Part One: Review and Advice

Identifying the Appropriate Statistical Analysis

The following questions may help you select an appropriate test. They are listed in arbitrary order.

1 How many samples and/or treatments do you have?
2 Do measurements within a sample represent true replication, or are they sub-samples?
3 Judging from sample frequency distributions, are the populations likely to be normally distributed? More appropriately, are the residuals (ε in a linear model) normally distributed? (parametric vs. non-parametric test)
4 Are the variances in your samples similar, or are they very different? (parametric vs. non-parametric test, or transformation prior to analysis)
5 Do you need to compare means, variances, or proportions?
6 If there are two samples, are their measurements paired? Is each measurement in one sample clearly related to one and only one measurement in the other sample? (paired vs. two-sample test)
7 Are you comparing means of three or more samples? (ANOVA) If so, how many factors influence each sample? (one: single-factor ANOVA; two: two-way ANOVA; three or more: take a course in experimental design)
8 Are factors in an ANOVA fixed or random?
9 Are all the hypotheses plausible? Avoid or revise null hypotheses that can be rejected a priori.

ANOVA Review

Given a description of a sampling design, you should be able to answer the following questions.

1 Is ANOVA the appropriate kind of analysis to test the hypothesis(es)? Why?
2 If ANOVA is appropriate, is (are) the factor(s) fixed or random?
3 Can you construct an ANOVA table, including sources of variation, SS, DF, and MS?
4 Can you determine the correct ratio of MS to test a particular hypothesis?
5 If you are given a partial ANOVA table and a study description, can you complete the table to test ANOVA hypotheses?
6 If you do a multiple comparisons test after concluding from ANOVA that the groups differ, in which order should you compare the various pairs of groups?
7 How would you interpret ambiguous results in a multiple comparisons test? (e.g., test concludes that groups 1 and 3 differ from each other, but that cannot conclude that group 2 differs from either group 1 or group 3)
8 After concluding from a multiple comparisons test that population means differ, can you calculate the 95% confidence interval for each mean? (and 90% CI, 99% CI, etc)

Goodness of Fit and Independence Review

Given a description of a sampling design you should be able to answer the following questions.

1 Chi-square tests are used to analyze both goodness of fit and independence of factors. What is the difference?
2 Given hypothesized proportions for a set of categories, and frequencies of sample data observed in each category, can you calculate the χ^2 statistic?
3 How would you test H_0: the sample was from a population with a set of proportions, $p_1, p_2, p_3, \ldots$?
4 If a sample is drawn from a population affected by two factors, how would you determine the frequencies of sample data that would be expected if the factors acted independently?
5 How would you test H_0: the factors are independent?

Part Two: Study Questions

1 You are studying mercury concentrations in a population of freshwater mussels. You want to have 75% power in your ability to detect a difference of 5 ppm between mercury concentrations in mussels and an EPA standard. Your significance level is 0.05. The variance in mussel mercury concentration obtained in a preliminary sample is 100 ppm^2. You have enough money to measure mercury concentration in 25 mussels. Will this be enough, or do you need to ask your boss for additional funds to collect a larger sample?

2 You are studying effects of air pollution levels on growth rates of Douglas fir trees. You measure growth rates at four different pollution levels, using sample sizes (number of replicates) of 2, 5, 9, and 15 trees. You do not obtain a significant effect of pollution level using single-factor analysis of variance. You suspect that there is a real effect of pollution level, but that your study design was not sufficiently powerful to detect it. What are two ways that you could increase power in a second study?
(Do not change significance level, α.)

3 Your neighbor Jed wants to know if fuel economy using 89 octane gasoline differs from fuel economy using 87 octane gasoline. Jed knows that you are a statistical whiz, so he takes great care to design an unbiased test. Each day, Jed drives his van along the same route to and from work. He drives at the same speed, with the same tire pressure, with the same amount of weight in the van, … he even wears the same shoes. Jed's van has two gas tanks, one for 87 octane and the other for 89 octane. Jed switches from one tank to the other each day. On his way home from work, Jed fills the tank he has been using that day, calculates fuel economy for that day, and then switches to the other tank. After following this routine for fifty days (25 days with each kind of gas), Jed performs a two-sample t-test on his fuel economy data. ($H_0: \mu_1 = \mu_2$, where μ_1 is mean gas mileage with 89 octane, and μ_2 is mean gas mileage with 87 octane.) He obtains a t-value of 2.10, which exceeds the critical value of $t_{0.05(2),48}$. Jed declares that 89 octane gasoline yields different gas mileage than mileage obtained with 87 octane gasoline. You declare Jed's test to be invalid. You are correct – why?

For the following four questions (4 - 7), describe the following.
(a) The appropriate statistical analysis to perform, including number of tails, fixed or random effects, and parametric or nonparametric tests.
(b) State any assumptions necessary in using the appropriate statistical analysis.
(c) State the null hypothesis or hypotheses to be tested.
(d) State the criteria for rejection of the null hypothesis or hypotheses.

4 Research question: Does the density of barnacles in patches of rocky intertidal habitat at Larrabee State Park affect the number of predatory snails found there? Snails were counted in ten quadrats each at four levels of barnacle density. Snail abundances appear to be normally distributed. Use a significance level of $\alpha = 0.10$.

5 Analysis in problem 4 did show an effect of barnacle density on number of snails. At which levels of barnacle density does snail number differ? Use a significance level of $\alpha = 0.10$.

6 How would you address problem 4 if snail abundances deviate severely from normality?

7 Research question: Do parasitoid wasps affect variability in abundances of their moth prey? Moth abundances were recorded in twelve experimental plots, four replicates at each of three wasp densities (none, low, high). Use a significance level of $\alpha = 0.05$.

8 Research question: Does nest productivity (number of fledglings produced) of songbird nests differ among nests in forests, wetlands, and grasslands? A significance level of 0.05 was selected. Productivity was recorded from a random sample of ten nests in each of the three kinds of habitats (30 nests total). Nest productivities were normally distributed, with equal variances among habitats. The following results were obtained.

Mean (number of fledglings):
Forests: 6.1 Wetlands: 7.1 Grasslands: 4.0

Source	SS	DF	MS
Total	250.0		
Among habitats	50.0		
Within habitats			

a) State the null hypothesis appropriate to address the research question using the study described above.

b) Complete the table above. Show both numerical values and formulas used.

c) State the criterion for rejection of the null hypothesis, including both symbolic and numerical expressions for the test statistic (e.g., criterion for a t-test might be: $t_{\alpha(2),\nu} = t_{0.05(2),60} = 2.000$).

d) Present a complete statistical analysis to test the hypothesis that nest productivity does not differ among the three habitats. Include a conclusion using words analogous to those in the research question.

9 Suppose analysis for problem 8 showed that mean nest productivity is not equal in forests, wetlands, and grasslands. Which habitats differ in mean productivity? Use a significance level of $\alpha 0.05$.

10 Research question: Does DDE in the tissues of birds cause them to lay thin eggs? You decide to address this question using simple linear regression, comparing eggshell thickness with DDE concentration in tissue samples from 100 thrushes. You obtain the following result.

a (intercept) = 30.0 s_a = 3.45
b (slope) = -2.8 s_b = 0.96

Source of variation	DF	SS	MS
Total	99	875.44	
Regression		224.31	
Residual		651.13	

a) Present a complete statistical analysis to test the hypothesis that there is no relationship between eggshell thickness in thrushes and DDE concentration in their tissues (i.e., that the slope of the regression line equals zero).

b) Write the equation that relates tissue DDE concentration (X) with eggshell thickness (Y).

c) What fraction of total variation in initial eggshell thickness is explained by regression results above?

d) Predict the thickness of shells laid by a thrush whose tissues contain DDE at 4.4 ppm.

11 You are trying to determine whether yellow warblers are migrating to breeding areas earlier in spring than they did two decades ago. (Yellow warblers are small songbirds that winter in Central America and breed throughout North America.) You have data on yellow warbler spring arrival dates two decades ago at twenty locations. If you record dates of yellow warbler arrival at those same twenty locations this spring, what is the minimum advance in arrival date you could detect with 90% power, at a significance level of 0.05? Your estimate of the variance in arrival date differences is 20.0 days^2.