Island Biogeography and the Design of Nature Reserves

In 1967 Robert MacArthur and E. O Wilson published an extremely influential book entitled *The Theory of Island Biogeography*. In it they argued that basic ecological principles could be used to predict the number of species found on islands of different sizes. They proposed that the number of species on islands represented a balance between rates of immigration and extinction. Because small islands have fewer individuals, extinction rates are expected to be higher on small islands. The high extinction rates in turn lead to lower equilibrium number of species. (See chapter 7 of your Gotelli text for a more complete discussion).

The process of extinction in small islands can be seen when fragments become isolated from once larger contiguous patches of habitat. For example, when the Panama Canal was completed in the 1920s and Gatun Lake was formed, it created many small islands in land that was once continuous tropical forest. The number of bird and mammal species quickly declined on the islands as they apparently reached a new equilibrium with island area.

MacArthur and Wilson derived a simple relationship between species number and area, $S = cA^z$. They collected data on species occurrences on islands of various sizes and showed that the exponent $z$ [or, equivalently, the slope $(z)$ of log(species) vs. log(area)] was remarkably constant for different sets of islands.

The same logic can also be applied to terrestrial “habitat islands” such as mountaintops or forest fragments where there are “islands” of suitable habitat within a “sea” of unsuitable habitat.

(*How might climate change affect these “terrestrial islands”?)

The objective of this lab is to examine island biogeography theory in the context of nature reserves run by the US Park Service.
Part 1, the Species-Area relationship for oceanic islands and habitat islands.

Procedures.

For the first part of this exercise we will make use of an extensive database on the flora and fauna in protected areas of the world:

(http://www.ice.ucdavis.edu/bioinventory/bioinventory.html).

That database (NPFAUNA) contains basic information about each park or preserve as well as the number of species present in various groups of organisms. We will use that dataset to test two hypotheses:

1. Species richness should be a positive function of park size of the type \( S = cA^z \). If we plot the log (number of species in a park) versus the log (area of that park), we should be able to fit a straight line through the points, and the line’s slope should be positive.
2. If we compare data from mainland and island parks, the relationships between area and species richness should be positive for both, but the intercepts should be different.

To access the database, enter the web address given above and enter by clicking “Protected Areas” and open United States Parks. All US Federal Parks (regardless of designation) are listed in alphabetical order.

For this exercise, you should examine two different taxonomic groups from the set of available data (amphibians, birds, mammals, reptiles, plants).

*Make sure all parks have at least 2 species in your chosen groups.

Initially we’ll use data from national parks in the US and its territories. The parklands in the Pacific Ocean represent the most extensive group of island parks in the US system and probably are the best to use. Therefore, tally species for:

- American NP
- Hawaii Volcanoes NP
- Channel Islands NP
- Haleakala NP
- Kālaupapa NHS
- NP of American Samoa

The easiest way to record the data is to make a set of columns with the following headings: Park name, park area (record this in \( \text{km}^2 \)), and the number of species recorded (Species Richness). (There is an Excel spreadsheet already set up for you to do this.)

You will do the same for a set of mainland parks. I suggest the parks in the southeast US, which, although quite different from the Pacific Islands, are nonetheless more
ecologically similar to the Pacific Island parks than are those in the rest of the database, which are mostly in the arid western US. Quantify species for:

- Big South Fork NR/NRA
- Colonial NHP
- Everglades NP
- George Washington Birthplace NM
- Great Smokey Mountains NP
- Mammoth Cave NP
- Shenandoah NP
- Valley Forge NHP
- Moore’s Creek NHP

Now plot species richness by park area for mainland and island parks. Both species number and park area should be converted to log10-units prior to plotting to ensure that the relationship is linear. Remember that species richness (S) is dependent on park area, so S is the Y variable, and park area (A) varies independently of species richness, so A is the X variable.

To make a plot in EXCEL:
1) Download the EXCEL Spreadsheet from WebCT and save it to the desktop.
2) Fill in the appropriate information for the first 3 columns in both the Terrestrial and Island Parks (Park Area, # Species Groups 1 & 2) (This should automatically fill in the spaces in the green box which are the logged values of the data you just entered.)
3) Highlight everything inside the green box including the column titles
4) Go to Insert -> Chart and choose an X-Y Scatter Plot as the Chart Type.
5) Continue through the options by clicking next (Be sure to enter a main title and titles for the X and Y axes)
6) Save your chart as a new sheet and hit FINISH.
7) You should now have a tab at the bottom of your spreadsheet that reads CHART1.

The key attributes of a species-area relationship are the slope and the y-intercept of the line describing the relationship. This line is often referred to as a “Best-Fit Line” or a Trendline. Specifically, you will need to find the parameters m and b for the equation describing that line:

\[ Y = mX + b \]

The statistic “m” describes the slope of the relationship and tells you how much of a change in Y (number of species) exists for a unit change in X (area). The statistic “b” is the Y-intercept and is the value of Y at \( X = 0 \). These two statistics uniquely define a line. (Keep in mind all values are log values and should be exponentiated \( 10^x \) before analysis.)
To find m and b using EXCEL:
1) Go to the chart you just created by clinking the bottom tab.
2) Click once on any data point so that all similar data points are highlighted.
3) Right click on one of the highlighted data points and go to ADD TRENDLINE
4) Keep the trendline type as LINEAR and hit the OPTIONS tab at the top of the window.
5) Check the box marked DISPLAY EQUATION ON CHART and hit OK.
6) An equation of a line in the same form as above should now be next to your trendline. (You can drag the equation to a clear space so you can read it, just keep track of which equations belongs to which trendline.)
7) The final step to adding a trendline is to change its color. Double click on your trendline and choose a new color for it under the PATTERN tab.
8) Repeat steps 2 through 7 for each of your species groups. You should have 4 trendlines and trendline equations when you’re done.

Questions for discussion:
1. Is the general prediction of increasing species richness with park area borne out in both the island and mainland setting? What factors do you think underlie the basic pattern of increasing species richness with park area?
2. Why should the intercept be lower for the island sites versus the mainland sites?
3. What is the value of calculating a line through the data?
4. Surely you observe some “noise” in the relationships for both the island and the mainland plots. What might account for this “noise”?
5. Consider the mainland data for species richness. If the parklands lost, on average, 90% of their area (e.g. 10,000 ha to 1,000, or 1,000 to 100), according to your calculations, by what percent would species number change?
6. How might isolation effects differ among taxa (e.g. amphibians vs. plants)? Why?
7. What does a large b (steep slope) tell you about the importance of park size?

Part II, Inter-Continental comparisons

Now that we have compared oceanic vs. terrestrial parks in the US, it is time to find out if other regions of the world have similar species-area relationships. To do this we will choose 5-8 parks from another area of the world and plot the species-area relationships for them to compare with our US findings. We will be using our terrestrial US parks as a comparison for this section so we should try to find a comparable set of international parks. A couple things to keep in mind when choosing your new set of parks:

1) They should also be terrestrial parks. (If you’re not sure, ask)
2) They should all be in the same general region. (i.e. Southeast Asia, or West Africa)
3) They should not have a radically different climate than the Southeastern US (i.e. No Antarctic or Himalayan parks)
4) They should span roughly the same size range as our US terrestrial parks. (None significantly larger or smaller)
5) Each park should have at least 2 species in each of your chosen taxonomic groups.
**Research Question:** Is the species-area relationship similar in the two datasets?

**To do this in EXCEL:**

1) Open the PART 2 Tab
2) The data that you entered in Part 1 should already be there so you only need to add the data for the park set you chose.
3) To find the international data you will go back into the NPFAUNA database but browse through the parks of other countries by scrolling down after entering the “Protected Areas” search site.
4) Again, as you add data, the logged data should appear to the right inside the red box.
5) After all your data are entered, highlight everything inside the red box and follow the steps for making a chart and adding trendlines from Part 1.
6) After you have your new chart with trendlines, compare the US parks to the international parks.

**Discussion Questions:**

1. Why were there so many guidelines for how to choose international parks? How would ignoring them affect your results?
2. What factors could influence differences you see between the two regions?
3. If we’d used island parks instead of terrestrial parks in Part 2, would you expect your results to be different?
4. What other information would be useful when trying to interpret differences in the species-area relationships?

**Part III: The SLOSS debate**

In the 1970s people figured out that the theory of island biogeography and the species-area relationship might be used to optimize the design of nature reserves. Jared Diamond proposed that because large areas hold more species, we should concentrate on protecting a few very large habitat areas at the expense of many small parks and reserves. Others, notably Dan Simberloff, argued that small reserves can encompass more kinds of habitats. If each habitat has a distinct set of species, then the number of protected species would be larger if the same total area was spread among many small reserves. These contrasting views produced a “vigorous” (to say the least) debate among conservation biologists and became known as the SLOSS debate (“Single Large or Several Small”).

One critical empirical factor was the question of whether small habitats contain subsets of the same species found on larger islands (which would favor the single large approach) or whether each contained its own set of unique species (which would favor several small).

Using national park inventory data for the US, we will test whether more total species are contained in single large or several small reserves.
Procedure:

The database is entitled NPFAUNA and can be accessed interactively through the Internet as before.

When you have accessed the site, again use your browser to select "Protected Areas" and enter the United States Park database.

To gather the data you need, first click the mouse on the name of the park in the alphabetical left hand box and press the “Select a Protected Area” button at the bottom. As before the information should show up in the right hand box. In this right hand box, click on the hyperlinked name of the park. A new box should come up with hyperlinked numbers after the different taxon groups. Select one of the species groups you focused on in the previous 2 sections (fish, amphibians, mammals ect.) and click on the number next to it to display a species list of all the species in that taxonomic group that occur in the park. This is how you will obtain your species lists for individual parks.

1. Use the same set of parks from the Eastern US that you examined in Part 1 and choose a single group of organisms that does not contain too many species (amphibians, reptiles, or mammals would be good choices).

2. Ignoring the largest reserve in your set, calculate the cumulative number of species found in all of the smaller reserves combined. To do that you will need to combine the individual species lists so each species is counted only once.

3. Compute the total area for the set of smaller reserves.

4. To graph this data, copy the park size and species count data for the taxonomic group you choose from the Part 1 Tab and paste it into the black box under the Part 3 Tab.

5. Also add the combined park area and species count into the lower black box.

6. Just as before, insert a chart by highlighting all of the data inside the blue box and add a trendline to the # of Species data.

7. You should now be able to evaluate the position of the point representing all of your small parks.

8. Before you exit EXCEL be sure to save the file to the desktop and email it to yourself and your partner. You will need it for your homework.
Discussion Questions:

1. Is your combined parks point above or below the line?

2. What does this tell you about the SLOSS debate (at least in this case)?

3. What are some other factors that would contribute to the sensibility of one sized park or the other?

One final caveat:

The debate about the design of nature reserves has helped ecologists and conservation biologists hone their thinking about factors that determine species distributions, but conservation planners are not as concerned about the issue as they once were. People have realized that reserves are rarely if ever designed from biological or ecological principles. Instead people usually opt to preserve whatever land is available and as big a parcel as they can afford. Those very practical considerations usually supercede the ecological theory when designing actual parks and reserves.

For Homework: Write a 2-3 page op-ed piece for a newspaper explaining which side of the SLOSS debate you support and why. (You must choose one or the other! No Flip-Floppers.) Include a brief description of the SLOSS controversy and any supporting graphs of the data you collected today. In addition, identify any other factors that you think are important in deciding where parks should be located and what landscape features would benefit most from preservation.

This should be standard font and margins and double spaced. The 2-3 pages do not include figures or graphs. One complete set of the three graphs should also be handed in per group with both names on the top. This will be due in your next lab.