Educational Module: **"Islands as a Tool for Teaching Ecology and Evolution"**

Island biogeography is the study of the distribution and dynamics of insular (island) species. Island biogeography can also provide a foundation for the design of conservation plans. Over the past 150 years, studies of islands systems played a fundamental role in the formation of ecological and evolutionary theory (Darwin, 1859; Wallace, 1902; MacArthur and Wilson, 1967) including advances in our understanding of processes related to **colonization, extinction,** and **speciation**. Today, new technology (e.g., DNA markers, GoogleEarth, GIS applications) allows intensive studies of island systems worldwide and these studies are providing new insights into these important biomes (Ricklefs and Bermingham, 2008; Trewick and Cowie, 2008). Studies of island systems are especially important for conservation efforts because islands harbor a very large number of **endemic** species and many are endangered (or already extinct). For all terrestrial vertebrates, more than 50% of all documented extinctions in the past 400 years have been island species.

It is important to think about the history of each island. Wallace (1902) proposed that islands can be classified as either **oceanic** or **continental** by assessing their geological origin. Oceanic islands are formed over oceanic plates and were never connected to continental landmasses. These islands typically are devoid of life at the outset but gradually accumulate species from distant mainland source populations. In contrast, continental (land bridge) islands are found on the continental shelf and in the past were directly connected to the mainland, often during the Pleistocene ice advances when sea level dropped as much as 130 m (Whittaker and Fernández-Palacios, 2007). Because of their proximity to the mainland, land bridge islands are more heavily dominated by repeated colonization than are distant island archipelagoes. Repeated

colonization can result in a relatively high diversity of lineages. Some organisms also have diversified (speciated) on islands to become endemic to only that area on earth.

Morphological characters, like body size, often change for island species. The Island Rule is a principle proposed by Foster (1964) that states that large species get smaller or bigger on islands. Millien (2006) showed that rates of morphological evolution are much higher for island mammal populations than for mainland populations with significant changes evident over time scales as short as a few decades. Cardini et al. (2007) suggested rapid morphologic variation of this island population (Millien, 2006), noting that insular populations may be distinctive due not only to temporally-deep separation, but also due to peculiarities that may arise rapidly from "island life" (e.g., changes in size, fecundity, population density, behavior, survival, aggressiveness, and so forth).

I) The Influence of Island Size, Distance, and Elevation on Species Richness across a northern latitude Archipelago"

Lesson Information:
1. Key Concepts:
   a. Island biogeography principles
   b. The scientific process and hypothesis testing
   c. Statistical methods (t-tests, regression)
   d. Online database use and availability

2. Taught in Biology 203: Ecology and Evolution. Textbook: "Biological Science 4th edition, Scott Freeman, Prentice Hall, 2010."
   a. Lecture should introduce the various island effects and species diversity.
      i. Chapters that address these topics include: Evolution by Natural Selection (ch24), Evolutionary processes (ch25), Biogeography (ch50), Species richness in ecological communities (ch53), and Biodiversity and conservation (ch55).
   b. The lab will address Arctos searches, and concepts reinforcing lecture topics. Most of the work will be done as homework or a semester project. Final lab report will be due at the end of the semester with intermediate "check points" throughout.

        i.   Relevant topics in the current lab manual include: Topic 20: Evidence of Evolution, and Topic 21: Natural Selection.
- C. This can be extended to higher level courses
- D. This can be extended to other "island" systems.

3. Skills:
   a. Computer/database search
   b. Simple statistical analysis
   c. Literature search and current literature
   d. Scientific writing
   e. Writing lab reports

4. This is a hypothesis testing activity

5. Lab Report Requirements:
   a. Title
   b. A basic question, hypothesis and associated predictions
   c. Methods
   d. Results

Discussion - must include reference to at least 2 scientific papers (1 provided, 1 found by students)

Background Information:

The study area for this particular assignment is the Alexander Archipelago (AA) of Southeast Alaska, with a focus on 46 of the 1,100 named islands. The AA is part of both the largest temperate rainforest in the world, and the largest National Forest in the United States, the Tongass. The 47 islands were chosen based on specimen availability in Arctos as well as the focal islands in Mammals and Amphibians of Southeast Alaska, MacDonald and Cook 2006. Island systems are natural laboratories for evolutionary processes, due to their natural fragmentation and variation in available area. This particular island system also provides the opportunity to address issues relating to latitudinal variation, as it is a high latitude archipelago. The observed patterns may reflect those observed for both oceanic and continental islands. The AA is a continental island, with varying degrees of isolation and connectivity, as a result of historical climate change and complex glacial history. The glacial history may result in the islands acting as oceanic islands, and the ice receded from the area, providing "new" opportunities for colonization.

Species distribution has resulted in many observed biogeographic patterns. These range from effects of latitude and elevation, to effects of precipitation levels and basic species distribution and competition. Many of these observations were formalized into "rules", for example Rapoport's rule which postulates that species at lower latitudes occupy smaller ranges than those at higher latitudes, or Gloger's rule that states that within a species, darker pigmentation occurs in more humid environments and lighter coloration in drier areas.

Key Island Biogeography Trends:

* Species diversity related to island area (first proposed by MacArthur and Wilson 1963):
- Compared to the mainland, all islands should have lower species diversity.
- Small islands should have lower species diversity than larger islands.
* Body size as related to island area (first proposed by Foster 1964):
- The optimal body size is 100g.
- For organisms smaller than 100g, compared to the mainland, within a species, organisms will become larger
- For organisms larger than 100g, compared to the mainland, within a species, organisms will become smaller

In any comparison of this sort, statistics is an important tool. There are two main approaches you will use in this lab: 1) t-tests, and 2) regression analysis. The strength or robustness of the results is determined with a "p-value". A p-value indicates the probability of obtaining an observed value given a particular distribution.

A t-test is a method for testing if two sets of data are from the same distribution. The probability the two sets of data are statistically the same is described by the p-value. A p-value < 0.05 suggests the two sets are statistically different.

A regression analysis is a technique of finding the straightest possible line that approximates the information in a group of data points. The analysis will produce 2 values of interest: 1) the R2 value, which indicates the proportion of variability in a data set that is accounted for by the model. For example, if the value is close to 0, then almost none of the variability in the data points is accounted for by the given variable. However, if the value is close to 1, almost all of the variability can be explained by this variable. The other indication of this relationship is 2) the p-value. If the p-value associated with this regression is significant, then the relationship is strong, regardless of the actual R2 value, and vice versa.

Activity:

1. Obtain the excel sheet from the TA with the list of islands that have samples on Arctos and their associated areas. There should be a total of 47 listed islands. Each island also has a size group associated with it. This will be used when choosing which islands to include in your data collection and analysis.
2. Choose one of the two approaches (or assign them to each group)
    a. Total # of species across the islands (2 groups total) for 2 islands from each island group.
    b. Select 1 species (or TA can assign the species) from the list of potential species, in the Excel file with island area, to assess changes in body size as related to island area, for 3 islands per island group (4 groups total). Treat all subspecies as the same species

3. Based off your background reading, formulate a hypothesis predicting the way species diversity or body size in mammals will relate to island area. Give a brief justification of your hypothesis. How could you test it?

Species Diversity:
    Choose 2 islands in each island size group (1, 2, 3, 4)
1. Go to the Arctos database (http://arctos.database.museum/SpecimenSearch.cfm) and log in (create a user ID if you do not already have one)
2. Search the specimens for:
    a. All databases
    b. Locality – Island Name
3. Make sure the specific island, the species, the family and the mass, along with any other information you want to save, are included in this display. You may need to "customize" the results.
4. Download search (save as CSV) and import it into Excel. You may need to separate text to columns (comma-delimited).
5. Repeat steps 2-4 for each island (for a total of eight islands).
6. Repeat steps 2-4 for mainland using the following: In Arctos, under Locality, choose "Select on Google maps" and highlight region that includes the Alexander Archipelago (see map on handout). Write "Alaska" in under State, and "Mammalia" under Class. Be sure to include "Island" among the information you will save. After exporting your data into excel, highlight this data, sort by "Island" and remove all islands.
7. To create a list of which species are found on each island, highlight all your data. Under "Data", select "Remove Duplicates" and elect Scientific Name and Island name. Click OK. Review the results and remove any additional subspecies or misspellings. Sum the total number of species for each island and the mainland.
8. In your TA-provided excel sheet, fill in the Species Diversity sheet using your search data.

9. Analyze your data to observe how variation (species richness or diversity) varies across the landscape.
    a. Sort data by island size then by island group. This will make it easier for the following analysis.
    b. Perform a t-test on the data to see if island size significantly impacts species diversity. In your Species Diversity sheet, the required pairs for the t-tests are highlighted in yellow - complete the grid.
    c. To perform a t-test in Excel 2007:
        i. Go to File and select "Excel Options"
        ii. Select "Add Ins" and select "Analysis Toolpak", click OK
        iii. Under the Data tab now, you should have a "Data Analysis" tool
        iv. Select "Data Analysis", then select "t-Test: 2-sample assuming equal variances" and click OK.
        v. Variable range 1 will be all samples within one group size (ie all the data for group 1)
        vi. Variable range 2 will be all samples within a different group size
        vii. Leave rest as default and click OK
        viii. Look at P(T<=t) two-tail. This will give you the p value.
    d. Run a regression analysis on the data 2 times, both with and without the mainland samples.
        i. Include only the islands, do not include the mainland. From the "Data Analysis" select "Regression". The "input y range" should be all species diversity values. The "input x range" should be the actual island area values, not the group values. Leave the rest default. Click "OK".
            1. From the output, observe the R2 value, and the "*significance F*" (which is the p-value of this output).
            2. Create a scatter x/y graph in Excel, make sure to add a "trendline" and display the R2 value. Compare this value with that from the Regression analysis.
        ii. Repeat the above procedure, but make sure to include the "mainland" in the analysis.
10. Give a 5 minute class presentation on your preliminary results. This will be followed by a class discussion so you can include in the discussion section of your lab write-up.
11. Write up a formal lab
    a. Use the online species database, such as MaNIS or Animal Diversity Web for background on the species/family.
    b. Find at least 1 additional scientific paper that is relevant to your questions and hypotheses.
    c. Formulate two alternative hypotheses and the associated predictions of outcomes. Make sure to address the assumptions you are making in your predictions.

II) The Island Rule (Foster 1958) –Island Life Impacts Body Size

    Choose one island per island group and one species from the provided list.
12. Go to the Arctos database (http://arctos.database.museum/SpecimenSearch.cfm) and log in (create a user ID if you do not already have one)
13. Search the specimens for:
    a. All databases
    b. Locality – Island Name
14. Make sure the specific island, the species, the family and the mass, along with any other information you want to save, are included in this display. You may need to "customize" the results.
15. Download search (save as CSV) and import it into Excel. You may need to separate text to columns (comma-delimited).
16. Repeat steps 2-4 for each island (for a total of eight islands).
17. Repeat steps 2-4 for mainland using the following: In Arctos, under Locality, choose "Select on Google maps" and highlight region that includes the Alexander Archipelago (see map on handout). Write "Alaska" in under State, and "Mammalia" under Class. Be sure to include "Island" among the information you will save. After exporting your data into excel, highlight this data, sort by "Island" and remove all islands.
18. Sort by Island and delete any unwanted data.
19. In your TA-provided excel sheet, fill in the Foster's rule sheet using your search data.
20. Analyze your data to observe how body size varies across the landscape.
    a. Sort data by island size then by island group. This will make it easier for the following analysis.
    b. Perform a t-test on the data to see if island size significantly impacts body size for your organism. In your Foster's rule sheet, the required pairs for the t-tests are highlighted in yellow - complete the grid.
    c. To perform a t-test in Excel 2007:
        i. Go to File and select "Excel Options"
        ii. Select "Add Ins" and select "Analysis Toolpak", click OK
        iii. Under the Data tab now, you should have a "Data Analysis" tool
        iv. Select "Data Analysis", then select "t-Test: 2-sample assuming equal variances" and click OK.
        v. Variable range 1 will be all samples within one group size (ie all the data for group 1)
        vi. Variable range 2 will be all samples within a different group size
        vii. Leave rest as default and click OK
        viii. Look at P(T<=t) two-tail. This will give you the p value.
    d. Run a regression analysis on the data 2 times, both with and without the mainland samples.

        i.Include only the islands, do not include the mainland. From the "Data Analysis" select "Regression". The "input y range" should be all species diversity values. The "input x range" should be the actual island area values, not the group values. Leave the rest default. Click "OK".

1. From the output, observe the R2 value, and the "*significance F*" (which is the p-value of this output).
2. Create a scatter x/y graph in Excel, make sure to add a "trendline" and display the R2 value. Compare this value with that from the Regression analysis.

        ii.Repeat the above procedure, but make sure to include the "mainland" in the analysis.

21. Give a 5 minute class presentation on your preliminary results. This will be followed by a class discussion so you can include in the discussion section of your lab write-up.
22. Write up a formal lab
    a. Use the online species database, such as MaNIS or Animal Diversity Web for background on the species/family.
    b. Find at least 1 additional scientific paper that is relevant to your questions and hypotheses.
    c. Formulate two alternative hypotheses and the associated predictions of outcomes. Make sure to address the assumptions you are making in your predictions.

This activity will focus on the impact of island size on mammal size and diversity.

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