11. Answers to Review Problems

a) For all normality tests:
H_O: distribution is normal
H_A: distribution is not normal

Colony 1 Clutch size: no obvious skews, mild platykurtosis
$W = 0.929266$, $P = 0.3497 > \alpha = 0.05$, we fail to reject H_O.

Colony 1Wing length: positive skew, platykurtic
$W = 0.912174$, $P = 0.2163 > \alpha = 0.05$, we fail to reject H_O.

Colony 2 Clutch size: mild negative skew, platykurtic
$W = 0.942464$, $P = 0.0796 > \alpha = 0.05$, we fail to reject H_O.

Colony 2 Wing length: mild negative skew, no obvious kurtosis
$W = 0.982223$, $P = 0.8674 > \alpha = 0.05$, we fail to reject H_O.

Colony 3 Clutch size: mild positive skew, platykurtic
$W = 0.959134$, $P = 0.2116 > \alpha = 0.05$, we fail to reject H_O.

Colony 3 Wing length: mild negative skew, platykurtic
$W = 0.955024$, $P = 0.1530 > \alpha = 0.05$, we fail to reject H_O.

None of the samples provides significant evidence of non-normality.

b) H_O: $\mu_1 = \mu_2 = \mu_3$
H_A: not all the means are equal

<u>Clutch Size:</u> Tests of variance indicate that the variances are not all equal.
(df = 2,86, $P < \alpha = 0.05$, therefore we reject Ho that $\sigma_1^2 = \sigma_2^2 = \sigma_3^2$)

Test	***F***	***P* Value**
Levene	5.3795	0.0063
Bartlett	4.6345	0.0097

Note: There is no need to report the results of all methods for testing equal variance. For the lab exam rely mainly on the Levene's test. It is less powerful than the Bartlett's test, but it is more robust to departures from the assuymption of normal populations.

This is count data, so a reasonable expectation is that the square root transformation (square root of clutch plus one half) would solve problems of unequal variance. After the transform, variances are more similar and we fail to reject H_O at α=0.05 (df = 2,86):

Test	**F**	***P* Value**
Levene	2.2206	0.1147
Bartlett	2.4160	0.0893

An ANOVA for the transformed data provides an $F = 2.4019$ and $P = 0.0966$ so we fail to reject Ho; we have no evidence that clutch sizes differ.

(A Kruskal-Wallis [non-parametric] test on the raw data provides a $\chi^2 = 4.5638$ and $P = 0.1021$, so it would fail to reject H_O. If a transform works, it is a better to use the ANOVA since it is more powerful. Unfortunately, in this case, no transformation helped. As a final twist, an ANOVA on the raw data gives us a *P* value of 0.0367, which would allow us to reject the null. Since we didn't meet the assumptions of ANOVA, however, this result is invalid and a poor approximation of the true probabilities.)

<u>Wing length:</u> Variance tests provide no evidence of differing variances

Test	**F**	***P* Value**
Levene	0.3824	0.6834
Bartlett	0.4760	0.6213

The ANOVA yields an F = 2.6389 and $P = 0.0772 > \alpha$, so we fail to reject H_O, we have no evidence that wing lengths differ among the three colonies.

c) In our ANOVA of transformed clutch size we had power = 0.4726 (we had less than a 50% chance of rejecting H_O). The minimum sample size to reject the null hypothesis would have been 115, while our actual sample size was 89. There is no purpose to carrying out power analysis on the raw clutch data since an ANOVA on this data would not be valid.

For our ANOVA of wing lengths, we had a power to reject the null of 0.5118. The smallest sample size that would have let us reject was 105 (rounded up from 104.09).

d) H_O: ratios of fir nests to alder nests are the same for all colonies
(tree use is independent of colony)
H_A: tree use is not independent of colony, the ratios vary.

Use contingency test: df = 2, $G = 8.710$ and $P = 0.0128$ or $\chi^2 = 9.315$ and $P = 0.0095$, so we can reject H_O; it appears that the ratios are different.

e) H_O: $\mu = 500$
H_A: $\mu \neq 500$

$\nu = 88$, $t = 0.7059$, $P = 0.4821 > \alpha = 0.05$, therefore we fail to reject H_O; there is no evidence that female wing length differs from the North American average.

H_O: $\mu = 4$
H_A: $\mu \neq 4$

$\nu = 88$, $t = -0.3806$, $P = 0.7044 > \alpha = 0.05$, therefore we fail to reject H_O; there is no evidence that clutch size differs from the North American average.

f) H_O: $\beta = 0$
H_A: $\beta \neq 0$

Comparing a spline fit with $\lambda = 100$ to our linear fit, it appears that the relationship is roughly linear. A residual plot is messy but shows no obvious heterogeneity of variances. Residuals are slightly non-normal ($p = 0.042$); however, regression is somewhat robust to minor departures from normality. These suggest that a transform is not necessary for this data set.

$F = 131.6415$, $P < 0.0001 < \alpha = 0.05$, so we reject H_O; it appears that body size (wing length) can be used to predict clutch size. The best description of this predictive relationship is the equation of the line:

$$\text{Clutch size} = -40.764 + 0.08914\,(\text{wing length})$$