

# BIOL 208 Lab 9 – Island Biogeography Online

## Overview

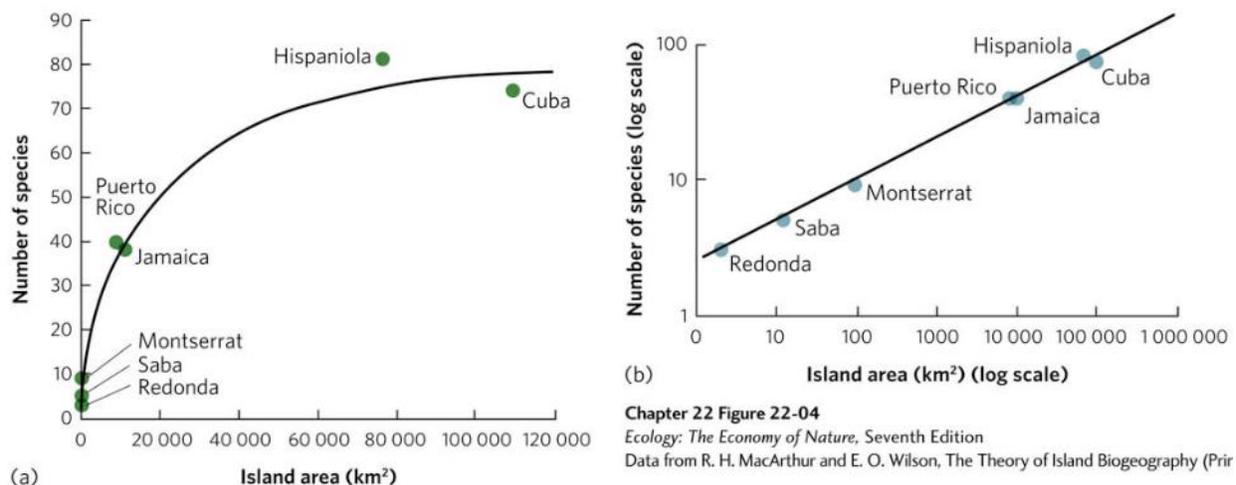
In this lab you will test the predictions of **Species Area Relationship theory (SAR)** and **Equilibrium Theory of Island Biogeography (ETIB)**.

### SAR

SAR states that increasing habitat area (island size) will increase species number at a declining rate. This pattern has been robustly supported through research on oceanic islands of different size (Figure 1). Some causes of lower species number with smaller area are as follows:

- Many species require **large areas which have abundant habitat**
- Species encounter and **colonize larger patches more frequently**
- Some **species cannot tolerate edge conditions** and edge:core ratios are higher in smaller islands
- **Smaller populations are prone to extinction**
- **Extinctions can disrupt community interactions** reducing other species populations

Figure 1



In our lab we will be simulating a SAR for different communities living on islands using the following web simulator:

<http://virtualbiologylab.org/ModelsHTML5/IslandBiogeography/IslandBiogeography.html>

### Equilibrium theory of island biogeography (ETIB)

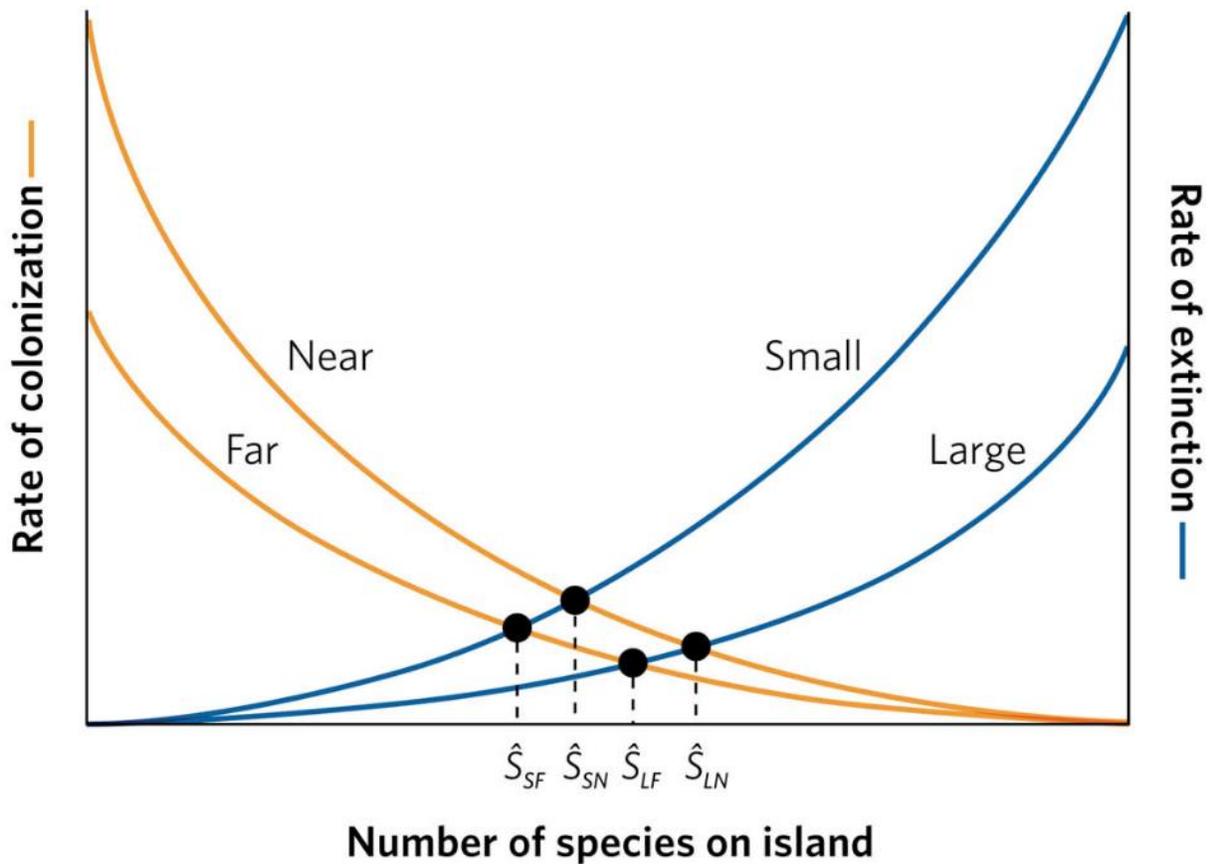
SAR theory broadly explains patterns of species abundance with island size, which can be considered a correlate of **patch quality**, but it does not explain why an island ends up with a stable abundance of species over time? Nor can it explain how variation in isolation, which can be considered a correlate of **matrix quality**, affects species colonization.

When seeking to explain why islands/patches have a particular number of species, it is sensible to think about the balance between the **extinction rate** and the **colonization rate**. The interactions between colonization and extinction is important, because species on island/patches where populations are small can often go extinct by chance. Unless new species colonize, islands/patches will decrease in species richness, until the rate of species loss is matched by the rate of new species colonizing the island. In theory, **species numbers become stable when colonization rate = extinction rate**. Extinction is largely affected by size (see SAR), while colonization is largely affected by isolation and the size of the island (likelihood of encounter).

The key information to know is as follows:

- **Smaller islands/patches have a higher extinction rate**
- **Smaller islands/patches have a lower colonization rate**
- **More isolated islands/patches have a lower colonization rate.**

This theory has been termed the *equilibrium theory of island biogeography* (ETIB). This is illustrated in the figure below, considering when extinction and colonization are in balance for islands of different size (small versus large) and distance from the nearest colonization source (near versus far), such as a continental landmass.



During your lab today, you will explore the ETIB using the same simulator with which we'll explore the species area relationship (SAR).

### Habitat Fragmentation

Notably, SAR theory and ETIB theory are now informing our understanding of **habitat fragmentation**. Although habitat fragments are not strictly speaking 'islands', we can see that the broader concept of ISAR relates to the area of a habitat patch, its isolation from other patches (matrix and distance), and the characteristics of the other patches (how many species they contain).

We may predict that species numbers will decline as human land-use both, **(i) decreases habitat patch size, (ii) decreases patch quality, (iii) decreases connectivity between habitat patches and (iv) decreases matrix quality (colonization)**. Consequently, habitat fragmentation poses a significant threat to biodiversity and is a major conservation concern. Measures to promote increased habitat patch size and connectivity through **creation of habitat corridors and ecological restoration of large habitat patches** have therefore been promoted.

### Principles of species diversity

So far we have explored models that predict species diversity in the environment. We measure factors such as island/patch size and isolation/matrix. However, these are simply correlates of the underlying causes of species extinctions (habitat quality) and dispersal capacity (matrix quality). Try to think about what mechanisms are driving these patterns?

**Why does island size correlate with species diversity?**

**Why does isolation correlate with species diversity?**

**What other factors might affect species diversity on islands?**

#### Timeline

- (15 mins) Introduction and reading
- (60 mins) Models in Virtual Biology Lab – Island Biogeography
- (30 mins) Questions and Analyses

#### Pre-lab

- Read chapter 22 '*Landscape Ecology, Biogeography and Global Biodiversity*', in the course text book. Also read the following manuscript on Moodle if desired:

Whittaker, R.J., Fernández-Palacios, J.M., Matthews, T.J., Borregaard, M.K. and Triantis, K.A., 2017. Island biogeography: Taking the long view of nature's laboratories. *Science*, 357(6354)

#### Learning Outcomes

- **Run model simulations to test theory**
- **Collect data to test species-area relationship on islands of different sizes**
- **Explain how size and isolation of habitat patches affect species diversity**
- **Run models to investigate predictions of equilibrium theory of island biogeography**
- **Compare experimental treatments using simple statistics**

#### Activity 1 – Virtual Biology Lab – Island Biogeography

Open the website lab simulator:

<http://virtualbiologylab.org/ModelsHTML5/IslandBiogeography/IslandBiogeography.html>

Read the simple instructions and then follow the directions below as you experiment.

- Start with the basic settings with both islands, don't change the size or the distance. Begin your simulation at normal speed, watch the species establish and reach a relatively stable average in the Data window.
  - Speed up the running average to 8x and run for around 1000 generations, this is a good speed for each of your simulations as you experiment, but 2000 is better for accurate results.
  - Change the Migration rate to 1 and the mortality rate to 0.1, then reset your islands (clear islands). This yields clearer results.
- Now try a few of your own combinations of settings for size and distance to island, habitat type and taxa. Hint, try changing distance or size and then move between taxa or habitats. Changing one thing at a time makes this clearer.

*These are some example settings to try showing: (i) the experimental design window and (ii) the matching data collection window.*





Copy and paste your excel data here, replacing the table below

Island Size	$\pi D$	Log area ( $\pi D$ )	Species #	Log Species #	Species # class data	Log Species # Class data
64.00	201.06	2.30				
96.00	301.59	2.48				
128.00	402.12	2.60				
160.00	502.65	2.70				
192.00	603.19	2.78				
224.00	703.72	2.85				
256.00	804.25	2.91				

3. Plot Figures to show your own data and the class data and paste these below

*Insert figures here*

4. What relationship does the class data show?
5. How and why do your data and the class data differ?
6. Why does species richness increase with island size? Try to think of at least three causes.
7. Does the class data show logarithmic growth? Why might the rate of increase slow as species richness increases?

### Activity 3 – Equilibrium Theory of Island Biogeography (ETIB) – Part 1

We'll now explore the Equilibrium Theory of Island Biogeography. This theory recognises that species richness is a consequence of island size and isolation. Together these determine the rates of species colonization and species extinction, the outcome of these two processes will be the species richness of an island. ETIB makes several assumptions about how island area and distance from mainland will affect colonization and extinction. Consider these in the following questions:

8. Why might extinction rates be higher on smaller islands?

9. Why might colonization rates be lower on smaller islands?

10. Why might colonization rates be lower the further islands are from a colonization source?

- Now run model simulations where you practice testing the ETIB. Feel free to try a different taxa or habitat. Fill in the table below for your own data where you do the following:
  - o vary island distance while keeping size the same.
  - o vary island size while keeping distance the same.

	Near	Far
Small		
Large		

**Questions:**

11. How does island distance to the mainland affect species richness?

12. How does island size affect species richness?

13. Why does the actual number of species on an island fluctuate over time?

14. What equilibrium point does the average species richness represent?

- Now run your own model simulations to compare how taxa and island distance interact for a medium island (128)

	Near (10)	Medium (190)	Far (410)
Arthropods			
Mammals			

15. What relationship do arthropods show with island distance from the mainland compared to mammals and why might this be?

- Now run your own model simulations to compare how arthropods vary with island size at a set distance (410)

	Small (64)	Medium (128)	Large (256)
Arthropods			

16. For arthropods, Is the relationship between island size and species richness the same as for island distance and species richness? Why might these differ?

### Activity 3 – Equilibrium Theory of Island Biogeography (ETIB) – Part 2

In this section we will test the main predictions of ETIB:

#### Species diversity resolves when colonization events = extinction events

To test the **Equilibrium theory of Island Biogeography (ETIB)**, we will each run the following two simulations and average the class results.

Simulation 1: Copy the parameters in the image below and run the simulation. Pause between 500 – 550 and enter the data in the tables below:

**Experimental Design**

Habitat: Tropical, **Subtropical**, Temperate, Tundra, Desert

Island Distance (Km): Island 1: 10, Island 2: 350

Island Diameter (Km): Island 1: 64, Island 2: 64

Taxon: Arthropods, **Birds**, Reptiles, Mammals

Migration Rate: 1, Mortality: 0.01

Clear Islands

8X To Data



**Experimental Design**

Habitat: Tropical, **Subtropical**, Temperate, Tundra, Desert

Island Distance (Km): Island 1: 10, Island 2: 350

Island Diameter (Km): Island 1: 224, Island 2: 224

Taxon: Arthropods, **Birds**, Reptiles, Mammals

Migration Rate: 1, Mortality: 0.01

Clear Islands

8X To Data



Simulation 2: Do this simulation after Simulation 1

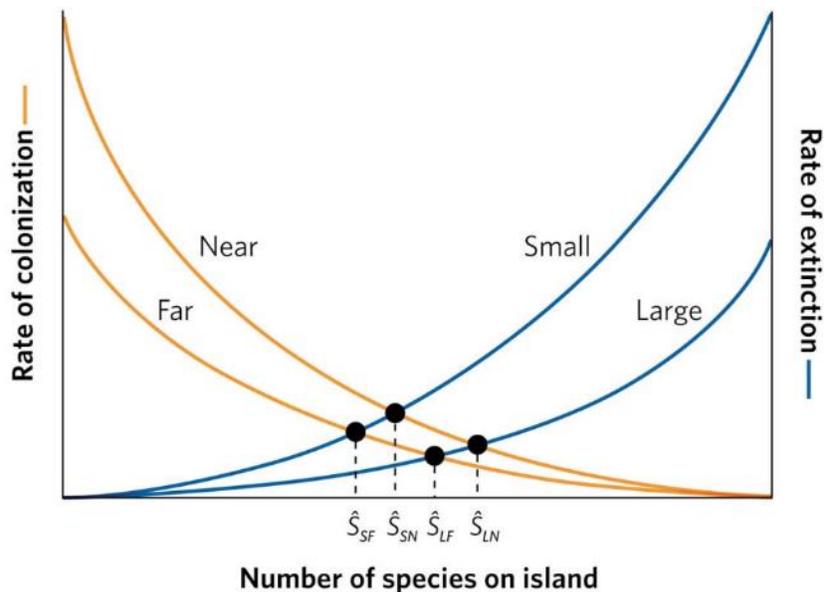
Own Data	Near	Far
Small		
Large		

Enter your data into the class results in the online spreadsheet

Class data	Near	Far
Small		
Large		

Consider the patterns observed in relation to the figure below illustrating the ETIB.

17. Do the class data for average species richness correspond to the black circle points in the figure?



### Activity 3 – Equilibrium Theory of Island Biogeography (ETIB) – Part 3

So far, we have explored the predictions of ETIB by examining species richness, but we have not tested whether the species richness values observed are a consequence of extinction and colonization rates.

18. How might we test this?

#### Methods:

- Compare islands with the following 4 sets of characteristics and with standardized habitat and taxa as for part 2. Set up islands with the following characteristics.

- o Big and near
- o Big and far
- o Small and near
- o Small and far small

Note: you will work on only one island at a time even though there are two on the screen

- Run the simulator for 500runs at 8x
- Slow the run speed to 1x, and then count colonization on one island for 1000 - 1250 runs as exactly as possible (ignore the other island)
  - o Colonization = every time the species number increases on the island; ignore when the number goes down.
- Then count extinction from 1250-1500 runs (ignore the other island)
  - o Extinction = every time the species number goes down; ignore when the species number goes up.
- Example where colonization = **bold** and extinction would equal *italic*
- **0, 1, 3, 2, 3, 4, 3, 2, 1, 0, 1, 2, 1,
  - o If this pattern occurred from 1000-1250 then you would record  $7/250 =$  colonization
  - o If this pattern occurred from 1250-1500 then you would record  $6/250 =$  extinction**
- We don't count colonization and extinction at the same time because it would get confusing to tally both simultaneously.
- Repeat these steps for each of the four island types
- Now use your methods to test the predictions of the ETIB. You will have to make a data table and insert it here, check the excel document for possible options.

*Paste data table here*

19. Plot the outcome of colonization and extinction rate for island size and island proximity

*Paste figure here*

20. Did colonization rate increase with:

a. Proximity:

b. Island Size:

21. Did extinction rate increase with:

a. Proximity (would we expect this):

b. Island Size:

22. Did these results confirm or negate the equilibrium theory of island biogeography. Why or why not?

**When complete, please upload your lab to the eLearn folder**