JMP Instructional data set 023

Monarch Butterflies: Male/Female Comparison

JMP STATISTICAL DISCOVERY

JMP platforms and statistical methods

Graph Builder:	Comparative dot plots
Distribution:	Goodness of fit test for normal distribution
Fit Y by X:	Normal quantile plots; two-sample variance test; two-sample comparison of means
Multivariate:	Scatterplot matrix; correlation

Problem statement

To better understand how differences in morphological features in monarch butterflies might explain higher migratory success of females over males, a study was conducted by ecologists at the University of Georgia [1].

The study selected 47 male and 45 female monarch specimens. Eleven different morphological features, such as the size and weight of various body parts and color of the wings, were measured. (Figures 1A and 1B).

Figure 1A

Figure 1B

Focus of the analyses will be to perform statistical tests comparing the means of these various features between the males and females to identify those features where there is a significant difference.

Data

IDS_023.jmp

Sex	Sex (Male , Female)
Total Wing Area	Area (mm2) of forewings and hindwings
Live Weight	Weight (mg) of butterfly live after eclosion
Dry Weight	Total Weight (mg) of butterfly after drying
Thorax Weight	Weight (mg) of thorax after drying
Relative Thorax Size	(Thorax Weight)/(Dry Weight)*100
Abdomen Weight	Weight (mg) of Abdomen after drying
Forewing Weight	Weight (mg) of forewing after drying
Relative Forewing Weight	(Forewing Weight)/(Total Wing Area) (mg/mm2)
Wing loading	(Live Weight)/(Total Wing Area) (mg/mm2)
Orange Hue	Hue of the orange portion of the wings (measured in degrees on a color wheel with lower values being more red and higher values indicating more yellow)
Black Density	Measure of the darkness of the black portion of the wings (measured in units relative to light reflectance with 0 corresponding to no light reflectance [i.e., completely black] and 255 corresponding to full light reflectance [i.e., completely white]).

Exercises

1. Create comparative dot plots for each of the 11 morphological features vs. Sex. Identify the variables where there appears to be a difference between the males and females.

> ***Instructions:***
> *Graph > Graph Builder. Place 'Total Wing Area' on the Y axis, and 'Sex' on the X. Instead of creating 11 different comparative dot plots, it would be best to utilize the Column Switcher tool so all the variables can be viewed from the one graph by selecting the variable to display on the Y Axis. To do so, select Redo > Column Switcher under the red triangle. Select the current variable used for the Y as the Column to Switch ('Total Wing Area'), and choose that along with all the others to use as the Replacement Columns. Now any of the variables can be selected to display on the graph.*

2. Evaluate if the normal distribution is an appropriate probability distribution to use to model these data? Examine this for each variable and sex separately. Make note of any variable where you believe the assumption of normality isn't appropriate as this will impact which method we use in subsequent analyses.

Instructions:
Analyze > Fit Y by X. Place 'Total Wing Area' in the Y, Response, and 'Sex' in the X, Factor. Click OK. Select Redo > Column Switcher under the red triangle. Select the current variable used for the Y as the Column to Switch ('Total Wing Area'), and choose that along with all the others to use as the Replacement Columns. Now any of the variables can be selected to use for the analysis.

To assess normality visually:
Select Normal Quantile Plot > Plot Quantile by Actual under the red triangle.
Moving through each variable, assess if the data follow the straight lines on the graph that correspond to the normal distribution.

To assess normality via a statistical test:
Analyze > Distribution. Place 'Total Wing Area' in the Y, Columns, and 'Sex' in the By role. Click OK. Use the Redo > Column Switcher tool to set up the ability to select the variable to use for the analysis display.
For each sex, select Continuous Fit > Fit Normal under the red triangle next to the variable name.
In the Fitted Normal Distribution table added to the report window, select Goodness of Fit under the red triangle. Using the Anderson-Darling test for normality, identify if there are any variables for any of the sexes that have p-values < 0.05.

3. Perform a statistical test for each feature comparing the variability between males and females? Is there any statistically significant evidence produced to conclude a difference in variability for any of the features?

Instructions:
Analyze > Fit Y by X. Place 'Total Wing Area' in the Y, Response, and 'Sex' in the X, Factor. Click OK. Select Redo > Column Switcher under the red triangle. Select the current variable used for the Y as the Column to Switch ('Total Wing Area'), and choose that along with all the others to use as the Replacement Columns. Now any of the variables can be selected to display on the graph.

Select Unequal Variances under the red triangle. Multiple methods for testing equality of variance are displayed. For those variables where you believe the normality assumption holds, examine the p-value for Bartlett's test. If there are any variables where you are concerned about the normality assumption, use Levene's test.

4. Perform statistical tests comparing the means for each feature between the males and females. Summarize the results by indicating those features that show a statistically significant difference from those that do not. Does this change any of the conclusions you reached when doing the comparisons visually in Exercise 1? For those where you identified a statistically significant difference in the means, examine the confidence intervals and provide an interpretation of these intervals in language appropriate for the researchers.

> ***Instructions:***
> *In the Fit Y by X report, select both Pooled t test and the t Test.*
> *If there were any variables where you believed the variances were not equal, it's best to view the t Test as that assumes unequal variability between the group. Otherwise, examine the Pooled t test as that's a more powerful analysis if the assumption of equal variance holds.*
> *Use significance level of 0.05 for the analyses.*

5. Calculate the correlations between all pairs of variables and create a scatterplot matrix. Identify the pairs of variables that have the strongest and weakest correlation. Examine the Scatterplot Matrix. Do these plots provide any additional insights into differences between the males and females that the analyses comparing each variable individually did not identify?

> ***Instructions:***
> *Choose a color for each sex so they can be observed separately in the graphs.*
> *Rows > Color or Mark by Column. Choose 'Sex'. Click OK.*
>
> *Analyze > Multivariate Methods > Multivariate. Place all the feature variables in the Y, Columns role. Click OK.*

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Supporting materials

1. Davis, Andrew K. ; Holden, Michael T. "Measuring Intraspecific Variation in Flight-Related Morphology of Monarch Butterflies (Danaus plexippus): Which Sex Has the Best Flying Gear?" *Journal of Insects*, vol. 2015, Article ID 591705, 6 pages, 2015. https://doi.org/10.1155/2015/591705

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