Chapter 5

Species Interactions and Community Ecology

PowerPoint® Slides prepared by
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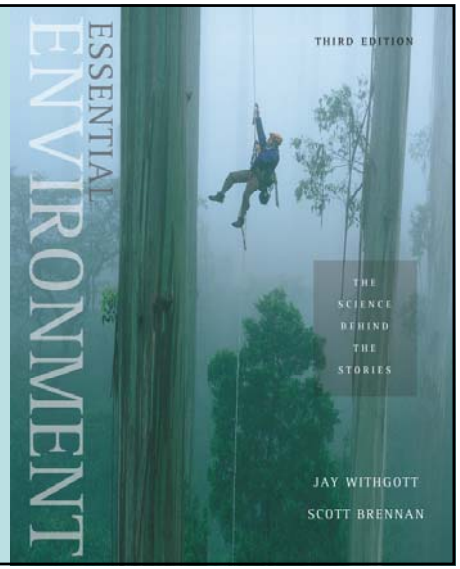


This lecture will help you understand:

- Species interactions
- Feeding relationships, energy flow, trophic levels, and food webs
- Keystone species
- The process of succession
- Potential impacts of invasive species
- Ecological restoration
- Terrestrial biomes

Case Study: Black and white and spread all over

(a) Clogging a pipe

- Small, black and white shellfish native to western Asia and eastern Europe
- Introduced in 1988 to Lake St. Clair, Canada, in discharged ballast water
- By 1994, zebra mussels had invaded all 5 Great Lakes, the Mississippi river, 19 U.S. states, and 2 Canadian provinces.
  - No natural predators, competitors, or parasites
- These mussels cost the U.S. economy hundreds of millions of dollars of damage to property each year.
  - They also cause enormous ecological damage.

Species interactions

- Species interactions are the backbone of communities.

TABLE 6.1 Effects of Species Interactions on Their Participants

Type of interaction	Effect on species 1	Effect on species 2
Mutualism	+	+
Commensalism	+	0
Predation, parasitism, herbivory	+	−
Neutralism	0	0
Amensalism	−	0
Competition	−	−

"+" denotes a positive effect; "−" denotes a negative effect; "0" denotes no effect.

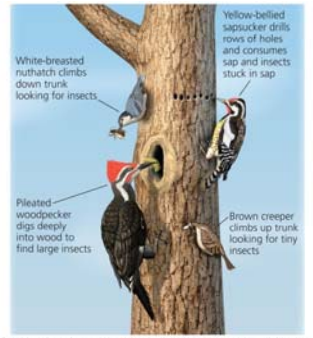
Competition occurs with limited resources

- **Competition**: relationship where multiple organisms seek the same limited resources they need to survive
  - Generally subtle, not outright fighting
  - Food, water, space, shelter, mates, sunlight, etc.
- **Intraspecific competition**: between members of the same species
- **Interspecific competition**: between members of 2 or more species
- Effective competitors can completely exclude other species
  - i.e., Zebra mussels displace native mussels
  - But some species can coexist by using different resources

Resource partitioning

In competitive relationships, each participant has a negative effect on the other participant.

- To reduce competition, species can use a resource in slightly different ways.
- **Resource partitioning**: when species divide shared resources by specializing in different ways
  - Examples: one species is active at night, another in the daytime; one species eats small seeds, another eats large seeds



Predation

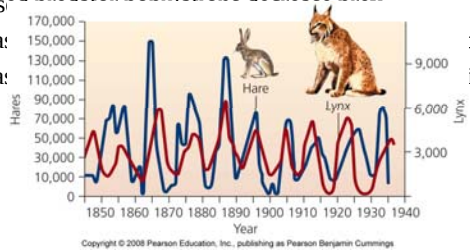
- **Exploitative interactions**: a type of interaction where one species benefits while another is harmed
  - Predation, parasitism, herbivory
- **Predation**: process by which individuals of one species (**predators**) capture, kill, and consume individuals of another species (**prey**)
  - Structures food webs
  - Influences community composition by determining numbers of predators and prey

An example of predation: zebra mussels

- Zebra mussels prey on zooplankton.
  - Zooplankton decrease in lakes with zebra mussels.
- Zebra mussels prey on phytoplankton.
  - Compete with zooplankton
- Zebra mussels are becoming prey for some North American predators.
  - Ducks, fish, muskrats, crayfish

Predation can drive population dynamics

- Increased prey populations increase predators.
  - Predators survive and reproduce.
- Increas[illegible] prey.
- Decreas[illegible]ors.
- Decreas[illegible]ions.



Predation has evolutionary ramifications

- Natural selection leads to evolution of adaptations that make predators better hunters.
- Individuals who are better at catching prey…
  - Live longer, healthier lives
  - Take better care of offspring
- Since prey are at risk of immediate death…
  - They develop elaborate defenses against being eaten

Natural selection to avoid predation

Parasites exploit living hosts

- **Parasitism**: a relationship in which one organism (**parasite**) depends on another (**host**) for nourishment or other benefit, while simultaneously harming the host
  - Usually does not immediately kill the host
- Some species are free-living, and infrequently contact their hosts.
  - Cuckoos and cowbirds lay eggs in other birds' nests.
- Many species live within the host.
  - Disease, tapeworms
- Other species live on the exterior of their hosts.
  - Sea lamprey

Coevolution

- **Coevolution**: evolution of hosts and parasites in response to each other
  - They become locked in a duel of escalating adaptations.
  - Has been called an "evolutionary arms race"
  - Each evolves new responses to the other
  - It may not be beneficial to the parasite to kill its host.

Herbivores exploit plants

- Exploitation in which animals feed on the tissues of plants
  - Widely seen in insects
  - May not kill the plant, but affects its growth and survival
- Defenses against herbivory include:
  - Toxic or distasteful chemicals
    - Thorns, spines, or irritating hairs

Mutualists help one another

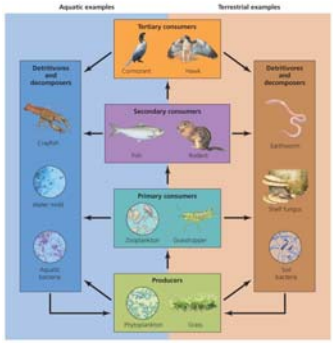
- **Mutualism**: a relationship in which interacting species benefit from one another
- **Symbiosis**: mutualism in which the organisms live in close physical contact
  - Plant roots and fungi
  - Coral polyps and algae (zooxanthellae)
- **Pollination**: bees, bats, birds, and others transfer pollen from one flower to another, fertilizing its eggs
  - Species may encounter each other infrequently.
  - Bees pollinate 73% of our crops.

Ecological communities

- **Community**: an assemblage of species living in the same place at the same time
  - Members interact with each other.
  - These interactions determine the composition, structure, and function of the community.
- **Community ecologists**: people interested in:
  - How species coexist and relate to one another
  - How communities change
  - Why patterns exist

Energy passes among trophic levels

- One of the most important species interactions is who eats whom.
- Matter and energy move through the community.
- **Trophic levels**: rank in the feeding hierarchy
  - Producers
  - Consumers
  - Detritivores and Decomposers



Trophic levels

- **Autotrophs** ("self-feeders"): organisms that capture solar energy for photosynthesis to produce sugars
  - Green plants, cyanobacteria, algae
- **Primary consumers**: organisms that consume producers and comprise the second trophic level
  - **Herbivores** such as deer and grasshoppers
- **Secondary consumers**: prey on primary consumers and comprise the third trophic level
  - **Carnivores** (wolves, birds) that consume meat
- **Tertiary consumers**: predators that feed at higher trophic levels
  - Hawks, owls

Detritivores and decomposers

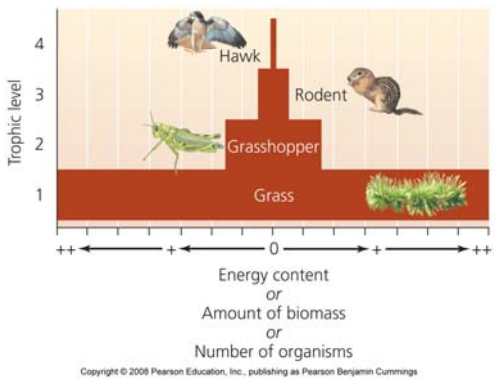
- Organisms that consume non-living organic matter
- **Detritivores**: scavenge waste products or dead bodies
  - Millipedes
- **Decomposers**: break down leaf litter and other non-living material
  - Fungi, bacteria
  - Enhance topsoil and recycle nutrients

Energy decreases at higher trophic levels

- Most energy organisms use is lost as waste heat through respiration.
  - Less and less energy is available in each successive trophic level.
  - Each level contains only 10% of the energy of the trophic level below it.
- With less energy available, there are far fewer organisms at the highest trophic levels.

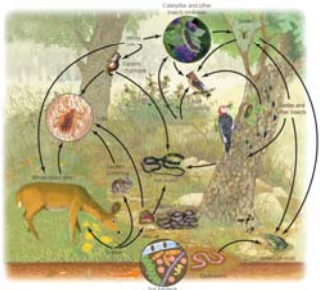
A human vegetarian's ecological footprint is smaller than a meat-eater's footprint.

Pyramids of energy, biomass, and numbers



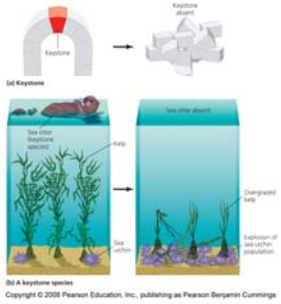
Food webs show relationships and energy flow

- **Food chain**: a linear series of feeding relationships
  - Ecological systems are far more complex than this.
- **Food web**: a visual map of feeding relationships and energy flow
  - Includes many different organisms at all the various levels
  - Greatly simplified; leaves out the majority of species



Some organisms play big roles

- **Keystone species**: has a strong or wide-reaching impact far out of proportion to its abundance
- Removal of a keystone species has substantial ripple effects.
  - Alters the food web



Keystone species can change communities

- Large-bodied secondary or tertiary consumers are often keystone species.
  - Extermination of wolves led to increased deer populations, which led to overgrazed vegetation and changed forest structure.
- **Ecosystem engineers**: physically modify the environment and exert strong community-wide effects
  - Beaver dams, prairie dogs, fungi

Communities respond to disturbances

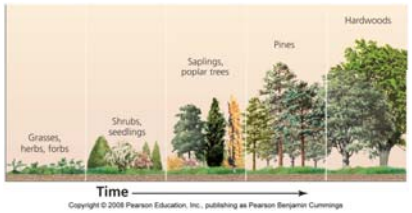
- Communities experience many types of disturbance.
  - Removal of keystone species, spread of invasive species, natural disturbances
  - Human impacts cause major changes
- **Resistance**: community that resists change and remains stable despite the disturbance
- **Resilience**: a community changes in response to a disturbance, but later returns to its original state
  - Some communities may be permanently changed.

Primary succession

- **Succession**: the predictable series of changes in a community following a disturbance
- **Primary succession**: disturbance eliminates all vegetation and/or soil life
  - A community is built from scratch
  - Glaciers, drying lakes, volcanic lava
- **Pioneer species**: the first species to arrive in a primary succession area (i.e., lichens)
  - New organisms arrive, increasing vegetation and diversity

Secondary succession

- **Secondary succession**: a disturbance dramatically alters, but does not destroy, all local organisms
  - Parts of the previous community remain and serve as "building blocks."
  - Fires, hurricanes, farming, logging



Community change is variable

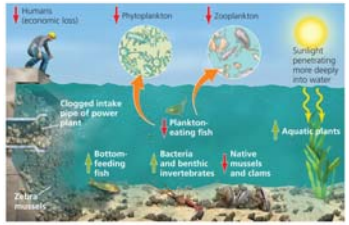
- **Climax community**: the community resulting from successful succession
  - Remains stable until another disturbance restarts succession
- Community change is variable and unpredictable.
  - Conditions at one stage may promote progression to another stage.
  - Organisms, through competition, may inhibit progression to another stage.
  - Other factors (e.g., soil conditions) also help determine communities.

Invasive species threaten communities

- **Invasive species**: non-native (exotic) organisms that spread widely and become dominant in a community
  - Can substantially alter a community
  - Growth-limiting factors (predators, disease, etc.) are removed or absent
  - They have major ecological effects
  - Fish introduced for sport outcompete and exclude native fish
- Some species help people (i.e., European honeybee).

Two invasive mussels

Zebra mussels impact other species, either positively or negatively.



(a) Impacts of zebra mussels on members of a Great Lakes nearshore community

(b) Occurrence of zebra mussels in North America, 2005

(c) Occurrence of quagga mussels in North America, 2007

Controlling invasive species

- Techniques to control invasive species:
  - Remove manually
  - Toxic chemicals
  - Drying them out
  - Depriving of oxygen
  - Introducing predators and diseases
  - Stressing them
    - Heat, sound, electricity, carbon dioxide, ultraviolet light

Prevention, rather than control, is the best policy.

Changed communities need to be restored

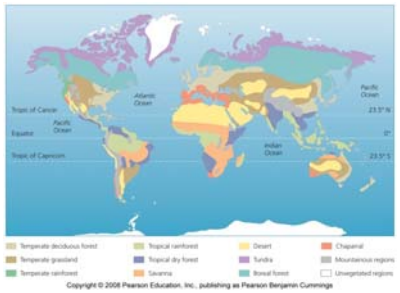
- Humans have altered Earth's landscape to such a degree, that no area is truly pristine.
- **Ecological restoration**: returning an area to unchanged conditions
  - Informed by **restoration ecology**: the science of restoring an area to the condition that existed before humans changed it
  - It is difficult, time-consuming, expensive
  - Best to protect natural systems from degradation in the first place

Restoration efforts

- Prairie Restoration
  - Native species replanted and invasive species controlled
- The world's largest project: Florida Everglades
  - Depletion caused by flood control practices and irrigation
  - Populations of wading birds dropped 90-95%.
  - It will take 30 years and billions of dollars to undo dams and diversions.
  - Restoring ecosystem services will prove economically beneficial.

Earth's biomes

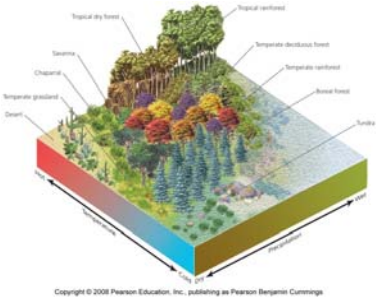
- Around the world, communities share strong similarities.
- **Biome**: a major regional complex of similar communities recognized by:
  - Plant type
  - Vegetation structure



A variety of factors determine the biome

- The biome in an area depends on a variety of abiotic factors.
  - Temperature, precipitation, ocean and air circulation, soil
- **Climatograph**: a climate diagram showing an area's temperature and precipitation

Similar biomes occur at similar latitudes.



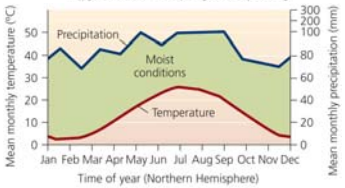
Aquatic systems have biome-like patterns

- Various aquatic systems have distinct communities.
  - Coastlines, continental shelves
  - Open ocean, deep sea
  - Coral reefs, kelp forests
  - Coastal systems (marshes, mangrove forests, etc.)
  - Freshwater systems (lakes, rivers, etc.)
- Aquatic systems are shaped by:
  - Water temperature, salinity, and dissolved nutrients
  - Wave action, currents, depth
  - Substrate type and animal and plant life

Temperate deciduous forest

- **Deciduous trees** lose their leaves each fall and remain dormant during winter
- Mid-latitude forests in Europe, East China, Eastern North America
- Fertile soils
- Forests: oak, beech, maple

(a) Temperate deciduous forest

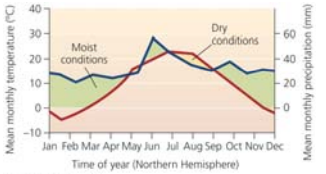


(b) Washington, D.C., USA

Temperate grasslands

- More extreme temperature difference between winter and summer
- Less precipitation
- Also called **steppe** or **prairie**
  - Once widespread throughout parts of North and South America and much of central Asia
  - Much was converted for agriculture
  - Bison, prairie dogs, antelope, and ground-nesting birds

(a) Temperate grassland

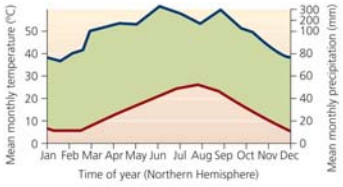


(b) Odessa, Ukraine

Temperate rainforest

- Coastal Pacific Northwest region
- Great deal of precipitation
- Coniferous trees: cedar, spruce, hemlock, fir
- Moisture-loving animals
  - Banana slug
- The fertile soil is susceptible to erosion and landslides.
- Overharvesting has driven species to extinction and ruined human communities.

(a) Temperate rainforest

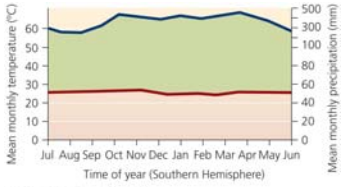


(b) Nagasaki, Japan

Tropical rainforest

- Central and South America, southeast Asia, west Africa
- Year-round rain and warm temperatures
- Dark and damp
- Lush vegetation
- Highly diverse species, but at low densities
- Very poor, acidic soils
- Nutrients contained in plants

(a) Tropical rainforest

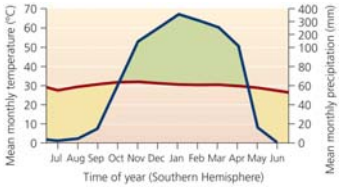


(b) Bogor, Java, Indonesia

Tropical dry forest

- Tropical deciduous forest
- India, Africa, South America, northern Australia
- Wet and dry seasons
- Warm, but less rainfall
- Converted to agriculture
- Erosion-prone soil

(a) Tropical dry forest

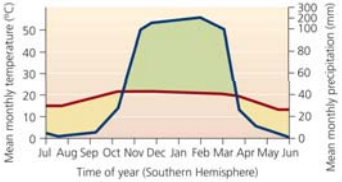


(b) Darwin, Australia

Savanna

- Tropical grassland interspersed with trees
- Africa, South America, Australia, India
- Precipitation only during rainy season
- Water holes
- Zebras, gazelles, giraffes, lions, hyenas

(a) Savanna

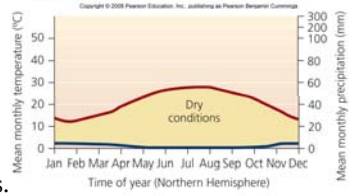


(b) Harare, Zimbabwe

Desert

- Minimal precipitation
- Some deserts are bare, with sand dunes (Sahara).
- Some deserts are heavily vegetated (Sonoran).
- They are not always hot.
  - Temperatures vary widely
- Saline soils ("lithosols")
- Nocturnal or nomadic animals
- Plants have thick skins or spines.

(a) Desert

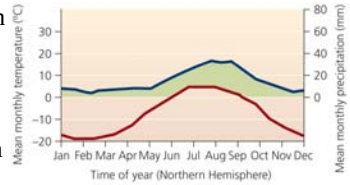


(b) Cairo, Egypt

Tundra

- Canada, Scandinavia, Russia
- Minimal precipitation
  - Nearly as dry as a desert
- Seasonal variation in temperature
  - Extremely cold winters
- **Permafrost**: permanently frozen soil
- Few animals: polar bears, musk oxen, caribou
- Lichens and low vegetation with few trees

(a) Tundra

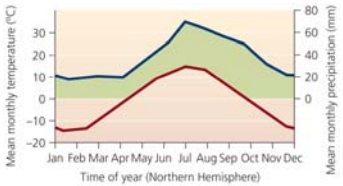


(b) Vaigach, Russia

Boreal forest (taiga)

- Canada, Alaska, Russia, Scandinavia
- Variation in temperature and precipitation
- Cool and dry climate
  - Long, cold winters
  - Short, cool summers
- Poor, acidic soil
- Few evergreen tree species
- Moose, wolves, bears, migratory birds

(a) Boreal forest

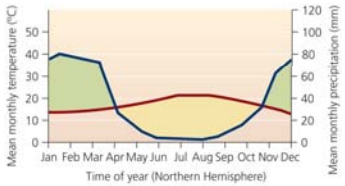


(b) Archangelsk, Russia

Chaparral

- Mediterranean Sea, California, Chile, and southern Australia
- High seasonal
  - Mild, wet winters
  - Warm, dry summers
- Frequent fires
- Densely thicketed, evergreen shrubs

(a) Chaparral



(b) Los Angeles, California, USA

Conclusion

- Biomes and communities help us understand how the world functions.
- Species interactions affect communities.
  - Competition, predation, parasitism, mutualism
- Feeding relationships are represented by trophic levels and food webs.
  - Keystone species are particularly influential.
- Humans have altered many communities.
- Ecological restoration attempts to undo the negative changes that we have caused.