Colloquium 22: The Resilient(?) Earth

Assignment #3
Due in class on Tuesday April 14

Be sure that you have read:
Wilson, E. O. (1992) Chapters 11: *Life and Death of Species* and Chapter 12: *Biodiversity Threatened* and
Diamond, J.A. (1975) *The Island Dilemma: lessons of modern biogeographical studies for the design of natural reserves*.
before starting this assignment.

We have discussed the modern extinction crisis but only indirectly have we quantitatively come to grips with the magnitude of modern extinction. The purpose of this assignment is to evaluate estimates for the size of the modern extinction crisis made using Wilson's island biogeography model –the model from which some of the most commonly cited numbers on the scale of modern extinction are derived.

Island biogeography
It has been noted that as the size of an island gets larger, its biodiversity increases. There are few species on small islands with more species found as the size of an island gets larger. The increase in biodiversity does not increase linearly with island size but tends to follow a power law of the form:

$$S = C\ A^{z} \qquad \text{where}$$

S — is the number of species on the island

C — is an experimentally determined constant that relates to both island biodiversity and the taxa considered.
C represents the number of species that would be found on an island of unit area. If area is given in km^2, then C represents the number of species found on a hypothetical 1 km^2 island.
C is higher for the rainforest than for the desert (greater rainforest biodiversity) and is higher for bugs than it is for birds (more species of bugs per square kilometer).

A — is the area of the island (in km^2 here)

z — is an experimentally determined constant that could range from 0.15-0.35. Higher values of z correspond to greater endemism (fewer species with large geographic ranges).

From our readings
Wilson (p. 222) looked at amphibians and reptiles on islands in the West Indies. The biodiversity of these islands can be expressed by the species area equation:

$$S = 5.7\ A^{.24} \text{ (area in square kilometers).}$$

Diamond (p. 131) looked at non-marine bird species on islands near New Guinea. The bird diversity of these islands can be expressed by a different species area equation:

$$S = 18.9\ A^{.18} \text{ (area in square kilometers).}$$

These models indicate that both reptile and bird diversity increase by ~15% when island size doubles. The higher exponent (z) for reptiles in the West Indies indicates that they are somewhat more endemic than birds near New Guinea. The higher value of the constant C for Diamond's birds indicates that they are approximately three times as diverse as Wilson's reptiles (more bird species than reptile species).

Below are a series of questions that allow us to quantitatively investigate the island biogeography model. The first 4 questions ask you to perform island biogeography calculations about biodiversity. Do these calculations, think about the questions and answer each of the questions with a brief paragraph or two. The final question asks you to think carefully about assumptions that are implicit in the answers that you gave to the first four questions. Think carefully about this and answer in a paragraph or two.

Question 1:

Do island biogeography models make **qualitative** sense to you? Should biodiversity increase as island size increases? Should this effect decrease as islands get larger? Is there some other relationship between size and biodiversity that seems reasonable to you? If so, explicitly describe that relationship -describe how you would expect diversity to relate to size and why.
(Write an answer to this question before proceeding further with this assignment.)

Island biogeography and the global species count

It is impossible to count all of the species on Earth yet it is important to be able to **estimate** the number of species on our planet. Because rainforests are considered to house the bulk of Earth's biodiversity, great effort has gone into estimating the number of rainforest species. Even here, an accurate species count is not possible, so proxy methods such as the island biogeography model have been used to estimate rainforest biodiversity. The island biogeography model is nice -IF we know the exponent **z** in the model, then all we need to do is count the number of species on a single arbitrary small "island". Using the measured values of **S** and **A**, we can calculate the value of **C**.

The biodiversity of the rainforest is so high that hundreds of species may be found in a single tree. We can use information on the number of species collected from a small rainforest plot to come up with a rainforest species-area relationship. On our hypothetical small ~football-field size (100 m x 50 m) plot we find 3000 different species of plants and animals. From this, we can determine the following hypothetical species-area equations.

If	$z = 0.2$ (low value)	$S = 8656\ A^{0.2}$	(area in square kilometers)
If	$z = 0.3$ (high value)	$S = 14{,}704\ A^{0.3}$	(area in square kilometers)

We can now use the island biogeography model to extrapolate from this single plot to the entire rainforest using an approximate area of 10 million square kilometers for the world's rainforests. The 2 values of z given above are chosen to represent the range that is possible.

Question 2a:

Determine the global rainforest species count using BOTH of the values of z. What do you think about our assumptions? Does the species count from our plot seem high or low? Think this through, how many different kinds of plants and animals have you seen on a football field, is 3000 high or low? How does your choice of z affect the global species count? Which value seems better? Why -even though "how should I know" might seem like a reasonable answer, try to think of criteria that you would use to evaluate the two estimates (i.e. what does a choice of z mean)? *(Be very careful with this calculation, you will need to use it later.)*

Question 2b:

Wilson (p. 280) estimates that there are 10,000,000 species of plants and animals in the rainforest. How does this compare with your estimates? For BOTH z=0.2 and z=0.3, estimate how many species would be on your football field sized plot if there where as many as 10,000,000 species in the global rainforest. Does this make sense to you (i.e. does this seem like a reasonable number of species to find on a football field)?

Island biogeography and extinction

We just used the island biogeography model to estimate global rainforest biodiversity. Following Wilson, we can use the same model to estimate biodiversity loss if the rainforest is cut. If we decrease the area of rainforest, we can use the model to calculate how many species the smaller rainforest will support.

Question 3:

Using BOTH of your island biogeography values of z (0.2 and 0.3) determine the number of species predicted to go extinct if 10% of the rainforest is cut down. If 50% of the rainforest is cut down. How about if 90% of the rainforest is cut down?

What is the percentage of biodiversity lost in each of these 3 cases? How does your choice of **z** affect the number of species lost? How does your choice of **z** affect the percentage of species lost?

Island biogeography and refuges

The island biogeography model suggests that any time there is habitat loss we should expect to see extinction. However, it also suggests that the effect is not huge until the habitat loss has become extensive. The island biogeography model also allows us to evaluate models to preserve biodiversity

Suppose we create refuges –islands of remnant rainforest that are surrounded by developed land, what should we expect for biodiversity in each of our refuges? How many refuges do we need to create to preserve the present biodiversity? How big should the refuges be?

Question 4:

Using BOTH of the z values determine the number of species that would exist in a moderate sized (100 km^2) refuge. How many refuges are needed to preserve the present biodiversity (the number of species that you calculated in question 2)? Repeat this calculation with small (10 km^2) refuges.

Does this make sense? Why or why not? Does this suggest a "solution" to the extinction crisis? Based on your calculations (and only your calculations), should we try to create large or small refuges? Does this make sense? Why or why not?

The island biogeography model

The island biogeography model IS a GOOD model, but as David Jablonski said, "all mathematical models are wrong … the question is: are they usefully wrong…?"

Question 5:

Now that you have made some calculations using the island biogeography model, what do you think about it? Did it allow you to estimate rainforest biodiversity? The magnitude of the modern extinction crisis? The structure of refuges needed to preserve biodiversity? How is the model "usefully wrong"? Are there ways that the model is "meaninglessly wrong"? Is there anything that was ignored by your calculations? Think very carefully about this question. How do the assumptions that we made affect conclusions drawn from your calculations?