

6. ANSWERS TO PROBLEMS

1. Meta-analysis of plant competition.

- a) $\bar{X} = 0.986$. 95% CI: $0.647 \leq \mu \leq 1.326$
- b) The interval may or may not contain the true population mean μ . However, when repeated random samples are obtained from the same population, and a 95% confidence interval is computed each time, 95% of the cases will include the population mean μ .
- c) We assumed that the variable (*Competition effect size*) has a normal distribution in the population. The histogram, boxplot, and normal quantile plot reveal that the data contain several outliers. The normal quantile plot deviates from a straight line: the data appear platykurtic (middle-heavy). A Shapiro-Wilks goodness-of-fit test of
 Ho: Effect size is normally distributed
 Ha: Effect size is not normally distributed
 rejected Ho (Shapiro-Wilk $W=0.941$, $n=43$, $P=0.039$). Therefore, our assumption of normality was not justified, and the 95% confidence interval may be inaccurate.
- d) The sum of a large sequence n of random variables (or their average) is approximately normally distributed. This means that \bar{X} may be approximately normally distributed even if X is not, provided that our sample size of $n = 43$ is sufficiently large. If so, then we can regard our confidence interval as accurate despite the non-normal distribution. However, it is not easy to tell whether this sample size of $n = 43$ really is large enough in the present case. For this reason we should take a cautious approach.
- e) Ho: $\mu = 0$
 Ha: $\mu \neq 0$
 $t=5.8625$, $v=42$, $P<0.001$. Alternatively: signed-rank=382.5, $n=43$, $P<0.001$. Reject Ho, conclude that mean *Competition effect size* is different from (in this case greater than) zero. Given that the data depart significantly from a normal distribution, the signed-rank test is the most appropriate test. However, despite departures from normality, the t -test gave the same result as the signed-rank test.
- f) 0.05 (if we use the conventional significance level of 0.05).
- g) This is indeed a problem for your analysis. On average, two measurements from the same study are likely to be more similar to one another than two measurements picked from different studies because experimental conditions are probably similar. In other words, measurements from the same study may not be independent and hence the set of measurements in the data file is not a random sample. (In the present case, our suspicions are valid: a plot of measurements from different studies using **Fit Y by X**, where **Y** is *Competition effect size* and **X** is *Source of data*, reveals that measurements from the same study are indeed similar to one another.)

A solution to this problem is to use the average measurement from each study: Select **Tables** → **Summary**; in the pop-up window put *Source of data* into the **Group** box. Select *Competition effect size* and immediately select **Statistics**→**Mean**. When you click **OK** a new data table is generated containing the means for each value of *Source of data*. A signed-rank test again rejects the null hypothesis that the mean effect size is zero.

2. Specific activity of Na⁺-K⁺-ATPase in hagfish gills.

a) Ho: $\mu \leq 3.33$

Ha: $\mu > 3.33$

Note that this is a one-tail test: $t=2.477$, $v=59$, $P=0.0081$. Reject Ho. Conclude that mean Na⁺-K⁺-ATPase activity in hagfish is significantly greater than that in freshwater fish.

b) The test assumes that activity is normally distributed in the population. A test of

Ho: Na⁺-K⁺-ATPase activity is normally distributed

Ha: Na⁺-K⁺-ATPase activity is not normally distributed

did not reject Ho (Shapiro-Wilk $W=0.976$, $n=60$, $P=0.504$). This does not mean that the distribution is truly normal (we never accept Ho), but at least a test of this hypothesis found no reason to reject it. Proceed cautiously.

3. Shrinking Galápagos marine iguanas.

a) Ho: $\mu = 0$

Ha: $\mu \neq 0$

Signed-rank = -470 , $n=64$, $P=0.001$. Reject Ho, conclude that mean length changed during the El-Niño event. Because the data depart significantly from a normal distribution (the Shapiro-Wilks test rejected Ho: distribution of length changes is normally distributed; $W=0.914$, $n=63$, $P=0.0001$), the signed-rank test is the most appropriate test. However, sample size is reasonably large, and the departures from normality are not enormous, so a one-sample t -test may be also be justified in this case.

[We will learn in later labs and lectures that the recommended statement of the null and alternative hypotheses is modified when carrying out a non-parametric test such as the Wilcoxon signed rank, since the rank tests are best regarded as tests of the “location” of the distribution rather than mean of the distribution. In the above case, the statement of hypotheses should read “Ho: length did not change” and “Ha: length changed”.]

b) No, because there was no control (perhaps iguanas also shrink in years other than El-Niño years). Also, the data are observational, not experimental (perhaps another feature of environment changed coincidentally at the same time as the El-Niño event, and was the major cause of shrinkage).

c) To answer this question you will need to create a new **Formula** variable calculated as $100 \times \frac{\text{Change in length}}{\text{Length before El-Niño}}$. The mean of this variable is calculated as -1.174% . This is not a large average effect (keep in mind that some iguanas shrank a great deal, whereas others actually grew, so the data are still interesting). In other words,

rejecting “ $H_0: \mu = 0$ ” does not imply that μ is large. With a large enough sample size, H_0 could be correctly rejected even if μ is tiny and uninteresting. Therefore, there is no straightforward relationship between the P -value and the magnitude of an effect.

- d) The data are not normally distributed, so the 95% confidence interval for change in body length cannot be completely accurate. However, the sample size is reasonably large, and the confidence interval may be a good approximation.
- e) Most large individuals appear to have shrunk, whereas many small individuals grew.
 H_0 : Direction of change unrelated to iguana size.
 H_a : Direction of change associated with iguana size.
 Use the 2×2 contingency test. $\chi^2 = 21.71$, $df=1$, $P < 0.0001$. Reject H_0 . Recall that JMP IN does not include the Yates correction, so the χ^2 value is incorrect by Biology 300 rules. However, the Fisher’s exact test confirms that the result is correct in this case.

4. Visit to the confidence limits page of the Rice Virtual Lab in Statistics.

- a) 95% percent of the 95% confidence intervals should contain the population mean $\mu = 50$, by definition. You may get a proportion different from this on the basis of only 100 samples, but on average, 95% will be correct (keep clicking the Sample button to take more samples, and the percentage will converge to 95%. Similarly, 99% of 99% confidence intervals should contain the population mean.
- b) 99% confidence intervals are wider than 95% confidence intervals.
- c) Sample size does not affect the number of intervals that bracket the population mean. Instead, the width of the interval is reduced when sample size is increased, such that the probability of a 95% confidence interval based on a random sample bracketing the population mean remains at 0.95.
- d) Increasing sample size reduces the width of the 95% and 99% confidence intervals.
- e) The widths of the intervals vary even at a fixed sample size because of variation from sample to sample in the estimate (s^2) of population variance, σ^2 . If we knew what the population variance was (this is very hypothetical: we can never know it) and used this in the formula for the 95% confidence interval, then every 95% confidence interval based on random samples from this population would have the same width.