Chapter 52
An Introduction to Ecology and the Biosphere

Lecture Outline

Overview: The Scope of Ecology

- Biologists record and transmit data on the annual 8,000-km migration of gray whales that calve in Baja California, collecting information that has helped this population recover from the brink of extinction.
  - A century ago, whaling had reduced this population to a few hundred individuals.
  - After 70 years of protection, more than 20,000 gray whales travel to the Arctic each year.
- What environmental factors determine the geographic distribution of gray whales? How do variations in their food supply affect the size of the gray whale population?
- These questions are the subject of **ecology**, the scientific study of the interactions between organisms and their environment.
  - These interactions occur on a hierarchy of scales from organismal to global.

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Concept 52.2 Interactions between organisms and the environment limit the distribution of species.

- Ecologists have long recognized distinct global and regional patterns in the distribution of organisms.
- *Biogeography* is the study of past and present distributions of individual species in the context of evolutionary theory.
- Ecologists ask a series of questions to determine what limits the geographic distribution of any species.
- Ecologists ask *why* species occur where they do, focusing on the factors that determine the distribution of species.
- **Biotic** factors include all the living organisms in the individual's environment.
- **Abiotic** factors are nonliving chemical and physical factors such as temperature, light, water, and nutrients that influence the distribution and abundance of organisms.
  - For example, red kangaroos are abundant in areas of Australia that have sparse and variable rainfall.
  - An abiotic factor—precipitation—may determine where red kangaroos live.
  - It is also possible that climate influences red kangaroo populations indirectly, through biotic factors such as pathogens, parasites, predators, competitors, and food availability.

Species dispersal contributes to the distribution of organisms.

- The movement of individuals away from centers of high population density or from their area of origin is called **dispersal**.
  - Perhaps there are no kangaroos in North America due to barriers to their dispersal.

- The dispersal of organisms is crucial to understanding geographic isolation in evolution and the broad patterns of current geographic distribution of species.
    - For example, cattle egrets were found only in Africa and southwestern Europe in the early 1800s.
    - After these birds crossed the Atlantic Ocean and colonized northeastern South America, they were able to spread throughout Central America, reaching North America by the 1950s.
    - Today, cattle egrets have breeding populations as far west as the Pacific Coast and as far north as southern Canada.
- One way to determine whether dispersal is a key factor limiting distribution is to observe the results when humans have accidentally or intentionally transplanted a species to areas where it was previously absent.
- For the transplant to be considered successful, the organisms must not only survive in the new area but also reproduce there.
    - If the transplant is successful, then the *potential* range of the species is larger than its *actual* range.
    - In other words, the species *could* live in areas where it currently does not.
- Ecologists rarely conduct transplant experiments today because species introduced into new geographic locations may disrupt the communities and ecosystems to which they are introduced.
    - Instead, ecologists study the outcome when a species has been transplanted accidentally or for another purpose.

Behavior and habitat selection contribute to the distribution of organisms.

- Sometimes organisms do not occupy all of their potential range but select particular habitats.
- Does behavior play a role in limiting the distribution in such cases?
- Habitat selection is one of the least-understood ecological processes, but it appears to play an important role in limiting the distribution of many species.
    - Female insects often deposit eggs only in response to a very narrow set of stimuli, which may restrict distribution of the insect to certain host plants.
    - For example, the European corn borer can feed on a wide variety of plants but is found only on corn. Egg-laying females are attracted by the odors of corn plants.

Biotic factors affect the distribution of organisms.

- Negative interactions with other organisms in the form of predation, parasitism, or competition may limit the ability of organisms to survive and reproduce.
- Survival and reproduction may also be limited by the absence of species on which the transplanted species depends, such as pollinators for flowering plants.
- Predators and herbivores are examples of biotic factors that limit the distribution of species.
- In certain marine ecosystems, there is an inverse relationship between the abundances of sea urchins and seaweeds.
    - Sea urchins graze on seaweeds, preventing the establishment of large stands of seaweeds.
- W. J. Fletcher tested the hypothesis that sea urchins are a biotic factor limiting seaweed distribution by removing sea urchins from experimental plots.
- He observed a dramatic increase in seaweed cover, showing that urchins limit seaweed distribution.
- The presence or absence of food resources, parasites, diseases, and competing organisms can act as biotic limitations on species distribution.

Abiotic factors affect the distribution of organisms.

- The global distribution of organisms broadly reflects the influence of abiotic factors such as temperature, water, and sunlight.
- The environment is characterized by *spatial heterogeneity* and *temporal heterogeneity*.
- Organisms can *temporarily* avoid stressful conditions through behaviors such as dormancy or hibernation.
- Environmental temperature is an important factor in the distribution of organisms because of its effect on biological processes.
  - Very few organisms can maintain an active metabolism at very high or very low temperatures.
  - Cells may rupture if the water they contain freezes, and most proteins denature at temperatures above 45^{0}C.
- Some organisms have extraordinary adaptations that allow them to live outside the temperature range habitable for most other living things, but more organisms function best within a specific range of temperatures.
  - Endotherms may expend energy regulating their internal temperature at temperatures outside that range.
- The variation in water availability among habitats is an important factor in species distribution.
  - Intertidal species may face desiccation as the tide recedes.
  - Terrestrial organisms face a nearly constant threat of desiccation and have adaptations that allow them to obtain and conserve water.
  - Desert organisms, for example, have a variety of adaptations for acquiring and conserving water in dry environments.
- The salt concentration of the environment affects the water balance of organisms through osmosis.
  - Most aquatic organisms have a limited ability for osmoregulation and are restricted to either freshwater or marine habitats.
  - High-salinity habitats such as salt flats typically contain few species.
- Sunlight provides the energy that drives nearly all ecosystems.
  - Light intensity is not the most important factor limiting plant growth in most terrestrial environments, although shading by a forest canopy creates intense competition for light in the understory.
- In aquatic environments, light intensity limits the distribution of photosynthetic organisms.
  - Every meter of water depth selectively absorbs 45% of red light and 2% of blue light passing through it.
  - As a result, most photosynthesis in aquatic environments occurs near the surface.
- Too much light can also limit the survival of organisms.
  - The atmosphere is thinner at higher elevations, absorbing less ultraviolet radiation. The sun's rays are more likely to damage DNA and proteins in alpine environments.
- The physical structure, pH, and mineral composition of soils and rocks limit the distribution of plants and, thus, of the animals that feed on them, contributing to the patchiness of terrestrial ecosystems.
  - The distribution of organisms at extreme acidic and basic conditions is limited.
  - pH can also have indirect effects by altering the solubility of nutrients and toxins.

- In streams and rivers, substrate composition can affect water chemistry, thus influencing the distribution of organisms.
- In freshwater and marine environments, the structure of substrates limits the organisms that can attach to or burrow in those habitats.

Four abiotic factors are the major components of climate.

- **Climate** is the long-term, prevailing weather conditions in a particular area.
- Four abiotic factors—temperature, water, sunlight, and wind—are the major components of climate.
- Climatic factors, especially temperature and water, have a major influence on the distribution of organisms.
- Climate patterns can be described on two scales.
- **Macroclimate patterns** are on global, regional, or local levels, and **microclimate patterns** are very fine patterns, such as the conditions experienced by a community of organisms under a fallen log.
- Global climate patterns are determined by sunlight and Earth's movement in space.
- The sun's warming effect on the atmosphere, land, and water establishes the temperature variations, cycles of air movement, and evaporation of water that are responsible for latitudinal variations in climate.
- Bodies of water and topographic features such as mountain ranges create regional climatic variations, while smaller features of the landscape affect local climates.
- Seasonal variation may influence climate.
- Ocean currents influence climate along the coast by heating or cooling overlying air masses, which may pass over land.
  - Coastal regions are generally moister than inland areas at the same latitude.
  - In general, oceans and large lakes moderate the climate of nearby terrestrial environments.
- In certain regions, cool, dry ocean breezes are warmed when they move over land, absorbing moisture and creating a hot, rainless climate slightly inland.
  - This pattern draws a cool breeze from the water across the land.
  - At night, air over the ocean rises, drawing cooler air from the land back out over the water and replacing it with warmer offshore air.
  - This *Mediterranean climate* pattern occurs inland from the Mediterranean Sea.
- Mountains have a significant effect on the amount of sunlight reaching an area as well as on local temperature and rainfall.
  - In the Northern Hemisphere, south-facing slopes receive more sunlight than north-facing slopes and are therefore warmer and drier.
  - These environmental differences affect species distribution.
- At any given latitude, air temperature declines 6°C with every 1,000-m increase in elevation.
  - This temperature change is equivalent to the change caused by an 880-km increase in latitude.
  - Biological communities on mountains are similar to those at lower elevations farther from the equator.
- As moist, warm air approaches a mountain, it rises and cools, releasing moisture on the windward side of the peak.

- On the leeward side of the mountain, cool, dry air descends, absorbing moisture and producing a "rain shadow."
  - Deserts are commonly on the leeward side of mountain ranges.
- The changing angle of the sun over the course of a year affects local environments.
  - Belts of wet and dry air on either side of the equator shift with the changing angle of the sun, producing marked wet and dry seasons at around 20° latitude, where many tropical deciduous forests grow.
- Seasonal changes in wind patterns produce variations in ocean currents, occasionally causing the upwelling of nutrient-rich, cold water from deep ocean layers.
  - This nutrient-rich water stimulates the growth of surface-dwelling phytoplankton and the organisms that feed on them.
- Many features in the environment influence microclimates.
- Forest trees moderate the microclimate beneath them.
  - Cleared areas experience greater temperature extremes than the forest interior.
- Within a forest, low-lying ground is usually wetter than high ground and tends to be occupied by different species of trees.
- A log or large stone shelters organisms, buffering them from temperature and moisture fluctuations.
- Every environment on Earth is characterized by a mosaic of small-scale differences in abiotic factors that influence the local distribution of organisms.
- Long-term climate changes profoundly affect the biosphere.
- One way to predict the possible effects of current climate changes is to consider the changes that have occurred in temperate regions since the end of the last ice age.
- Until about 16,000 years ago, continental glaciers covered much of North America and Eurasia.
- As the climate warmed and the glaciers melted, the distribution of trees expanded northward.
  - A detailed record of these migrations is captured in fossil pollen in lake and pond sediments.
- If researchers can determine the climatic limits of current geographic distributions for individual species, they can predict how that species distribution will change with global warming.
- A major question for tree species is whether seed dispersal is rapid enough to sustain the migration of the species as climate changes.
- An example to consider is the eastern hemlock, whose movement north was delayed nearly 2,500 years at the end of the last ice age.
- This delay in seed dispersal was partly attributable to the lack of "wings" on the seeds, which tend to fall close to the parent tree.
- The fossil record can inform predictions about the biological impact of current global warming trends on the geographic range of the American beech, *Fagus grandifolia*.
- Two different climate-change models are used to compare the current and predicted geographic ranges of this tree.
- These models predict that the northern limit of the beech's range will move 700–900 km north over the next century and its southern range will move northward even farther.
- The beech will have to migrate 7–9 km per year to maintain its distribution in a warming climate.
- However, since the ice age, the beech has migrated into its present range at a rate of only 0.2 km per year.
- Without human assistance, the beech will have a much smaller range and may become extinct.

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