**Problem Set #4: Analysis of Variance**

(1) (5 pts) A plant ecologist wishes to test the hypothesis that the height of coastal sage scrub depends on properties of the soil. She gathers soil from three sites (a sand dune, a site in the Santa Monica Mountains, and chaparral habitat) and also used sterilized potting soil. The soils vary in amount of nutrients, grain size, and many other characteristics. She plants five individual plants in each soil type in separate pots in the greenhouse. After four months, she measured the height of each plant (in cm). Do an ANOVA by hand, or using Excel, (do not use R) to test the hypothesis that these four soil types affect the size of coastal sage scrub. Assume that the data are normal and homoscedastic, so you don’t need to test for these. Write a single sentence describing the results (include F, df, and P).

|  |  |  |  |
| --- | --- | --- | --- |
| Sterile Soil | Sand Dune | Mountains | Chaparral |
| 11.3 | 11.1 | 9.9 | 12.9 |
| 11.4 | 12.3 | 10.7 | 13.3 |
| 9.7 | 11.5 | 11.5 | 13.1 |
| 10.5 | 13.1 | 11.8 | 14.7 |
| 10.1 | 12.5 | 10.9 | 14.1 |

(2) (7 pts) Anna is interested in whether the nutrient content of soils influences the root:shoot ratio of the plants growing in it. She tests the null hypothesis of no difference in root:shoot ratios under four different soil nutrient conditions that she has manipulated: low, ambient, 1.5X and 2.0X nitrogen. The data in the file “rootshoot” are the ratio of root to shoot biomass.

Do the data meet the assumptions of normality and homogeneity of variances? Is transformation required? Show diagnostic plots.

Use ANOVA to determine whether nitrogen level in the soil significantly affects the root to shoot ratio of this plant. Use a *post-hoc* test (Tukey HSD) to determine which treatments differ from each other. Interpret the data and present the results of the statistical tests in a sentence. Provide a publication-quality graph that corresponds to the statistical analysis.

(3) (7 pts) Granivorous desert rodents may influence plant densities by consuming seeds of plants. To test this hypothesis, plots surrounding individual plants were established as unmanipulated controls, rodent exclosures (using fine mesh wire fences buried 2 feet in the sand and 3 feet above ground), and a fence control treatment. The fence control had the same fencing as the exclosures, but holes in the side still allowed rodents to enter. The data in the file “seedsrodents” are the seed mass (in grams) of individual plants in the different treatments.

Use planned comparisons (*a priori* contrasts) to test two hypotheses: (1) there is no experimental artifact of using exclosures; and (2) rodents reduce the abundance of seeds (as estimated by mass of seeds). Give the coefficients that you used for each treatment for each contrast. Carry out the analyses and interpret the data in the context of the contrasts you designed above.

(4) (2 pts) Just so you can see how the results can differ, also do an ANOVA, followed by Tukey HSD post-hoc tests to make all possible pairwise comparisons of the three treatment means. Based on this *post-hoc* approach, would your interpretation of the experiment differ at all from that obtained by the planned comparison approach?

(5) (7 pts) Carla studied morphological variation in the Caribbean coral *Montastraea* *franksi*. She wanted to determine whether colonies of this coral differ in morphology. A morphological feature that can vary within coral species is the calyx – the portion of the skeleton where the polyp lies. Carla’s null hypotheses were that calyx area does not differ either (1) within or (2) among colonies of *M*. *franksi*.

To test her hypothesis, she randomly chose 3 colonies (genets), which she broke into 3 pieces each (ramets). All of the ramets from each colony were placed out in the field and allowed to grow, thus making them independent from one another. After 8 months, the ramets were collected for morphometric analysis. She took 10 measurements of calyx area from each ramet. The results are in the worksheet “**montastraea**”.

Quantify where most of phenotypic variation in calyx area lies in populations of *M. franksi* using variance components. Make a publication-quality graph with figure legend that shows differences among genets.

(6) (7 pts) Ananda conducted an experiment to test the effects of temperature and CO2 (pCO2) on growth rates of recently settled corals to evaluate the possible effects of these two stressors on a species of coral. She used two levels of temperature (ambient and high) and two levels of pCO2 (ambient and high) in a crossed (orthogonal) design. For each of the 4 treatment combinations, she had 4 replicate tanks, each containing 10 recently settled corals. She measures the growth in basal area (mm2) of each coral from digital photographs taken at the start of the experiment and at the end. She averages these among all corals in each tank and treats that average as a replicate. The data are in the worksheet “**temp\_CO2**”.

As always, evaluate whether the data meet the assumptions of the test and consider   
transforming them if they don’t.

Make a publication quality bar graph (with legend) that summarizes the results.

Conduct a two-way ANOVA with the factors temperature and pCO2). Present and interpret the statistical results in light of the biological questions.