Name: _____ Biometry Quiz #5 ____ / 50

1. She *et al.* (2015; Forests 6:4529-4539) examined allometric relationships for the xeric shrub *Artemisia ordosica*, a species endemic to the Mu Us Desert in China. In one part of their analysis they used crown area (CA; m^2) and habitat type to explain variability in above ground biomass (AGB; g) of individual *Artemisia* shrubs. Three habitats were considered – semi-fixed dunes (SF), fixed dunes (FD), and fixed dunes with soil crusts (FC). In their model fitting they assumed that the relationship between AGB and CA followed a power function. Use this information to answer the following questions.

   a) **[2 pts]** What is the response variable in this analysis? *Explain why.*

   b) **[5 pts]** Explain, given the author's assumption about the relationship following a power function, whether both, only one, or neither of the response and explanatory variables should be transformed for this analysis. *Demonstrate how you came to this conclusion.*

   c) **[4 pts]** Construct indicator variable(s) for habitats in the same way that R would construct them.

   d) **[5 pts]** Write the complete ultimate full model for this analysis?

e) **[4 pts]** Explicitly define the meanings of β_1, δ_1, γ_2, $\alpha+\delta_2$ from your ultimate full model in (d).

f) **[2 pts]** Show the models for the null and alternative hypotheses in a parallel lines test.

2. A variety of analyses for the data described in question 1 are shown in the attached handout. Use the background information in question 1 and the R analytical results to answer the following questions. Make sure to answer each question as thoroughly as possible and by citing supporting evidence where appropriate (you may want to label output on the handout).

   a) **[6 pts]** Write the equations (using estimated values for each parameter) for the relationship between the response and explanatory variable separately <u>for each habitat</u>. *Use 3 decimals for each parameter.*

   b) **[4 pts]** Is there a significant difference in the relationship between the response and explanatory variables among the habitats? *Provide specific evidence to support your answer.*

c) **[4 pts]** Is there a significant relationship between the response and explanatory variables? *Provide specific evidence to support your answer.*

d) **[2 pts]** Describe the meaning (on the original scale, if appropriate) of the first of the three values at the very bottom of the `compIntercepts()` results.

e) **[4 pts]** Determine whether the three values at the very bottom of the `compIntercepts()` results are significantly different or not. *Provide specific evidence and an explanation to support your answer.*

f) **[8 pts]** Explain what was learned about the response variable (including its relationship with the covariate) from this analysis. That is, what are take-home messages (there are at least three)?

```
> library(NCStats)
> d <- read.csv("Artemisia.csv")
> d$logCA <- log(d$CA); d$logAGB <- log(d$AGB)

> ## Linear model 1
> lm1 <- lm(AGB~CA*Habitat,data=d)
> summary(lm1)
    Coefficients:
                 Estimate Std. Error t value Pr(>|t|)
    (Intercept)   -122.92      76.39  -1.609  0.11211
    CA             903.61      65.59  13.777  < 2e-16 ***
    HabitatFD       20.17     120.33   0.168  0.86734
    HabitatSF     -157.62     119.88  -1.315  0.19287
    CA:HabitatFD  -359.60     109.29  -3.290  0.00157 **
    CA:HabitatSF  -306.62     101.57  -3.019  0.00354 **
    ---
    Residual standard error: 250.1 on 70 degrees of freedom
    Multiple R-squared: 0.8143,      Adjusted R-squared: 0.801
    F-statistic: 61.38 on 5 and 70 DF,  p-value: < 2.2e-16

> anova(lm1)
    Response: AGB
              Df   Sum Sq  Mean Sq  F value    Pr(>F)
    CA         1 15845295 15845295 253.3102 < 2.2e-16 ***
    Habitat    2  2452358  1226179  19.6023 1.738e-07 ***
    CA:Habitat 2   901027   450514   7.2021  0.001431 **
    Residuals 70  4378705    62553

> compSlopes(lm1)
    Multiple Slope Comparisons (using the 'holm' adjustment)
      comparison       diff   95% LCI   95% UCI p.unadj   p.adj
    1      FD-FC -359.60108 -577.5666 -141.6356 0.00157 0.00471
    2      SF-FC -306.62191 -509.2042 -104.0396 0.00354 0.00708
    3      SF-FD   52.97917 -180.0979  286.0562 0.65170 0.65170

    Slope Information (using the 'holm' adjustment)
      level   slopes  95% LCI   95% UCI p.unadj p.adj
    2    FD 544.0109 369.6631  718.3587       0     0
    3    SF 596.9901 442.3041  751.6761       0     0
    1    FC 903.6120 772.7998 1034.4241       0     0

> compIntercepts(lm1,common.cov=1)
    Tukey HSD on means adjusted assuming parallel lines
      comparison      diff   95% LCI    95% UCI        p.adj
    1      FD-FC -287.8532 -479.7270  -95.97935 1.711851e-03
    2      SF-FC -438.5094 -617.8714 -259.14738 3.866895e-07
    3      SF-FD -150.6562 -327.7229   26.41044 1.109589e-01

    Mean AGB when CA=       1
          FC       FD       SF
    749.9775 462.1244 311.4681
```

```
> ## Linear model 2
> lm2 <- lm(CA~AGB*Habitat,data=d)

> summary(lm2)
    Coefficients:
                  Estimate Std. Error t value Pr(>|t|)
    (Intercept)  0.2782242  0.0794457   3.502 0.000808 ***
    AGB          0.0008812  0.0000766  11.504  < 2e-16 ***
    HabitatFD   -0.0179455  0.1212418  -0.148 0.882757
    HabitatSF    0.3189577  0.1061418   3.005 0.003684 **
    AGB:HabitatFD 0.0007671  0.0001956   3.922 0.000202 ***
    AGB:HabitatSF 0.0004206  0.0001556   2.703 0.008627 **
    ---
    Residual standard error: 0.2958 on 70 degrees of freedom
    Multiple R-squared: 0.8186,      Adjusted R-squared: 0.8057
    F-statistic: 63.19 on 5 and 70 DF,  p-value: < 2.2e-16

> anova(lm2)
    Response: CA
              Df  Sum Sq Mean Sq  F value    Pr(>F)
    AGB        1 22.6924 22.6924 259.3661 < 2.2e-16 ***
    Habitat    2  3.2586  1.6293  18.6225 3.275e-07 ***
    AGB:Habitat  2  1.6902  0.8451   9.6594 0.0001974 ***
    Residuals  70  6.1244  0.0875

> compSlopes(lm2)
    Multiple Slope Comparisons (using the 'holm' adjustment)
      comparison     diff  95% LCI 95% UCI p.unadj   p.adj
    1      FD-FC  0.00077  0.00038 0.00116 0.00020 0.00060
    2      SF-FC  0.00042  0.00011 0.00073 0.00863 0.01726
    3      SF-FD -0.00035 -0.00080 0.00010 0.12836 0.12836

    Slope Information (using the 'holm' adjustment)
      level  slopes 95% LCI 95% UCI p.unadj p.adj
    1    FC 0.00088 0.00073 0.00103       0     0
    3    SF 0.00130 0.00103 0.00157       0     0
    2    FD 0.00165 0.00129 0.00201       0     0

> compIntercepts(lm2,common.cov=500)
    Tukey HSD on means adjusted assuming parallel lines
      comparison      diff     95% LCI   95% UCI        p.adj
    1      FD-FC 0.3170531  0.08361896 0.5504873 4.922455e-03
    2      SF-FC 0.5151412  0.29692899 0.7333535 8.757553e-07
    3      SF-FD 0.1980881 -0.01733161 0.4135079 7.789504e-02

    Mean CA when AGB=     500
           FC        FD        SF
    0.6950194 1.0120725 1.2101607
```

```
> ## Linear model 3
> lm3 <- lm(logAGB~logCA*Habitat,data=d)

> summary(lm3)
    Coefficients:
                   Estimate Std. Error t value Pr(>|t|)
    (Intercept)     6.43582    0.09610  66.972  < 2e-16 ***
    logCA           1.45731    0.08509  17.127  < 2e-16 ***
    HabitatFD      -0.51427    0.13059  -3.938 0.000192 ***
    HabitatSF      -0.95909    0.11910  -8.053 1.46e-11 ***
    logCA:HabitatFD  0.10428    0.12468   0.836 0.405811
    logCA:HabitatSF  0.27231    0.12824   2.123 0.037261 *
    ---
    Residual standard error: 0.3822 on 70 degrees of freedom
    Multiple R-squared: 0.9296,      Adjusted R-squared: 0.9246
    F-statistic: 184.9 on 5 and 70 DF,  p-value: < 2.2e-16

> anova(lm3)
    Response: logAGB
                 Df  Sum Sq Mean Sq  F value    Pr(>F)
    logCA         1 120.718 120.718 826.3413 < 2.2e-16 ***
    Habitat       2  13.655   6.827  46.7343 1.283e-13 ***
    logCA:Habitat 2   0.662   0.331   2.2642    0.1115
    Residuals    70  10.226   0.146

> compSlopes(lm3)
    Multiple Slope Comparisons (using the 'holm' adjustment)
      comparison    diff  95% LCI 95% UCI p.unadj   p.adj
    1      FD-FC 0.10428 -0.14440 0.35295 0.40581 0.41676
    2      SF-FC 0.27231  0.01653 0.52808 0.03726 0.11178
    3      SF-FD 0.16803 -0.09590 0.43196 0.20838 0.41676

    Slope Information (using the 'holm' adjustment)
      level  slopes 95% LCI 95% UCI p.unadj p.adj
    1    FC 1.45731 1.28761 1.62701       0     0
    2    FD 1.56159 1.37982 1.74335       0     0
    3    SF 1.72962 1.53825 1.92099       0     0

> compIntercepts(lm3,common.cov=log(1))
    Tukey HSD on means adjusted assuming parallel lines
      comparison       diff    95% LCI    95% UCI        p.adj
    1      FD-FC -0.5785629 -0.8540984 -0.3030274 1.032897e-05
    2      SF-FC -1.0530565 -1.3106248 -0.7954883 0.000000e+00
    3      SF-FD -0.4744936 -0.7287657 -0.2202215 8.432816e-05

    Mean logAGB when logCA=0
          FC       FD       SF
    6.504516 5.925953 5.451459
```

```
> ## Linear model 4
> lm4 <- lm(logCA~logAGB*Habitat,data=d)

> summary(lm4)
    Coefficients:
                     Estimate Std. Error t value Pr(>|t|)
    (Intercept)      -4.17671    0.19783 -21.113  < 2e-16 ***
    logAGB            0.64314    0.03442  18.684  < 2e-16 ***
    HabitatFD         0.64604    0.27165   2.378   0.0201 *
    HabitatSF         1.23058    0.26358   4.669 1.42e-05 ***
    logAGB:HabitatFD -0.05240    0.04848  -1.081   0.2834
    logAGB:HabitatSF -0.10735    0.04735  -2.267   0.0265 *
    ---
    Residual standard error: 0.2327 on 70 degrees of freedom
    Multiple R-squared: 0.9325,      Adjusted R-squared: 0.9277
    F-statistic: 193.5 on 5 and 70 DF,  p-value: < 2.2e-16

> anova(lm4)
    Response: logCA
                  Df Sum Sq Mean Sq  F value    Pr(>F)
    logAGB         1 46.707  46.707 862.1897 < 2.2e-16 ***
    Habitat        2  5.425   2.712  50.0674 3.167e-14 ***
    logAGB:Habitat 2  0.279   0.139   2.5751   0.08335 .
    Residuals     70  3.792   0.054

> compSlopes(lm4)
    Multiple Slope Comparisons (using the 'holm' adjustment)
      comparison     diff  95% LCI  95% UCI p.unadj   p.adj
    1      FD-FC -0.05240 -0.14908  0.04428 0.28344 0.49548
    2      SF-FC -0.10735 -0.20180 -0.01291 0.02648 0.07944
    3      SF-FD -0.05495 -0.14898  0.03908 0.24774 0.49548

    Slope Information (using the 'holm' adjustment)
      level  slopes 95% LCI 95% UCI p.unadj p.adj
    3    SF 0.53579 0.47093 0.60065       0     0
    2    FD 0.59074 0.52266 0.65882       0     0
    1    FC 0.64314 0.57449 0.71179       0     0

> compIntercepts(lm4,common.cov=log(500))
    Tukey HSD on means adjusted assuming parallel lines
      comparison      diff   95% LCI   95% UCI        p.adj
    1      FD-FC 0.3536390 0.1851529 0.5221250 1.041081e-05
    2      SF-FC 0.6522731 0.4947738 0.8097725 0.000000e+00
    3      SF-FD 0.2986342 0.1431504 0.4541179 5.219486e-05

    Mean logCA when logAGB=6.214608
            FC          FD          SF
    -0.2158515  0.1377875  0.4364216
```