Student Outline
with Arctos updates for 2023

Do Larger Islands Have Greater Species Richness?
Testing a Biodiversity Hypothesis Using Data from Natural History Collections

Figure 1. "Overcast skies over Kuiu Island" by Roy Luck / CC BY 2.0

Learning Objectives

- Formulate a testable hypothesis
- Evaluate assumptions of existing datasets
- Use digitized natural history collections data to test a biological hypothesis
- Analyze, explain, and predict patterns of species diversity on islands
- Manipulate, graph, and analyze data in a spreadsheet
- Determine if data support a hypothesis in context of biological theory
- Appreciate the importance of natural history collections

Pre-module Preparation

1. Watch video about using natural history collections by undergraduates (https://www.youtube.com/watch?v=rL7kAv323Bk)
2. Watch video about digitizing natural history collections data (https://www.youtube.com/watch?v=WyRc6QtZQgo)
3. Watch video about Arctos (https://www.youtube.com/watch?v=LvMPR8QbYB4)
4. Watch video about Excel tools to become familiar with Excel (https://www.youtube.com/watch?v=0tdlR1rBwkM)
5. Read the relevant sections of your textbook about Island Biogeography
6. Review the Glossary of Terms for any vocabulary that is unfamiliar

Modified from: Jordan, C. N., Krumm, J. L., Doan, T. M., Kilgore, J., & Linton, D. (2019). How many critters can an island hold? Using digitized natural history collections to test real hypotheses about island biogeography. *Tested Studies for Laboratory Teaching, Proceedings of the Association for Biology Laboratory Education, 40*, Article 9. Modified by: J. L. Krumm

Introduction

Island biogeography is the study of the distribution and dynamics of species on islands. Due to their natural fragmentation and variation in available area, island systems are natural laboratories for evolutionary processes. Island biogeography can also provide a foundation for the design of conservation plans, given that many habitats all over the world have become fragmented due to human-initiated habitat disturbance and loss. Over the past 150 years, studies of island systems have played a key role in the formation of ecological and evolutionary theory, including advances in our understanding of colonization, extinction, and speciation. Today, new technologies (e.g., DNA markers, Google Earth, Geographic Information Systems applications) allow intensive studies of island systems on a global scale, and these studies continually provide new insights about how nature works on islands. Studies of island systems are especially important for conservation efforts because islands harbor a large number of range-restricted endemic species of which many are endangered. Furthermore, among terrestrial vertebrates, more than 50% of all documented extinctions in the past 400 years have been island species.

Islands can be classified as either oceanic or continental by assessing their geological origin (Figure 2). 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 through primary succession. In contrast, continental (land bridge) islands are found on the continental shelf and in the past were directly connected to the mainland, most recently during the Pleistocene ice ages when sea levels dropped by as much as 130 m. Because of their proximity to the mainland, land bridge islands are more heavily dominated by repeated colonization than are distant island archipelagos. Repeated colonization can result in a relatively high diversity of organisms. Some organisms may also have speciated on the islands themselves, with new species arising that are endemic to only that area on Earth.

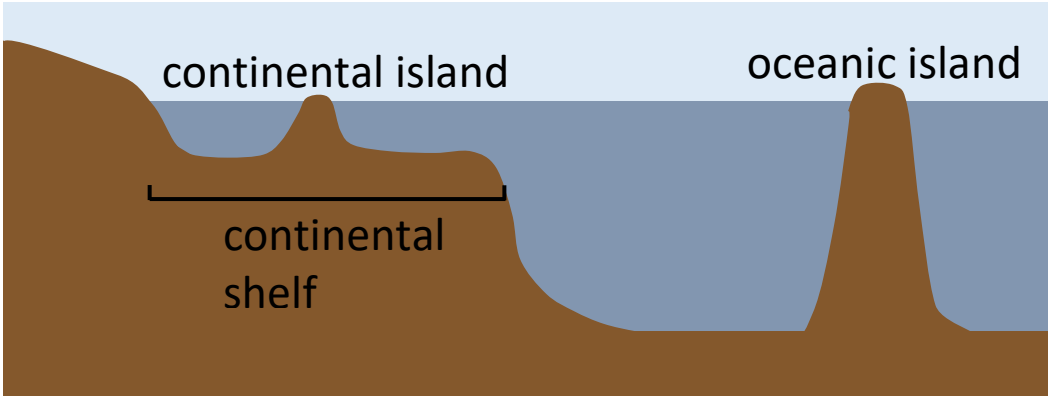

Figure 2. Continental and oceanic islands

The islands studied in this module are part of the **Alexander Archipelago** (AA) of Southeast Alaska (Figure 3). This archipelago contains about 1100 named islands, all of which are continental 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.

Figure 3. Map of the Alexander Archipelago. Modified from "Map of Alaska, Yukon Territory and British Columbia showing connections of the White Pass and Yukon route." Library of Congress.

This module will focus on a subset of the 1100 named islands. These islands were the focus of collection efforts for the publication of "Mammals and Amphibians of Southeast Alaska" (MacDonald and Cook 2006) and were chosen for this module based on specimen availability in digitized natural history collections. The AA is a continental island chain, with varying degrees of isolation and connectivity, as a result of historical climate change and a complex glacial history. For example, since some islands were covered in ice at different times, only when the ice receded could colonization occur to these islands as if they were isolated oceanic islands. Table 1 on the next page includes a list of the 29 islands with associated areas that will be used in your study.

Figure 4. Representative mammals of the Alexander Archipelago from the Museum of Biological Diversity, Ohio State University; photograph by Janice Krumm

Table 1. Alexander Archipelago islands available for study. Island name and land area (in m^2) are provided. Islands are sorted by increasing land area.

Island	Area (m^2)
West Brother	3,261,843
Hassler	4,348,176
Inian	12,275,281
Vank	14,153,023
Woewodski	15,227,909
Shelter	21,782,299
Lemesurier	27,502,850
Krestof	27,932,716
Warren	45,264,308
Bell	51,055,878
Woronkofski	59,548,409
Tuxekan	69,872,791
Lulu	73,852,111
Coronation	74,703,312
San Fernando	85,419,535
Noyes	97,369,520
Baker	115,552,154
Suemez	149,242,517
Sukkwan	166,256,014
Heceta	172,401,840
Gravina	244,366,553
Kruzof	438,573,289
Kosciusko	442,826,651
Zarembo	475,011,969
Dall	655,013,180
Etolin	874,560,363
Kuiu	1,922,681,313
Kupreanof	2,796,753,052
Baranof	4,056,530,258
Admiralty	4,341,948,688
Chichagof	5,312,164,867
Prince of Wales	6,611,533,020

In order to conduct research on publicly-available data, such as natural history collections data, we will:

1. Develop a testable hypothesis
2. Investigate the data resources
3. Collect (download) the data
4. Clean the data to remove errors and to discard unneeded data
5. Visualize the data to discover patterns
6. Explain the results and write conclusions

Develop a Testable Hypothesis

In this activity, you will be investigating the relationship between the size of an island and the number of species found on that island (i.e., species richness).

1. Discuss this idea with your team and develop a testable hypothesis. Write your hypothesis below.

2. Describe how you would test this hypothesis if you did not have access to any pre-existing data.

Investigate Data Resources

Fortunately, scientists have collected and stored data that can help you test your hypothesis. These data are located in natural history collections. Most of you know about some of the great museums, such as the Smithsonian or the American Museum of Natural History (remember the *Night at the Museum* movies?), where animal specimens are exhibited. These institutions derive their importance not only from the public exhibits, but they are also critically important repositories of the evidence underpinning everything we know about nature! Natural history collections data are based on archived specimens, maintained by qualified museum staff in perpetuity to serve as references for the taxonomy, evolution, and ecology of the species. These so-called voucher specimens are linked with valuable metadata (e.g., collection date, location, habitat, images, community assemblage, seasonality, climate) and remain accessible for repeatable or expanded observations when information needs to be verified, when new questions arise, or when new and better investigative techniques are developed. Natural history collections provide a source of biodiversity data that is unparalleled in temporal, geographic, and taxonomic complexity.

As you can imagine, such a huge repository of data is only useful if it can be widely accessed. As a consequence, museums have been diligently working to put their collection data into systems that allow researchers (and students!) to use this information with just a few clicks. The portal called Arctos is one such system.

Arctos integrates access to diverse types of collections (e.g., plants, insects, mammals, birds, amphibians, reptiles, fossils, parasites), including basic specimen data, field observations, availability of tissue samples for DNA studies, presence of parasites, and data on stomach contents. It can also be used to access other documents and media, such as photos, audio recordings, and video. The system can be used by professionals (e.g., collection managers, curators, scientists) and the public, but also by educators and their students to access natural history information.

3. For this activity, navigate to Arctos: http://arctos.database.museum/. Click "I agree" to access the database.
   a. Look at the webpage. Exactly how many records are accessible through the Arctos portal today?

   b. What are the different criteria that you can specify in the search tool?

Collect Species Richness Data

4. We will examine the data from all 32 islands. Your instructor will help you divide up the islands among teams of students. Each student should be able to do a search.

5. Go to the Arctos database (https://arctos.database.museum/), and create a user ID. Then click on your user name in the top right corner, then "Profile", and complete your personal profile. You must fill in all required yellow boxes.

6. Go back to the Arctos home page and perform a search for each of the islands you were assigned, following the instructions below.
   a. Under **Identifiers** click the blue **choose** button. Click the blue **Select All button** at the top of the page. Then click the yellow **Use Selected** button.
   b. Scroll down to the **Place** section of the search fields. In the **Any Geographic Element** box, type in **Alexander Archipelago**.
   c. In the **Specific Locality** box, type your island name (example: West Brother Island).
   d. Scroll down to the bottom and click on the blue **Submit Query** button.

7. Your results will appear at the bottom of the search page. Click on the **Customize Results** button. Make sure at least the following fields are selected with a blue check mark in the list displayed, then click on the yellow **Save** button.
   island group
   island
   state/province
   phylclass
   species

   Note: It is much easier to clean up your data in Excel, so don't worry about removing any unwanted rows before downloading.

8. Next to the **Customize Results** button, you will find a **Tools** dropdown box. Select **Download**. Choose **educational** as the purpose of the download and read and agree to the terms of use statement. Then select **Continue to Download**.

9. Rename your downloaded data file with the name of the island.

10. Repeat Steps 6–8 for each island that you were assigned.

11. What assumptions are we making about the data you have collected from Arctos?

12. What are the most common species on your islands?

Clean Your Data

13. To create a list of species found on each island, open each spreadsheet individually in Excel or Google Sheets. Select all of your data. Sort by "phylclass" and delete any rows that are not mammals.

14. Under the Data tab, select "Remove Duplicates" and select the column containing the Scientific Name. Click "remove duplicates". (If you are using Google Sheets you will need to activate the Add-On for Remove Duplicates.)

15. Sort by Scientific_Name and review the results. Treat all subspecies as the same species, i.e. remove any additional subspecies or misspellings.

16. Count the total number of species for each of your assigned islands, and enter these data into Table 2.

Table 2. Island areas and species richness.

Island Name	Area (m^2)	Number of Species

17. On the class Google Sheet prepared by your instructor, type or paste in your data from your table (Island Name, Area, and # Species). Be careful not to delete any data that were entered by other students.

Visualize Your Data

18. Create a scatterplot of number of species (Y-axis) vs. island area (X-axis) for all of the islands. Add labels to the axes, delete the title, and add a descriptive figure legend below the graph. Turn in the graph as directed by your instructor.

Explain Your Results

19. What relationship, if any, is shown by the graph?

20. Do these data support or reject your hypothesis? Explain your evidence.

21. What additional hypotheses might you be able to test using the types of data available in digitized natural history collections?

Glossary of Terms

Colonization: the action by an organism of establishing itself in an area.

DNA markers: genes or DNA sequences with a known location on a chromosome that can be used to identify individuals or species.

Endemic: a species whose range is restricted to a particular country or area.

Extinction: the dying out or termination of a species.

Fragmentation: the process of breaking or being broken into smaller parts.

Geographic Information Systems (GIS): a computerized system designed to capture, store, manipulate, analyze, manage, and present spatial or geographic data.

Google Earth: a browser that accesses satellite and aerial imagery and other geographic data over the internet to represent the Earth as a three-dimensional globe.

Pleistocene: the geological epoch that lasted from about 2.5 million years ago to 11,700 years ago, spanning the world's most recent period of repeated glaciations, also known as ice ages.

Primary succession: one of two types of ecological succession of organisms, occurring in an environment in which new land is devoid of vegetation and other organisms and usually lacking soil, such as a lava flow or area left from retreated glacier. Species arrive and begin to establish a new habitat.

Speciation: the formation of new and distinct species in the course of evolution.

Specimen: an individual animal, plant, piece of a mineral, etc., used as an example of its species or type for scientific study or display. Specimens may consist of the organism itself or a photo, audio recording, or other type of evidence.

Temperate: latitudes of Earth that lie between the tropics and the polar regions.

Terrestrial: living on or in the ground and not aquatic.

References

MacDonald, S. O. & Cook, J. A. (2007). Mammals and amphibians of Southeast Alaska. Special Publication Number 8. Albuquerque: Museum of Southwestern Biology. 191 p.