeans <- (emmeans(erod\_glm\_nointeraction, specs = ~ oera | oplottype))  
  
erod\_contrasts <- as.data.frame(pairs(erod\_emmeans))  
  
erod\_contrasts

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| contrast | oplottype | estimate | SE | df | z.ratio | p.value |
| a\_pre\_pb - b\_pre\_reorg | CC | -3.386130 | 0.5001406 | Inf | -6.770356 | 0.0000000 |
| a\_pre\_pb - c\_post\_reorg | CC | -1.219893 | 0.5482135 | Inf | -2.225215 | 0.0669914 |
| b\_pre\_reorg - c\_post\_reorg | CC | 2.166237 | 0.3674864 | Inf | 5.894741 | 0.0000000 |
| a\_pre\_pb - b\_pre\_reorg | EE | -3.386130 | 0.5001406 | Inf | -6.770356 | 0.0000000 |
| a\_pre\_pb - c\_post\_reorg | EE | -1.219893 | 0.5482135 | Inf | -2.225215 | 0.0669914 |
| b\_pre\_reorg - c\_post\_reorg | EE | 2.166237 | 0.3674864 | Inf | 5.894741 | 0.0000000 |

Estimates

Estimates from emmeans differ numerically (in the far decimals) from estimates obtained via predict() and back transformation. Below are estimates from emmeans, because those are what are used for contrasts. Estimates given on the response (not link) scale.

erod\_estimates <- as.data.frame(regrid(erod\_emmeans))  
  
erod\_estimates

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| oera | oplottype | prob | SE | df | asymp.LCL | asymp.UCL |
| a\_pre\_pb | CC | 0.0214594 | 0.0107953 | Inf | 0.0003010 | 0.0426177 |
| b\_pre\_reorg | CC | 0.3932264 | 0.0578821 | Inf | 0.2797796 | 0.5066733 |
| c\_post\_reorg | CC | 0.0691380 | 0.0243978 | Inf | 0.0213192 | 0.1169568 |
| a\_pre\_pb | EE | 0.0652294 | 0.0280600 | Inf | 0.0102329 | 0.1202260 |
| b\_pre\_reorg | EE | 0.6734300 | 0.0551609 | Inf | 0.5653165 | 0.7815435 |
| c\_post\_reorg | EE | 0.1911589 | 0.0495320 | Inf | 0.0940780 | 0.2882398 |

Estimates from predict:

erod\_glm\_se <- est\_glm\_ilink(erod\_glm, mutate(erodium\_treatments\_noz, period = year, censusdate = year)) %>%  
 dplyr::select(-period, -censusdate) %>%  
 dplyr::distinct()

## Joining, by = c("period", "oplottype")

erod\_glm\_se

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| fit | se.fit | residual.scale | est | lower | upper | oplottype | oera |
| -4.5732911 | 1.3382018 | 0.4037459 | 0.0102184 | 0.0007099 | 0.1304612 | CC | a\_pre\_pb |
| -2.5073243 | 0.4837128 | 0.4037459 | 0.0753463 | 0.0300393 | 0.1765500 | EE | a\_pre\_pb |
| -0.3048107 | 0.2583227 | 0.4037459 | 0.4243819 | 0.3054547 | 0.5527615 | CC | b\_pre\_reorg |
| 0.5852501 | 0.2663624 | 0.4037459 | 0.6422745 | 0.5131283 | 0.7536129 | EE | b\_pre\_reorg |
| -3.1065053 | 0.7049325 | 0.4037459 | 0.0428397 | 0.0108105 | 0.1549046 | CC | c\_post\_reorg |
| -1.2805469 | 0.3460368 | 0.4037459 | 0.2174572 | 0.1221077 | 0.3569852 | EE | c\_post\_reorg |