

On the Web: Measuring Biodiversity across North America

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Grades 9 – 12

National Education Science Standards Met—See Appendix A

I. Introduction

Biodiversity is a term of science that has made its way into the civic vocabulary, from news reporting to middle school lesson plans on rain forests. To many, biodiversity simply refers to the number of different kinds of living things, or species richness. Scientists often add species abundance, or the number of individuals within a species or population, to the commonly understood definition. The full definition adds genetic and ecological diversity to the kinds of living things. Biodiversity measures can be critical in valuing land- and seascapes. Biodiversity assessments tell us how rich areas are in supporting different kinds of organisms, and how unique one area is compared to other such areas. In this sense, investigating biodiversity uncovers both patterns of evolutionary processes, and the relative worth of one area to another, at least for this one, intrinsic value. Incidentally, the parallels to economics are striking when one thinks about taxa and individuals as currency. Table 1 depicts the three levels of biodiversity matched against the conservation values of irreplaceability and vulnerability. Essentially, this is the matrix by which value can be placed on landscapes.

		LEVELS OF DIVERSITY		
		Genetic	Taxonomic and Phylogenetic	Ecological
C O N S E R V A T I O N	Irreplaceability (loss)			
	Vulnerability (threats)			

Table 1. The relationship between biodiversity and conservation values.

Through this series on measuring biodiversity students will conduct investigations based on their own questioning, they will develop a methodology, collect and analyze data, test hypotheses, and communicate results. Each example given is a model for analysis with step-by-step procedures for investigating categories of questions on biodiversity and the inherent value of the different landscapes of North America.

Goals

As a result of completing an investigation into the biodiversity of North American Mammals, all students should develop an understanding of the following.

- The concept of biodiversity, and ways to measure the diversity of organisms
- The role of taxonomy in assessing biodiversity
- Associations between the distribution of organisms and environments
- How to plan and conduct an investigation

In addition, students should become more familiar with the mammal communities and ecoregions in their residential areas, the biomes and ecoregions across North America, and practice independent inquiry about the natural world.

II. Comparing different ecoregions

Example Case: The Biodiversity of the North American Deserts.

Are all the deserts and arid regions of the West and Southwest pretty much the same? This is a biome-level question that looks at the integrity or the evenness of species richness and composition across a biome. The question does not lead to comparisons of desert and semi-desert regions to other biomes, such as the taiga. Those questions can also be investigated using similar methods.

There are a few desert/semi-desert regions in the southwestern United States and northern Mexico, for example, the Sonoran Desert, Chihuahuan Desert, and Mojave Desert. One may wonder if the three deserts are pretty much the same in terms of species, and for this example, mammal species. One might also ask which of the three ecoregions has the greatest biodiversity, and whether that ecoregion is also the most unique, that is, having the greatest number of species not shared with the other ecoregions. Let's handle the first question.

Do the three deserts share the same mammal species?

Finding the number of mammal species for each desert is really simple using the interactive map on the [North American Mammals](http://www.mnh.si.edu/mna/) website (<http://www.mnh.si.edu/mna/>). Comparing the species across the three ecoregions is very doable as well, and it involves collecting and organizing information.

Smithsonian Institution

National Museum of Natural History

North American Mammals

Welcome to the National Museum of Natural History's North American Mammals web site. This is a searchable database of all living mammals of North America.

[Enter Site](#)

This site is based on *The Smithsonian Book of North American Mammals*, by Don E. Wilson and Sue Ruff (Smithsonian Institution Press, 1999) and *Mammals of North America*, by Roland W. Kays and Don E. Wilson (Princeton University Press, 2002).

To enjoy the enhanced features of this site, you'll need these plugins: Macromedia Flash · Quicktime · Adobe Acrobat Reader
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To begin, go online to the North American Mammals website (<http://www.mnh.si.edu/mna/>).

Once at the website's homepage, enter the site, and go to the "Map Search" page. This is a GIS map capable of searching locations for mammal species (To learn more about the map, go back to the menu by clicking on the Smithsonian logo in the upper left-hand corner, and go to "About Maps" in the navigation frame.)



Included in this biodiversity packet is a tutorial that plays in any browser—MapTutor (<http://www.mnh.si.edu/mna/Resources/MapTutor.swf>)—that dynamically demonstrates using the GIS map for this activity. Open MapTutor by dragging and dropping the file into an open browser, such as Internet Explorer or Mozilla Firefox, and it will play automatically.

The GIS map is easy to use, so if you feel adventurous and want a self-guided experience, then skip the demo and play with the labeled tools and map layers in the right hand column.

You are now ready to collect data on the three ecoregions. Turn on the ecoregion layer (click box), refresh the map, and activate the zoom tool. Zoom to the Mojave Desert region in the southwestern United States.



Ecoregions will appear after zooming in a couple times. Make an ecoregion query by activating the Ecoregion Search tool—it changes to orange--and clicking anywhere within the boundaries of the Mojave Desert. You will get a list of 129 mammal species ordered taxonomically. Congratulations! You have your first data set.

Search the Archive	Search Results
<ul style="list-style-type: none"> Species Name Family Tree Conservation Status 	<p>Ecoregion: Mojave desert</p> <p>129 records returned.</p> <p>Click the species name for a detailed record.</p> <ul style="list-style-type: none"> Order: Artiodactyla (Even-toed Ungulates) <ul style="list-style-type: none"> Family: Antilocapridae (Pronghorn) <ul style="list-style-type: none"> <i>Antilocapra americana</i> (Pronghorn) Family: Bovidae (Bison, Sheep and Goats) <ul style="list-style-type: none"> <i>Ovis canadensis</i> (Bighorn Sheep) Family: Cervidae (Deer) <ul style="list-style-type: none"> <i>Cervus elaphus</i> (Elk) <i>Odocoileus hemionus</i> (Mule Deer) <i>Odocoileus virginianus</i> (White-tailed Deer) Order: Carnivora (Carnivores) <ul style="list-style-type: none"> Family: Canidae (Dogs) <ul style="list-style-type: none"> <i>Canis latrans</i> (Coyote) <i>Urocyon cinereoargenteus</i> (Common Gray Fox) <i>Vulpes macrotis</i> (Kit Fox) Family: Felidae (Cats) <ul style="list-style-type: none"> <i>Lynx canadensis</i> (Canada Lynx) <i>Lynx rufus</i> (Bobcat) <i>Puma concolor</i> (Cougar)
<p>Collections</p> <ul style="list-style-type: none"> Skulls Bones and Teeth 	
<p>Field Guide</p> <ul style="list-style-type: none"> Map Search Location Search About Maps 	
<p>Glossary</p> <p>About the Site</p>	
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In Table 2 (a separate download from biodiversity package; http://www.mnh.si.edu/mna/Resources/Table_2.doc), these data are recorded along with the two other ecoregions. The table organizes the data for making comparisons, and for straightforward mathematical analysis. Looking at Table 2, it is easy to see which species occur in more than one ecoregion and which occur uniquely in only one ecoregion. This table is the basis for calculating the similarity between ecoregions, and Jaccard's Similarity Index is used for this purpose.

Table 2
Diversity of Mammals by Terrestrial Ecoregion

North American Mammals Website
<http://www.mnh.si.edu/mna>

Species Occurrence	Terrestrial Ecoregion		
	Mojave Desert	*Sonoran Desert	Chihuahuan Desert
Species Richness	129	152	149
Jaccard's Similarity Index		54%	38%
Unique Species as %	3.1%	.7%	20.8%
Threats (NT, V, E, CE)	2/5/0/2		
EVEN-TOED UNGULATES			
Pronghorn (<i>Antilocapra americana</i>)	X	X _e	X
Bison (<i>Bison bison</i>)		X	X
Bighorn sheep (<i>Ovis canadensis</i>)	X	X	X _v
Moose (<i>Alces alces</i>)			
Elk (<i>Cervus elaphus</i>)	X	X	X

Table 2. A partial image of the table. The entire table is available for download (see paragraph above)

Jaccard's Similarity index gives a numerical value to comparisons between two different samples. For this example, two of the three ecoregions in the set are each compared against the the third region, Mojave Desert.

Jaccard's Similarity Index works by dividing the number of things (species) common to two samples (j) by the number of unshared species found in both samples (r), multiplied by 100. The result is a percentage of similarity for two lists of things.

$$\text{Jaccard's Index} = j/r \times 100$$

Sample #1
 4 things

▲ * ■ *

Sample #2
 4 things

▲ * ● ●

$$\begin{aligned}
 \text{Jaccard's Index} &= 2/(2+2) \times 100 \\
 &= 2/4 \times 100 \\
 &= 50\%
 \end{aligned}$$

Using the data from Table 2, the pair-wise comparisons are as follows.

Mojave Desert compared with
 Sonoran Desert Jaccard's Index = 54%
 Chihuahuan Desert Jaccard's Index = 38%

Uniqueness of Regions

In addition to Jaccard's Similarity Index, the number of species that are unique to each region, compared to all others, gives another measure of the distinctiveness of a region. The number of endemic species is one way to assess the irreplaceability factor. Table 2 is used to identify and calculate the percentage of species that occur uniquely in one of the three regions, which are shown in Table 3.

Table 3 Uniqueness as % of Total Species		
Ecoregion	Number of Unique Species	Unique Species as Percentage of Total
Mojave desert	4	3.1%
Sonoran desert	11	.7%
Chihuahuan desert	31	20.8%

Table 3. Uniqueness as % of Total Species.

Based on the total number of species, Jaccard's Similarity Index, and both the total number and the percentage of unique species, one can conclude that the Chihuahuan desert is the most valuable ecoregion for mammalian fauna. This ecoregion ranks second in total species, first in both total number and the percentage of unique species, and has the lowest similarity index among the group.

This technique may be used for National Parks, States, or any predefined map layer. States, provinces, and parks can be queried using the "Location Search" feature on the [North American Mammals](#) website.

III. Comparing different latitudes

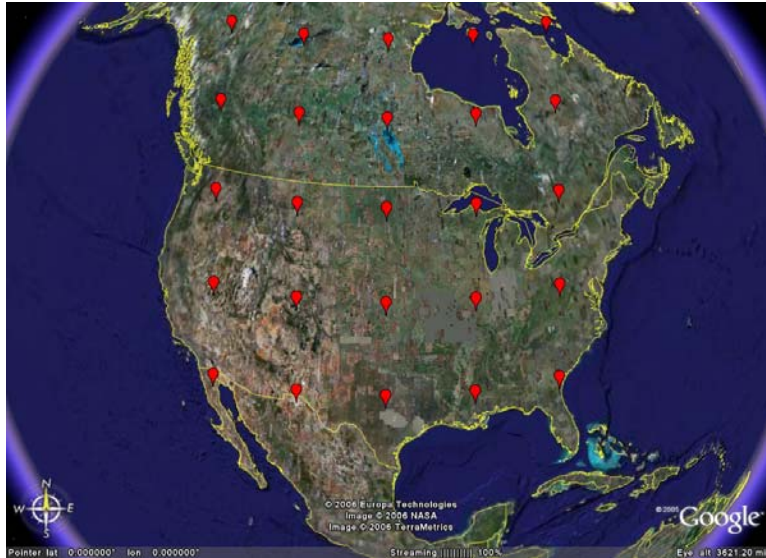
Example Case: Patterns of Biodiversity Associated with Changes in Latitude.

Rather than comparing ecologically cohesive areas, one may wish to investigate the influence or association of latitude on patterns of biodiversity. As latitudes are not actual areas, samples are collected across transects. This example uses a grid of roughly 500 mi. x 500 mi. For latitude, 7.5^o intervals were chosen spanning from 32^oN to 62^oN. 7.5^o latitude is close to 500 miles (more like 518 miles). Calculating degrees longitude at 500 mile intervals is trickier as the degrees of longitude vary with latitude when holding 500 miles constant. Calculating distances along longitudinal lines involves a bit of trigonometry. If students have not yet acquired the mathematical skills to calculate distances across latitudes and longitudes, there are a number of websites that will do this for them (see Web resources below). The important notion for creating a grid is to have a method that allows for sampling at intervals that are equidistant from one another. Table 4 provides the coordinate data for a roughly 500 x 500 mile grid; decimal degrees have been converted to degrees and minutes for use in the North American Mammals website.

Table 4 Sampling Points for North American Grid					
Latitude	32 ^o N	39 ^o 30' N	47 ^o N	54 ^o 30' N	62 ^o N
Longitude	81 ^o 30'W	80 ^o 00'W	77 ^o 30'W	73 ^o 30'W	67 ^o 30'W
	90 ^o 00'W	89 ^o 15'W	88 ^o 00'W	86 ^o 00'W	83 ^o 00'W
	98 ^o 30'W	98 ^o 30'W	98 ^o 30'W	98 ^o 30'W	98 ^o 30'W
	107 ^o 00'W	107 ^o 45'W	109 ^o 00'W	111 ^o 00'W	114 ^o 00'W
	115 ^o 30'W	117 ^o 00'W	119 ^o 30'W	123 ^o 30'W	129 ^o 30'W

Table 4. Sampling Points for North American Grid.

The mapping application Google Earth^{©2005} was used to place map pins on each of these locations as a way to see how it all looks. The points are available for download (<http://www.mnh.si.edu/mna/TeacherResources.cfm>).



Google Earth^{©2005} Image of Sampling Points.

To sample mammal species at each map pin, the latitude and longitude for each point is placed into the appropriate boxes on the North American Mammals website. A species list is generated for each point, and all the species ‘collected’ along a line of latitude are combined into one list, much like an ecoregion list. To see how this data are generated using the North American Mammals website, play the animated file, **SamplingTutor** (<http://www.mnh.si.edu/mna/Resources/SamplingTutor.swf>) in a browser. The latitude columns in a new species table, Table 5, correspond to the latitude columns in Table 4, the sampling grid table. A portion of this table is shown below. The table may be downloaded as a file.

Table 5
Diversity of Mammals across Line of Latitude

(Entries show species occurrence at any longitudinal point for a given latitude)

Species Occurrence					
Latitude	32° 00' N	39° 30' N	47° 00' N	54° 30' N	62° 00' N
Species Richness	135	132	103	63	48
EVEN-TOED UNGULATES					
Pronghorn <i>(Antilocapra americana)</i>	X	X	X		
Mountain goat <i>(Oreamnos americanus)</i>			X	X	
Bighorn sheep <i>(Ovis canadensis)</i>	X	X	X	X	
Dall's sheep <i>(Ovis dalli)</i>				X	
Moose <i>(Alces alces)</i>			X	X	X
Elk <i>(Cervus elaphus)</i>		X	X		

Table 5. Samples Across Lines of Latitude (partial image; complete table at http://www.mnh.si.edu/mna/Resources/Table_5.doc)

This is how to generate the data. On the “Location Search” page, enter the coordinate data for the first sample location; say **32⁰⁰N, 81³⁰W**.

Once the longitude and latitude are entered, mouse-click the “Search Species” button. The website will return a list of species for that location. These are the species with geographic ranges overlapping the location. A check of any species range maps from the species pages will verify this fact.



You can use Table 5 (http://www.mnh.si.edu/mna/Resources/Table_5.doc) or a BlankWorkSheet (<http://www.mnh.si.edu/mna/Resources/BlankWorkSheet.xls>; this Excel file includes all 426 species) as a template. To do so, enter the species from one location into the “Species Occurrence” column, and place an “X” in the cell for each species at the location that was sampled along a transect. For each following location along the same transect, only add those species that are not yet in the Species Occurrence column, and check them off as well. Continue filling in the table for as many sample locations as you plan to include. In making these comparisons, it is best to have the same number of sample locations representing each line of latitude; otherwise problems of scale and place may corrupt the investigation.

When all the data are collected and the table completed, pairwise comparisons can be made. The method for comparing biodiversity across latitudes is identical to the method we used to compare biodiversity across ecoregions. In this case, students should not only determine which transect represents the greatest biodiversity; they should also look for trends and patterns of diversity across transects.

By ranking transects according to their overall values for biodiversity, it is possible to see whether there is a trend of increasing diversity associated with decreasing latitude. Putting the data into a histogram is a nice way of graphically depicting biodiversity across transects. Any outlier in a perceived trend is an opportunity for further investigation. One variable that is not held constant in this particular approach is elevation. Students may want to consider how this might affect the results.



Appendix A National Education Science Standards

The named standards have been incorporated into the two lesson activities provided.

Unifying Concepts and Processes Standard

- Evidence, models, and explanation.
- Change, constancy, and measurement

Science as Inquiry Standards

- Skills necessary to become independent inquirers about the natural world.
- An appreciation of "how we know" what we know in science.
- Understanding of scientific concepts—Biological diversity, and biogeography

Other Important Elements Incorporated into these Lesson Activities

- Planning and conducting investigations
- Using appropriate tools and techniques to gather data
- Thinking critically and logically about relationships between evidence and explanations
- Diversity and adaptation of organisms
- Links to direct student observations of the natural world—to the ecoregions they live in
- Organisms and environments
- Emphasis on learning subject matter in the context of inquiry, technology
- Emphasis on groups of students analyzing and synthesizing data