Amphibian Islands: How Habitat Size and Connectivity affect Species Richness and Extinction Rates

Recommended Age/Grade Level: 8-12th grades with at least 4 students; See "Activity Modifications" below for College level classes

Potential Concepts Addressed:

- ☐ Evolution - MacArthur-Wilson Equilibrium Theory of Island Biogeography, Extinction, Adaptive Radiation, Bottleneck and Founder's effects, Allee Effect, Predation Release, Ability/Barriers to Adaptation
- ☐ Ecology and Conservation – Generalists vs. Specialists, Niche Partitioning, Release from Ecologic Barriers, Source-Sink Population Dynamics, Single Large or Several Small (SLOSS) Reserves, Habitat Fragmentation
- ☐ Amphibian Declines

Objective: This lesson plan is designed to help the learner better understand the MacArthur-Wilson Equilibrium Theory of Island Biogeography - including how the theory predicts the effect of habitat size and proximity to source populations on species richness and extinction - by using AmphibiaWeb's country and state search features and online research into various geographic regions. Additionally, students will practice transferable skills by presenting research findings and participating in discussions of how the theory connects with real world situations.

Background:

In 1967, ecologists, Robert MacArthur and E. O. Wilson published "the Theory of Island Biogeography" to explain the real world phenomena of varying numbers and densities of species (often called species richness) on different islands. They incorporated the size of the island, distance from the mainland, and age since isolation to predict how many species an island would have. The theory predicts that large islands close to the mainland would have the most species, while small, distant islands would have few species, and that islands that are older would have more species. The logic being that large islands could sustain more species than small islands (thus reducing extinction and emigration rates), islands closer to the mainland would be more likely to have colonization or immigration of new species onto the island, and older islands would have had more time for colonization events to occur. Because size and distance are two mutually independent factors the theory also had predictions for small close islands and large distant islands (figure 1).

Two years later the theory was tested by Wilson's graduate student, Daniel Simberloff, on mangroves in the Florida Keys and shown to hold true for distance only – all the mangrove islands were of similar size, and thus size was not tested. Since then the

Theory of Island Biogeography has been used to explain other species richness questions in areas where a species habitat is isolated, such as mountain-tops, and ponds and lakes. The theory has also been used to discuss how to set up optimal reserves for conservation purposes.

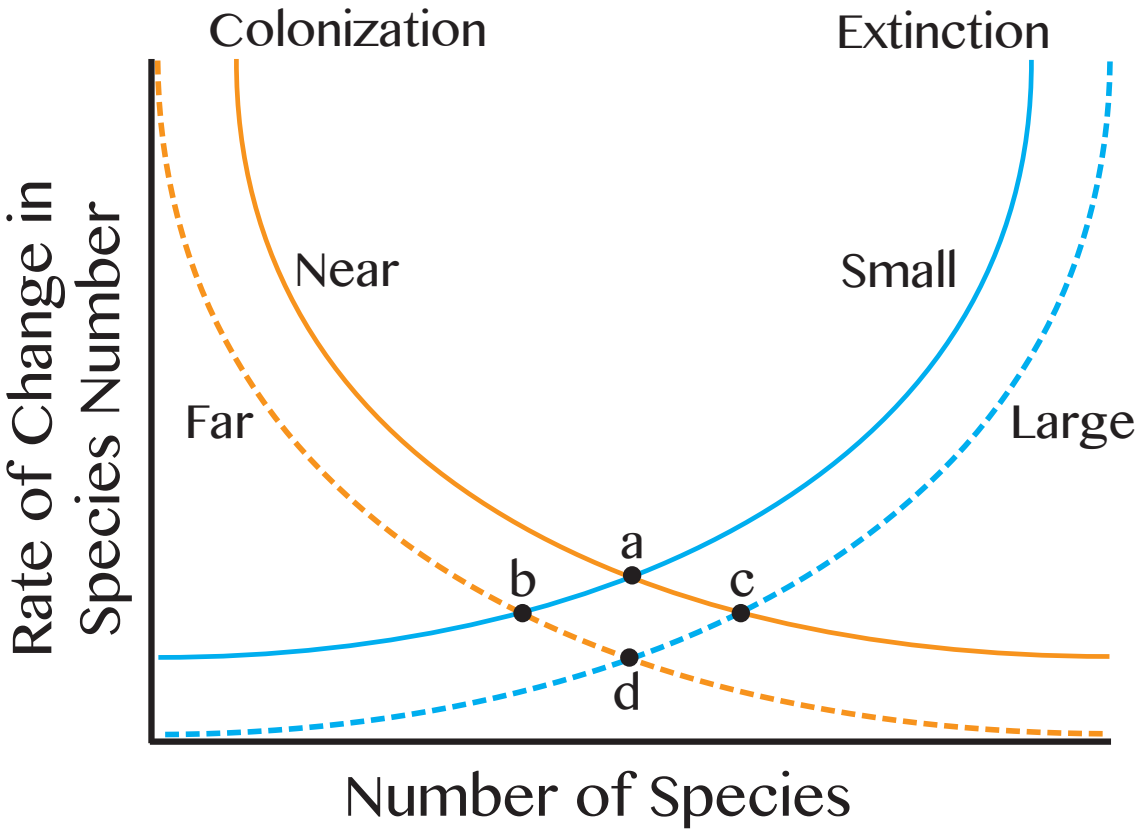

Figure 1: Rate of change in species number via extinction, colonization, immigration, and emigration predicted by the Theory of Island Biogeography for different sized islands with varying distances from the mainland where a) indicates the number of species found on small islands close to the mainland, b) indicates small islands far from the mainland, c) indicates large islands near the mainland, and d) indicates large islands far from the mainland. The rate of change shown here is a generalization and can have different slopes to indicate more gradual or rapid rates of change. Additionally islands could differ in distance to the mainland or size, which would be indicated by curves move upward and toward the center or downward and away from the center.

Materials/AWeb Pages Needed:

- ☐ Sample Prompts (See below)
- ☐ AmphibiaWeb Search page http://amphibiaweb.org/search/index.html
- ☐ Access to the internet

Length of Time for Activity: 5 days, or see modifications at the end of this document for a shortened version.

Set-up: Determine and print prompts for countries to research. Assign individuals or groups countries. Keep in mind some countries (like India) have a large number of species and may need more time to research or larger groups.

Procedure:
Individuals or groups of students will be given a prompt (see samples below) outlining a country or region in which amphibian decline may be a concern. Students will find the total number of species in their country or region using the AmphibiaWeb Country or State Search Options. Included in that search, students will determine the number of endemic species, the proportion or total number of species that are at risk of extinction and/or are extinct, and find what causes of decline are most prevalent (potentially by sub-setting for countries with high species diversity). After gathering information on AmphibiaWeb students will also research their assigned country over the course of several days to answer the following questions individually:

1. Are there any amphibian declines in your country? What is the general cause of declines in Amphibians in your country? How might the declines be alleviated?

2. How might the Theory of Island Biogeography apply to the causes of decline in your country? Hint: Are there geographic barriers in your country that create patches of habitats? Is your country an island or mainland? If it's an island, how far is it from the closest mainland?

Students will then present and discuss their findings to other students with different countries:

a. Compare your country with another group that shares a broad geographic region with you. Do your countries share the same species? Do you have similar answers for questions (1) and (2)? What does this tell you about your region and your country? Why might your answers to question (1) and (2) differ?

b. Compare your country with a group that has a very different geographic region. Do your countries share the same species? Do you have similar answers for questions (1) and (2)? What does this tell you about your region and your country? Why might your answers to question (1) and (2) differ?

Lastly, to wrap up the activity, bring the whole group together for a large discussion to see if/ensure that some of the above concepts have been touch upon. For suggested discussion questions see below.

Suggested Multi-day Schedule:
Day 1 and 2 – Introduction of assignment and research using AmphibiaWeb.org and other country information (potentially at home or in computer labs)
Day 3 – Small Group Presentation and Discussion: Question 1 - Regional comparisons of declines
Day 4 – Small Group Presentation and Discussion: Question 2 - Non-regional comparisons of declines.
Day 5 – Whole group Discussion

Suggested Countries: (See sample prompts at the end of this document)

1. Costa Rica (199 species/56 endemic species) – pair with Puerto Rico
2. Puerto Rico (26/14) – pair with Costa Rica
3. United Kingdom (15/0) – pair with France
4. France (42/4) – pair with the United Kingdom
5. Italy (48/14) – pair with Malta
6. Malta (2/0) – pair with Italy
7. Turkey (35/11) – pair with Cyprus
8. Cyprus (3/0) – pair with Turkey
9. Equatorial Guinea (50/2) – pair with Sao Tome and Principe
10. Gabon (96/6) – pair with Sao Tome and Principe
11. Sao Tome and Principe (7/7) – pair with Equatorial Guinea and/or Gabon
12. Mozambique (69/0) – pair with Madagascar, Mayotte, and/or the Seychelles
13. Tanzania (200/89) – pair with Madagascar, Mayotte, and/or the Seychelles
14. Madagascar (296/293) – pair with Mozambique and/or Tanzania.
    Note: Madagascar has more species than adjacent mainland countries because of differences in biomes. This can lead to a discussion of the effect of habitat and niches on species richness as well as vicariance.
15. Mayotte (1/0) – pair with Mozambique and/or Tanzania
16. Seychelles (12/11) - island chain, pair with Mozambique and/or Tanzania
17. India (347/246) – pair with Sri Lanka
18. Sri Lanka (120/101) – pair with India
19. China (396/256) – pair with Taiwan
20. Taiwan (42/18) – pair with China
21. Australia (238/217) – pair with New Zealand
22. New Zealand (7/4) – pair with Australia
23. Also consider the **U.S. State** of Hawaii, which only has introduced amphibians to enable discussion of isolated island chains and modern transportation (7/0)

Caveats:

- ☐ Be sure students determine if species are introduced (which can be found on individual species accounts) as it is not explicit in the search results.
- ☐ When choosing island countries, be sure to only pick islands that are single countries. Islands that are part of a mainland country will show species for the whole country rather than just the island. Islands composed of several islands will not specify endemics to specific islands. And islands that contain multiple countries will only give search results for countries not the whole island.
- ☐ Related to the previous point, the Philippines and Papua New Guinea (along with Madagascar) are the most species rich islands, but they are composed of several disperse islands and divided into two countries respectively. Thus they are not appropriate for this exercise.

Discussion Questions: Please note this list is not exhaustive and we welcome your comments or suggestions on more discussion questions.

Basic Questions (with sample answers):

Amongst the islands researched, which islands had the most species? Does this fit with MacArthur-Wilson's theory? What might be some reasons your islands do or don't?

> Sample answer: In addition to larger islands being able to sustain more individuals and more species and closer islands having more source material for more species, the latitude of the islands may play a role in real life. As ectotherms, few amphibians can live in very cool climates. Thus islands closer to either pole are less likely to have high amphibian richness in comparison to islands along the tropics are more likely to have high amphibian richness.

What are some reasons that larger island size contributes to greater species richness?

> Sample answer: Larger islands have more resources allowing for a higher carrying capacity. Additionally, larger islands have greater potential for more niches (or diversity of habitats) that would allow for niche partitioning of species and adaptive radiations (a great example of this is in the anole group of lizards). On the other hand, small islands are more likely to suffer from Allee Effects - problems associated with small population size, such as individuals being unable to find each other for mating and greater risk of inbreeding – or genetic drift – the loss of genetic variation due to random events such as natural disasters or loss of habitat through man-made events.

What are some reasons islands closer to the mainland would have greater species richness?

> Sample Answer: When islands are closer to the mainland they are more likely to have immigration onto the island and emigration off. Increased immigration allows for greater genetic diversity from more "founding" events and quicker re-colonization after disasters. Emigration to the nearby mainland helps the chances of survival of individuals when the carrying capacity of the island is reached because they have a better chance of successfully leaving the island. Both immigration and emigration help increase genetic diversity of the species on both the island and mainland. The effect of movement can also be beneficial in tight clusters of islands, but to a smaller extent. However, increased genetic exchange may not always be beneficial. If selection pressures of different populations are very different or opposing, immigration and emigration would cause the lost of local adaptations and could actually be detrimental to the migrating individual or to local populations if several migrating individuals were to successfully reproduce.

In what instances might an island have greater species richness than the mainland?

> Sample Answer: An island could have greater species richness if its habitat is significantly different than the mainland and better suited for a particular type of species. The best example of this is that Madagascar, which has six climate regions and many rivers, has more amphibian species than the closest mainland countries, which are largely desert climates. Another extreme and theoretical reason an island could have more species is if the island is a natural reserve while the mainland is highly degraded or has experienced a large scale natural disaster.

Evolution Questions:

What characteristics do you think would be necessary for a species to colonize a newly formed island?

What features on the island and/or of the species would allow a species to undergo adaptive radiation once it settled on an island?

How might increased global transportation affect immigration rates to islands? What consequences does this have on food webs, local ecology, and the evolutionary potential of introduced species?

Ecology and Conservation Questions:

Island Biogeography has been used to debate reserve management for conservation purposes. The main debate is whether to have one large reserve or several small reserves that are near each other (this debate is often abbreviated to SLOSS for Single Large or Several Small). What are some of the pros and cons for both types of reserves?

Habitat fragmentation is a major cause of amphibian declines. How might this affect your stance on the SLOSS debate? What might you do to alleviate habitat fragmentation if you could only have several small reserves?

In some cases, patches of habitat may appear to be appropriate but actually lack an essential feature for a species' survival. In terms of Island Biogeography, these patches, or islands, stay occupied because of emigration from the "mainland". This is called source-sink population dynamics, where the source is the mainland and the sink is the island. How would you identify this dynamic, and if your reserve is a sink, how would you fix it?

Activity Modifications:

- ☐ Reduce activity to a 2-day activity by:
    - Choosing a smaller geographic area to focus on and not exploring the country's background. Suggested regions include:

        - Caribbean island countries and surrounding mainland countries
        - India, Sri Lanka, and the Maldives
        - Tanzania, Mozambique, Madagascar, Mayotte, Comoro Island, Seychelles, Reunion, and Mauritius – be prepared to discuss the effect of different biomes and vicariance
    - Having students look up the species decline at home and spend the first day in small group discussions and the second day on whole group. discussions covering 1-5 of the potential concepts in further detail.
- ☐ Grades 11 to College Modifications:
    - Instead of or in addition to the group discussion, have students write essays taking a position on SLOSS given their understanding of Island Biogeography.
    - Include Hawaii and have an extended discussion about how global transportation affects conservation efforts. Be sure to include benefits, such as ease of translocations and increase genetic diversity, as well as detriments, such as introducing invasive species. Alternatively, use this as an essay prompt.

References/Further Reading:

Allee W.C., Bowen E. 1932. Studies in animal aggregations: mass protection against colloidal silver among goldfishes. Journal of Experimental Zoology 61(2):185–207.

Losos, J., Rickefs, R. 2010. Theory of Island Biogeography Revisited. Princeton Univ Press.

Pulliam, H.R. 1988. Sources, sinks, and population regulation. American Naturalist 132:652-661.

MacArthur, R.H., Wilson, E.O. 1967. The Theory of Island Biogeography, Princeton University Press

Simberloff, D.S., and Wilson, E.O.1969. Experimental Zoogeography of Islands: The Colonization of Empty Islands. Ecology 50:278–296.

You are a citizen scientist in **Costa Rica**. You have been finding fewer and fewer species of amphibians in your area over the last two decades. Finding out about AmphibiaWeb.org, you decide to investigate your observation on the website; are the declines real or could it be individual error?

1. Are there any amphibian declines in your country? What is the general cause of declines in Amphibians in your country? How might the declines be alleviated?

2. How might the Theory of Island Biogeography apply to the causes of decline in your country? Hint: Are there geographic barriers in your country that create patches of habitats? Is your country an island or mainland? If it's an island, how far is it from the closest mainland?

You are a researcher in **Puerto Rico**. You notice that some of the salamanders you study are just as easy to find as always, but other species are becoming more rare. Using AmphibiaWeb.org as a resource, find out which species are in decline and which are doing well.

1. Are there any amphibian declines in your country? What is the general cause of declines in Amphibians in your country? How might the declines be alleviated?

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You are a student in **India**. You just learned about amphibian declines and AmphibiaWeb.org in class. You're curious about how well amphibians are doing in your country and decide to investigate.

1. Are there any amphibian declines in your country? What is the general cause of declines in Amphibians in your country? How might the declines be alleviated?

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You are a researcher in **Sri Lanka**. Aware of habitat modification in your area and global amphibian declines, you decide to investigate how the local amphibians are faring by using AmphibiaWeb.org.

1. Are there any amphibian declines in your country? What is the general cause of declines in Amphibians in your country? How might the declines be alleviated?

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As a researcher in **Australia**, you are aware of problems with Cane Toads (*Rhinella marina*) on the continent but want to know what other threats amphibians face. Using AmphibiaWeb.org, estimate or find the major causes of amphibian declines.

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You are a teacher in **New Zealand** who is about to cover local ecology in your class. You know there aren't many amphibians in your country, but decide to look up how many and what their threat status is on AmphibiaWeb.org to create a new lesson plan.

1. Are there any amphibian declines in your country? What is the general cause of declines in Amphibians in your country? How might the declines be alleviated?

2. How might the Theory of Island Biogeography apply to the causes of decline in your country? Hint: Are there geographic barriers in your country that create patches of habitats? Is your country an island or mainland? If it's an island, how far is it from the closest mainland?