BIOGEOGRAPHY

Teacher's Manual

The Kuril Biocomplexity Project: www.kbp.org

Table of contents

Subjects:
Earth Sciences, Life Science

Duration:
One class period (~60 min.) +

Class size:
10 - 30

Summary

Overview:

This module deals primarily with the geography of the Kuril Islands and the constraints that this geography puts on the numbers and kinds of animals (including humans) that are able to inhabit the islands. The scientific study of this relationship is called island biogeography. For information on the distribution of plants (phytogeography) and how this might have changed through deep time, please consult the Paleoclimate teaching module.

Goals:

To familiarize students with the science of biogeography, as well as the wide range of physical and geological processes that help to structure biogeographic patterns.

Objectives:

- Students will be able to explain how animals can populate islands
- Students will be able to compare animal distributions in time and space and create hypotheses for changes over time or differences in space

Material:

- Introductory Slide Show
- Student worksheets

Vocabulary

Biogeography:

The scientific study of how geography affects where different species of animals live (see also **phytogeography**).

Chlorophyll A:

A pigment used by plants to store energy from the sun through the process of photosynthesis.

Colonize:

To establish a breeding population in an area that had not previously been occupied.

Disperse:

To spread outward from a species' native home range. To "disperse to" a new area simply means to arrive there safely (see also colonize).

Distribution:

1. The geographical patterning or location/s of something (e.g., the distribution of sea ice in the Sea of Okhotsk).
2. In statistics, the patterning, or spread, of a series of data points (e.g., the distribution of radiocarbon dates through time)

Fast ice:

Ice that is connected to shore.

Pack ice:

Free-floating chunks of ice that drift across the ocean pushed by wind and water circulation.

Phytogeography:

The scientific study of how geography affects where different species of plants live (see also biogeography).

Phytoplankton:

Free-floating plants that are usually made up of a single cell. Phytoplankton get their energy from the sun, and make up the base of the food chain.

Primary productivity:

A measure of how much of the sun's energy is captured by plants and made available in the food chain.

Zooplankton:

Free-floating microscopic and macroscopic animals.

Background Information

The Kuril Island Chain is part of a volcanic island arc that began forming 90 million years ago (during the Cretaceous Period) when an oceanic tectonic plate collided with the Siberian continent. The oldest island in the chain is Urup, which emerged from the sea 4.21 million years ago.

Island chains have a variety of characteristics that make them special in the biological world. They come in all manner of different shapes and sizes. Given that different kinds of animals have different home ranges, the size of an island can have a significant influence on the kinds of animals that are able to survive there.

By the same token, the distance between islands, or between any given island and the mainland, will influence what species are likely to disperse to an island as well.

This is due to the fact that there are only three paths animals can take to get to an island:

- By land
- By sea
- By air

There are, of course, different options within each of these paths. For instance, "by land" can involve crossing dry land during periods of lower sea level, but it could also involve walking across sea ice.

Likewise, one image of how animals might arrive "by sea" involves swimming. This works well for marine mammals and fish, but for most terrestrial mammals this is only feasible for crossing narrow gaps between islands.

Consider, though, that small animals may raft across water crossings on logs, vegetation, or ice, and when it comes to water travel, humans have been very good at making boats for many thousands of years.

Finally, the "by air" pathway is limited to those animals that can fly such as insects, birds, and bats. In this module, the only flying animals we will deal with are birds, although both insects and bats are found throughout the Kurils.

All of these limitations will influence which species can (a) disperse to and (b) successfully colonize islands within the Kuril Island Chain.

Even for many of the animals that can easily swim or fly to islands, such as birds or pinnipeds (seals, fur seals, and sea lions), they are often still tied to terrestrial habitat as part of their breeding cycle. Sea birds, for instance, often nest on cliffs or in burrows. Likewise, even though pinnipeds can stay at sea months or years at a time, they must return to land to mate and give birth to their pups.

This need to return to shore makes sea birds and pinnipeds particularly vulnerable to predation by terrestrial predators such as foxes, bears, and humans.

For a more detailed consideration of how the geography of the islands and the geological history may have affected the resulting animal distributions, examine Figure 1, which shows the relative distances between the islands and the depths of the passes between them. Even during the Last Glacial Maximum (LGM), when world-wide sea levels were 150 m lower than they are today, only a few islands were connected to their neighboring mainlands (Kunashir to Hokkaido, in the south, and Paramushir and Shumshu to Kamchatka, in the north).

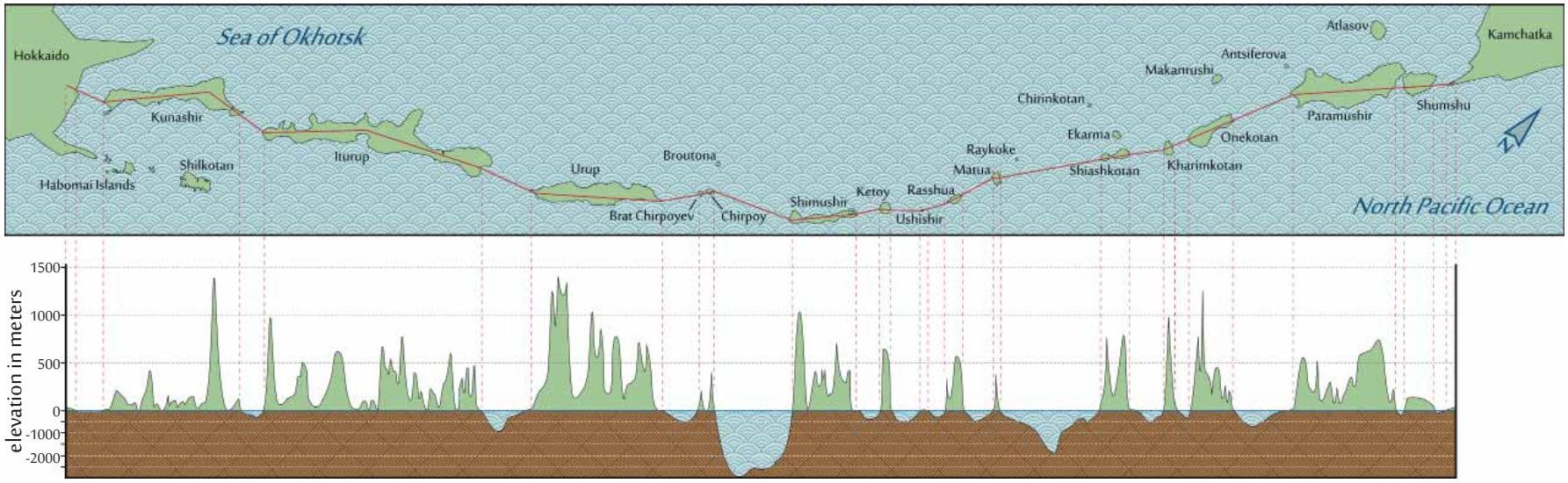

Figure 1: Cross section of Kuril islands showing topography (green) and bathymetry (blue). Vertical scaling is exaggerated to highlight the mail features.

There are two more important pieces to the biogeography "puzzle" at work in the Kuril Islands: sea ice distribution, and the distribution of marine nutrients. Sea ice primarily plays a role as a dispersal mechanism for terrestrial mammals, but sea ice is also important to several species of pinnipeds, including ringed seals and walrus. In most places in the northern hemisphere, northern areas tend to have more ice accumulation than southern areas, but this is not the case in the Kuril Islands. Counter-intuitively, sea ice concentrations in the Kurils tend to be highest in the southern portion of the island chain. This is because sea ice produced in the northern Sea of Okhotsk circulates counter-clockwise in ocean currents, and accumulates in late spring around Kunashir and Iturup, and occasionally Urup, as well. The presence of sea ice provides an important avenue of dispersal for terrestrial mammals coming to the Kurils from Hokkaido.

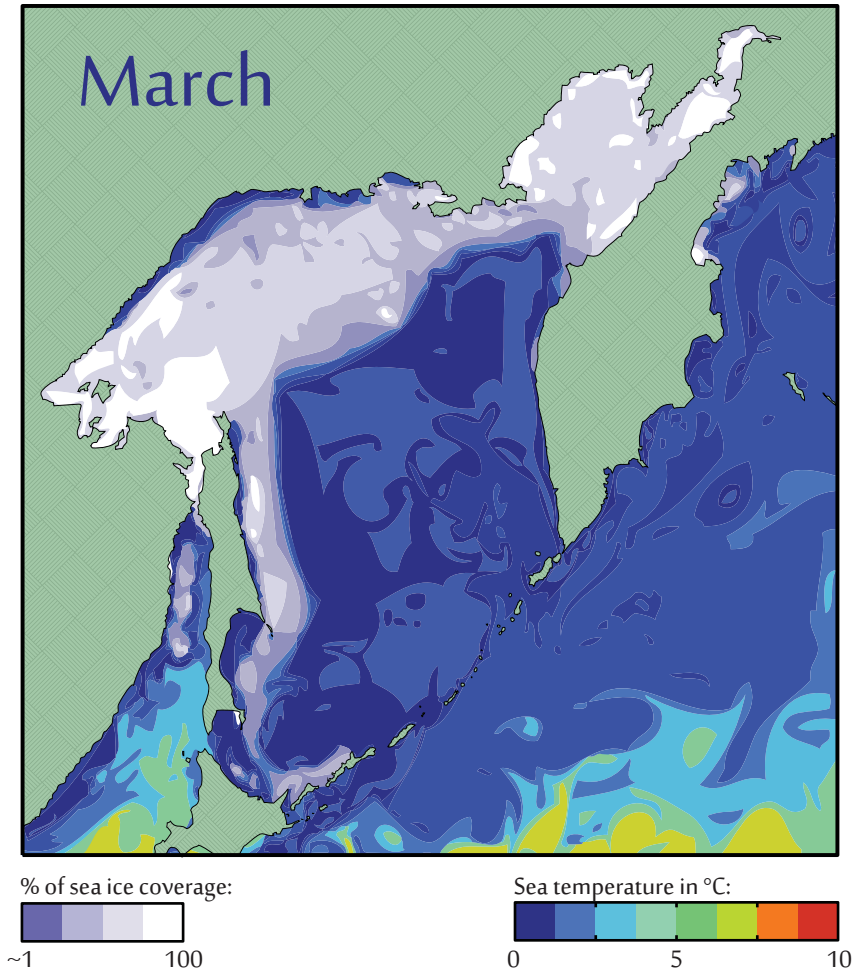

Figure 2: Average sea ice concentration in the Sea of Okhotsk and the Kuril Islands in March.

Background Information

Continued

Another factor that plays a crucial role in determining the distributions of animals throughout the Kuril Islands is the distribution of marine nutrients. Marine nutrients are not uniformly distributed throughout the ocean—they get concentrated in certain areas by a variety of mechanisms. The greatest concentrations actually tend to be on or near the ocean floor, due to the accumulation of dead and decomposing phytoplankton and zooplankton from near the surface. However, phytoplankton, the very base of the food chain, require sunlight and nutrients in order to thrive. As a result, phytoplankton growth is highest in those areas where marine nutrients are brought to the surface from the ocean floor through a process called upwelling.

One of the areas that this happens consistently in the Kurils is in the passes between the islands. With each tidal exchange, huge volumes of water pass between the Pacific Ocean and the Sea of Okhotsk. This exchange of water between the passes results in very well-mixed, nutrient-rich water close to the surface (see Figure 3).

Areas that support high phytoplankton growth also support large populations of zooplankton (feeding on the phytoplankton), which also supports high populations of larger marine predators. (see Figure 4)

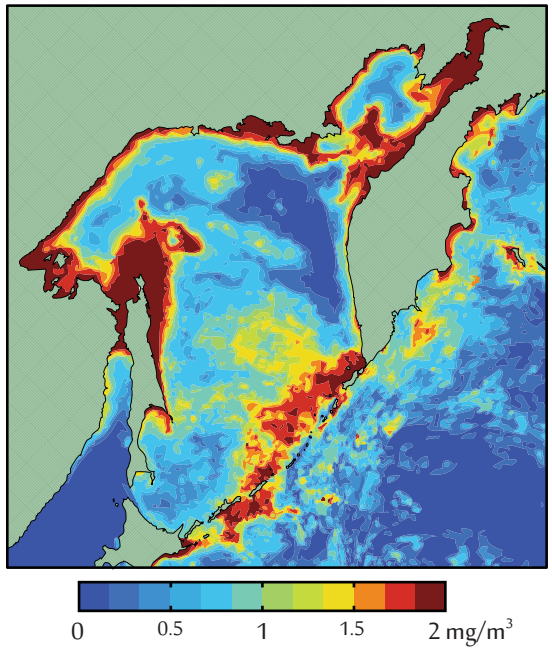

Figure 3: July average concentrations of chlorophyll over 10 years (1999-2008), which is an index of primary productivity (phytoplankton growth).

Finally, it is quite likely that these concentrated areas of high marine productivity influenced the distribution of human settlements in the Kuril Islands. Please refer to the "Settlement Module" for more information.

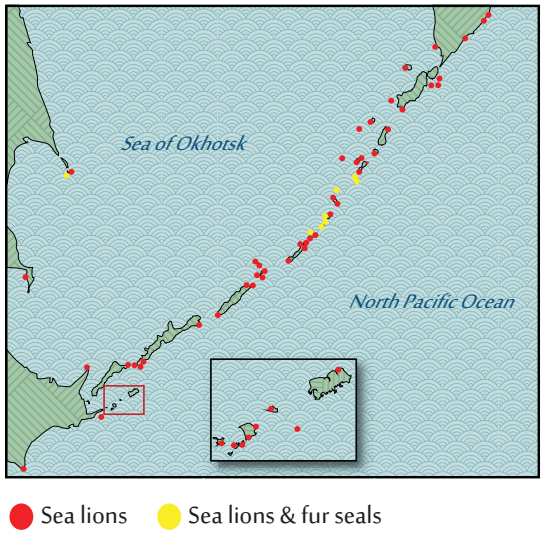

Figure 4: Map showing the distribution of sea lion and fur seal colonies. Note that on large islands, the colonies tend to be located toward the ends of the island (near the passes)

Procedure

Warm up:

Ask students to brainstorm how geography could influence where different kinds of animals live. Introduce the concept of biogeography. Ask students why the concept of biogeography may be important for archaeologists to study. The answer is: biogeography affects people directly (what areas of the planet are habitable), as well as indirectly (what kinds of animal resources are available for food, raw materials, etc.).

Procedure:

1. Present the slide show to your students. The slide show features many of the animals that are commonly found in the Kuril Islands, and provides some commentary on the ecological and cultural roles those species play today or have played in the past.

2. After presenting the slide show, distribute the student packets and have them work on the exercises in small groups.

3. Come back as the whole class and discuss the answers. Talk about comparing current and paleo (or past) species distributions – what would that be useful for? (changes in species over time can tell about environmental changes and influence of humans on the ecosystems).

4. Explore the Smithsonian's North American Mammals website and compare a few of the current mammal distributions with the data from Neotoma, which presents historic ranges of the same species. You can do this by either having each student go to the site on a personal computer and follow the teacher's instructions, or by pulling up the maps on one computer and projecting onto a screen.

a. Go to the Smithsonian's "North American Mammals" web site. http://www.mnh.si.edu/mna/main.cfm .

b. Look at the range maps for white-tailed deer (*Odocoileus virginianus*) and mule deer (*Odocoileus hemionus*, also called black-tailed deer), two very closely-related species. There are several approaches you can use to show the range maps for these species, but one approach will let you display the range maps for both species at the same time. To do that, go to the site listed above, and click on the "Enhanced Map Search (BETA)" link.

c. The simplest way to pull up the maps for the two species of deer is to type "Odocoileus" in the search bar at the top right corner of the screen. Then click the box next to each species' name, and the range map will appear on the left. With both species selected, both the range maps should show at the same time.

d. Ask the students to describe, in general terms, the modern distribution of white-tailed and mule (black-tailed) deer (Answer: Mule deer is mostly limited to the western half of the Continent. White-tailed deer are wide spread across most of the continent) and compare that to the "paleo" map you generated in the Zooarchaeology Unit (They are basically the same).

e. On the Smithsonian web site, clear the "Odocoileus" from the search bar and enter "Elk." Click on the box next to the species, and examine the range map for elk.

f. Ask the students to describe, in general terms, the distribution of elk (Elk are found mostly in the western US).

g. Using the Neotoma web site, conduct a search on "Taxon Name" using the full scientific name for elk (*Cervus elaphus canadensis*).

h. Ask the students to compare the paleo distribution of elk to the modern distribution (Elk were much more widely distributed in the past, with bones showing up in archaeological sites all across the continental US).

Conclusion:

As a class, discuss some of the possible explanations/hypotheses for why the paleo distribution of elk is quite a bit different from the modern range. Encourage students to think of ways that you could test specific hypotheses about why the distribution, or geographic range, of elk has changed (For example, loss of habitat can be tested by determining what the habitat requirements of elk are, and study whether or not that habit has disappeared. You could also search for a map showing human population densities in the US. Another possible explanation is changes in predator abundance which can be tested by determining what the main predators on elk are [wolves and cougars], and then finding out what the modern and paleo distributions for those species are).

List of Terrestrial Mammals Spicies

Name of species	Able to disperse?	Able to colonize?	# of species from Hokkaido	# of species from Kamtchatka
Brown Bear			1	1
Marten			1	1
Moose			0	1
Pica			1	1
Rabbit			1	1
Red fox			1	1
Reindeer			0	1
Shrew			6	5
Squirrel			0	2
Vole			3	6
Weasel			2	2
Wolf			0	1
Wolverine			0	1

Examine the lists of terrestrial mammal species that are native to Hokkaido, Japan, and Kamchatka, Russia. Based on what you know about these species, which would you predict would be able to colonize the Kuril Islands. Does it matter if they are colonizing from the south (from Hokkaido) or from the north (from Kamchatka)? Why?

Answer:

(See table 1 for the characteristics of the different species)

Some possible answers include: brown bear, Sitka deer and reindeer, red fox. The sea ice in the south might make it easier for relatively small animals to cross over to the islands.

Which of these species might be beneficial to humans?

Answer:

Some possible answers include: Deer, squirrels, and rabbits could be hunted as a source of protein and/or skins and furs. Red foxes and river otters are also valuable for their furs.

Which of these species might be detrimental to humans?

Answer:

Some possible answers include: Bears might be a nuisance and/or physically dangerous. Bears and red foxes might destroy caches of stored food. Small rodents might transmit diseases.

Table 1:

Name	Characteristics
Brown Bear	Can swim large distances; require very large territories
Marten	Can swim moderate distances, but typically live in forests
Pica	Related to rabbits, cannot swim appreciable distances; typically live in high elevation tundra
Rabbit	Poor swimmers; once established, populations grow quickly
Red Fox	Can swim moderate distances, but very good at crossing sea ice; populations often limited by availability of prey during winter
River Otter	Excellent swimmers, often inhabit marine environments;
Shrew	Cannot swim appreciable distances, and high metabolism limits their ability to cross sea ice; once established, populations grow quickly
Sika Deer	Can swim moderate distances; require large territories; prefer areas of shrubs or forests
Squirrel	Cannot swim appreciable distances, and high metabolism limits their ability to cross sea ice; once established, populations grow quickly
Vole	Cannot swim appreciable distances, and high metabolism limits their ability to cross sea ice; once established, populations grow quickly
Weasel	Excellent swimmers, and very good at crossing sea ice
Moose	Can swim moderate distances; require large territories; prefer areas of shrubs or forests
Reindeer	Can swim moderate distances; require large territories; prefer areas of tundra
Wolf	Excellent swimmers; require very large territories
Wolverine	Can swim moderate distances; typically live in mountainous terrain

Now examine the map showing the number of land mammal species that occurs naturally on islands and the adjacent mainland. Island size and distance to the mainland are the two main factors that influence the number of land mammal species any given island can support. For each of the islands identified in Figure 1, indicate which of those two factors you think is MOST important, and indicate why.

Alaid:

Shumshu:

Paramushir:

Urup:

Iturup:

Kunashir:

Shikotan:

Habomai: