Community Structure and Biodiversity

Chapter 46
Impacts, Issues

Fire Ants in the Pants

- Imported fire ants disturb community structures; in the US, phorid flies are being introduced to control them – tipping the balance once again
Community structure refers to the number and relative abundances of species in a habitat.

**Habitat**
- The type of place where a species normally lives

**Community**
- All species living in a habitat
Which Factors Shape Community Structure?

- Many factors influence community structure
  - Climate and topography
  - Kinds and amounts of food and other resources
  - Species’ adaptations to habitat conditions
  - Species interactions
  - Timing and history of disturbances
Species’ Adaptations to Habitat Conditions

- Fruit-eating pigeons in Papua New Guinea, adapted to eat fruits of different trees.
The Niche

- **Niche**
  - The unique ecological role of each species in a community
  - Described in terms of conditions, resources, and interactions necessary for survival and reproduction
Categories of Species Interactions

- **Commensalism** benefits one species and does not affect the other
- **Mutualism** benefits both species
- **Interspecific competition** hurts both species
Categories of Species Interactions

- **Predation** and **parasitism** help one species at another’s expense

- **Predators**
  - Free-living organisms that kill their prey

- **Parasites**
  - Live on or in a host and usually do not kill it
Categories of Species Interactions

- **Symbionts**
  - Species that spend most or all of their life cycle in close association with each other
  - Parasitism, commensalism, and mutualism can all be types of *symbiosis*

- **Coevolution**
  - Species that interact closely over extended periods act as selective agents on each other
## Direct Two-Species Interactions

<table>
<thead>
<tr>
<th>Type of Interaction</th>
<th>Effect on Species 1</th>
<th>Effect on Species 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commensalism</td>
<td>Helpful</td>
<td>None</td>
</tr>
<tr>
<td>Mutualism</td>
<td>Helpful</td>
<td>Helpful</td>
</tr>
<tr>
<td>Interspecific competition</td>
<td>Harmful</td>
<td>Harmful</td>
</tr>
<tr>
<td>Predation</td>
<td>Helpful</td>
<td>Harmful</td>
</tr>
<tr>
<td>Parasitism</td>
<td>Helpful</td>
<td>Harmful</td>
</tr>
</tbody>
</table>
46.1 Key Concepts
Community Characteristics

- A community consists of all species in a habitat.

- Each species has a niche—the sum of its activities and relationships.

- A habitat’s history, its biological and physical characteristics, and the interactions among species in the habitat affect community structure.
46.2 Mutualism

- Mutualism is a species interaction in which each species benefits by associating with the other
  - Flowering plants and animal pollinators
  - Birds that disperse seeds
  - Lichens, mycorrhizae, and nitrogen-fixing bacteria that help plants obtain nutrients

- Mitochondria and chloroplasts may have originated as mutualistic endosymbionts
Mutualism

- Some mutualists can’t complete their life cycles without each other
  - Yucca plants and the moths that pollinate them
Mutualism

- Some mutualists defend one another
  - Sea anemone and anemone fish
46.3 Competitive Interactions

- Resources are limited; individuals of different species often compete for access to them.

- Competition among individuals of the same species is more intense than interspecific competition.
Interspecific Competition

- Interference competition
  - One species actively prevents another from accessing a resource

- Exploitative competition
  - Species reduce the amount of a resource available to the other by using that resource
Interference Competition

- Two scavengers compete for a carcass
Effects of Competition

- **Competitive exclusion**
  - When two species require the same limited resource to survive or reproduce, the better competitor will drive the less competitive species to extinction in that habitat.

- Competitors can coexist when their resource needs are not exactly the same.
  - Competition suppresses growth of both species.
Competitive Exclusion in *Paramecium*

**A** *Paramecium caudatum* and *P. aurelia* grown in separate culture flasks established stable populations. The S-shaped graph curves indicate logistic growth and stability.

**B** For this experiment, the two species were grown together. *P. aurelia* (brown curve) drove *P. caudatum* toward extinction (green curve).

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Animation: Competitive exclusion

- Graph showing relative population density over time for different species.
- Image of Paramecium with various components.
Effects of Competition in Salamanders

- Where two species coexist, competitive interactions suppress the populations of both.
Resource Partitioning

- **Resource partitioning**
  - Subdividing of an essential resource reduces competition among species that require it

- *Example:* Roots of three annual plant species in the same field take up water and nutrients at different depths
Resource Partitioning Among Annual Plants

- Bristly foxtail roots
- Indian mallow roots
- Smartweed roots

Bristly foxtail

Indian mallow

Smartweed

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Character Displacement

- **Character displacement**
  - Over generations, a trait of one species diverges in a way that lowers the intensity of competition with other species
  - Trait modification prompts resource partitioning
  - *Example:* Changing beak sizes in finches
46.4 Predator–Prey Interactions

- **Predators** are consumers that get energy and nutrients by capturing, killing, and eating **prey**

- Relative abundances of predators and prey shift over time in response to species interactions and changing environmental conditions.
Three Predator Responses to Changes in Prey Density

- **Type I response (passive predators)**
  - Number of prey killed depends on prey density

- **Type II response**
  - Number of prey killed depends on the predator’s capacity to capture, eat and digest prey

- **Type III response**
  - Number of kills increases only when prey density reaches a certain level
Responses of Predators to Prey Density

A. Number of prey killed per predator per unit time vs. Prey population density

B. Number of kills per day vs. Caribou per square kilometer
Number of prey killed per predator per unit time vs. Prey population density.

Lines I, II, and III represent different scenarios or conditions.
Animation: Predator-prey interactions
Cyclic Changes in Predator and Prey Abundance

- Time lag in predator response to prey density can lead to cyclic changes in abundance

- When prey density is low, predators decline, prey are safer, prey numbers increase

- When prey density is high, predator numbers increase, prey numbers decline
The Canadian Lynx and Snowshoe Hare
Coevolution of Predators and Prey

- Predator and prey populations exert selective pressures on one another.
- Genetic traits that help prey escape will increase in frequency.
- Defensive improvements select for a countering improvement in predators.
46.5 An Evolutionary Arms Race

- Predators select for better prey defenses, and prey select for more efficient predators.

- Prey defenses include exoskeletons, unpleasant taste, toxic chemicals or stings, and physical adaptations such as camouflage.
Some Physical Adaptations of Prey

- **Camouflage**
  - Body shape, color pattern and behavior that make an individual blend in with its surroundings

- **Warning coloration**
  - Many toxic or unpalatable species have bright colors and patterns that predators learn to avoid

- **Mimicry**
  - A harmless animal looks like a dangerous one
Camouflage
Warning Coloration and Mimicry
Adaptive Responses of Predators

- Predators find ways of avoiding prey defenses
  - Grasshopper mice and spraying beetles
  - Koalas and noxious eucalyptus leaves
  - Predator speed
  - Predator camouflage
Predator Responses to Prey Defenses
46.6 Parasite–Host Interactions

- **Parasites** spend all or part of their life living on or in other organisms, from which they steal nutrients.

- Parasites harm but generally don’t kill their host:
  - Some are pathogens, cause sterility, or make the host more vulnerable to predation or disease.
A Deadly Parasitic Infection

- Trout with whirling disease caused by infection with parasitic *Myxobolus cerebralis*
Parasite Hosts and Vectors

- Some parasites spend their entire life in or on a single host species

- Other parasites have different hosts during different stages of the life cycle; vectors (such as insects) convey a parasite from host to host.
Parasitic Plants

- Some nonphotosynthetic plants, such as dodders, obtain nutrients from a host plant.
- Some photosynthetic plants, such as mistletoes, steal nutrients and water from a host.
Dodder: A Parasitic Plant
Parasitic Invertebrates

- Parasitic invertebrates include many tapeworms, flukes, some roundworms, ticks, many insects, and some crustaceans.
Parasitoids and Social Parasites

- **Parasitoids**
  - Insects that lay eggs in other insects
  - Larvae eat the host’s body and kill it
  - *Example:* phorids

- **Social parasites**
  - Animals that take advantage of host behavior to complete their life cycle
  - *Examples:* cuckoos and cowbirds
Some parasites and parasitoids are raised commercially for use as biological control agents

- *Example:* Parasitoid wasps lay eggs in aphids
Cowbirds are social parasites that lay their eggs in other birds’ nests
  - Young cowbirds are fed by foster-parent hosts

Cowbirds parasitize at least 15 kinds of native North American birds, some of which are threatened or endangered
  - One cowbird can parasitize 30 nests per season
Cowbirds: Social Parasites

- Brown-headed cowbirds (*Molothrus*) were commensal with bison
Commensalism, mutualism, competition, predation, and parasitism are types of interspecific interactions. They influence the population size of participating species, which in turn influences the community’s structure.
Ecological succession is a process in which one array of species replaces another over time.

It can occur in a barren habitat such as new volcanic land (primary succession) or a disturbed region in which a community previously existed (secondary succession).
Pioneer Species

- **Pioneer species** are opportunistic colonizers of new or newly vacated habitats.

- Primary succession begins when pioneer species such as lichens and mosses colonize a barren habitat with no soil.

- Pioneers help build and improve soil for later successional species.
Factors Affecting Succession

- Species composition of a community changes frequently, in unpredictable ways.

- Which species are present in a community depends on (1) physical factors such as climate, (2) biotic factors such as which species arrived earlier, and (3) the extent of disturbances.
Intermediate Disturbance Hypothesis

- **Intermediate disturbance hypothesis**
  - Species richness is greatest in communities where disturbances are moderate in their intensity and frequency
Observed Primary Succession: Alaska’s Glacier Bay
Experiments in Primary Succession: Mount Saint Helens
The loss or addition of even one species may destabilize the number and abundances of species in a community.

Keystone species
- A species that has a disproportionately large effect on a community relative to its abundance.
In a rocky California intertidal zone, predation by sea stars (*Piaster ochracenus*) normally controls mussel populations.

When sea stars were removed, mussels crowded other invertebrates out (competitive exclusion) – species diversity fell from 15 species to 8.
Periwinkles and Algae: Effects of Competition and Predation

- Images and graphs illustrating periwinkles and algal diversity in different environments.

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Fig. 46-21d, p. 830

*d* Algal diversity in tidepools

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Algal diversity on rocks that become exposed at high tide

Fig. 46-21e, p. 830
Geographic dispersal happens in three ways:

- A population may expand its home range by slowly moving into outlying regions
- A population might be slowly moved from its home range by continental drift
- Individuals might be rapidly transported over great distances by other agents (jump dispersal)
Species Introductions

- Humans are a major cause of jump dispersal
  - Intentional or accidental introduction of exotics

- Exotic species
  - A species that is dispersed from its home range and permanently established in a new community
  - Often outcompetes native species, untroubled by competitors, predators, parasites and diseases that kept it in check in its own habitat
### Effects of Some Species Introductions in the US

**Table 46.2 Outcomes of Some Species Introductions Into the United States**

<table>
<thead>
<tr>
<th>Species Introduced</th>
<th>Origin</th>
<th>Mode of Introduction</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water hyacinth</td>
<td>South America</td>
<td>Intentionally introduced (1884)</td>
<td>Clogged waterways; other plants shaded out</td>
</tr>
<tr>
<td>Dutch elm disease:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Ophiostoma ulmi</em> (fungus)</td>
<td>Asia (by way of Europe)</td>
<td>Accidental; on infected elm timber (1930)</td>
<td>Millions of mature elms destroyed</td>
</tr>
<tr>
<td>Bark beetle (vector)</td>
<td></td>
<td>Accidental; on unbanked elm timber (1909)</td>
<td></td>
</tr>
<tr>
<td>Chestnut blight fungus</td>
<td>Asia</td>
<td>Accidental; on nursery plants (1900)</td>
<td>Nearly all eastern American chestnuts killed</td>
</tr>
<tr>
<td>Zebra mussel</td>
<td>Russia</td>
<td>Accidental; in ballast water of ship (1985)</td>
<td>Clogged pipes and water intake valves of power plants; displaced native bivalves in Great Lakes</td>
</tr>
<tr>
<td>Japanese beetle</td>
<td>Japan</td>
<td>Accidental; on irises or azaleas (1911)</td>
<td>Close to 300 plant species (e.g., citrus) defoliated</td>
</tr>
<tr>
<td>Sea lamprey</td>
<td>North Atlantic</td>
<td>Accidental; on ship hulls (1860s)</td>
<td>Trout, other fish species destroyed in Great Lakes</td>
</tr>
<tr>
<td>European starling</td>
<td>Europe</td>
<td>Intentional release, New York City (1890)</td>
<td>Outcompetes native cavity-nesting birds; crop damage; swine disease vector</td>
</tr>
<tr>
<td>Nutria</td>
<td>South America</td>
<td>Accidental release of captive animals being raised for fur (1930)</td>
<td>Crop damage, destruction of levees, overgrazing of marsh habitat</td>
</tr>
</tbody>
</table>

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Nonnative species introduced by human activities are affecting native communities on every continent.
Battling Algae

- A hybrid strain of aquarium algae (*Caulerpa taxifolia*) released in 1984 blankets thousands of acres of seafloor – and is spreading
The Plants that Overran Georgia

- Introduced in 1876 to the US with no native herbivores or pathogens to stop it, kudzu grows 200 feet/year and blankets anything in its path.
The Rabbits That Ate Australia

- Two dozen European rabbits released in 1859 became 200 to 300 million, turning shrublands and grasslands into eroded deserts
The gray squirrel, native to North America, has become a pest in Britain, where it outcompetes native European red squirrels.

Gray squirrels also carry a virus that kills red squirrels – but not grays; imported grays now outnumber reds 66 to 1.
Key Concepts
Community Stability and Change

- Communities have certain elements of stability, as when some species persist in a habitat

- Communities also change, as when new species move into the habitat and others disappear

- Physical characteristics of the habitat, species interactions, disturbances, and chance events affect how a community changes over time
Biogeography

- Scientific study of how species are distributed in the natural world
- Patterns differ from one habitat or region of the world to another
Mainland and Marine Patterns

- Generally, species richness is highest in the tropics and lowest at the poles
  - Tropical habitats have conditions that more species can tolerate (sun, rain, growing season)
  - Tropical communities have often been evolving longer than temperate ones
  - Species richness may be self-reinforcing
Latitude: Two Patterns of Species Diversity

(a) Species richness decreases with increasing latitude in the Northern Hemisphere. (b) Species richness increases with increasing latitude in the Southern Hemisphere.
Island Formation

- When a new island forms, species richness rises over time, and then levels off.

- Island of Surtsey formed in the 1960s
  - Vascular plants became established in 1965
  - Establishment of nesting seagulls in 1986 increased rate of introduction of new species
  - Equilibrium has not yet been reached
Surtsey: Colonization of a New Volcanic Island
Equilibrium Model of Island Biogeography

- **Equilibrium model of island biogeography**
  - The number of species on an island reflects a balance between immigration rates for new species and extinction rates for established ones.
  - The distance of an island from a colonizing source affects immigration (**distance effect**).
  - The size of an island affects immigration and extinction rates (**area effect**).
Distance Effects and Area Effects

![Graph showing the relationship between species richness and area (square kilometers). The graph includes two lines: one for islands less than 300 kilometers from a source, and another for islands more than 300 kilometers from a source. The x-axis represents area (square kilometers) ranging from 5 to 1,000,000, and the y-axis represents species richness (number of species) ranging from 5 to 1,000. The graph illustrates that species richness increases with area, with a steeper increase for islands closer to the source.](https://example.com/graph.png)

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Notes on Island Communities

- The equilibrium model of island biogeography can also be used to describe parks and wildlife preserves set in a “sea” of degraded habitat.

- Island populations face different selection pressures, and evolve in different ways.
Biogeographers identify regional patterns in species distribution.

They have shown that tropical regions hold the greatest number of species, and also that characteristics of islands can be used to predict how many species an island will hold.
Animation: Area and distance effects
Animation: Chemical defense
Animation: Effect of keystone species on diversity

- **Enteromorpha**
  - Algal diversity vs. periwinkles per square meter in tidepools

- **Chondrus**
  - Algal diversity vs. periwinkles per square meter in emergent rocks

(Reset Animation)
Animation: Hairston’s experiment
Animation: Resource partitioning
Animation: Species diversity by latitude
Animation: Succession
Animation: Wasp and mimics
Video: Fire ants in the pants
Video: Clownfish with anemone
Video: Finch at nest
Video: Owl with mouse