Chapter 54

Community Ecology

A biological **community** is an assemblage of populations of various species living close enough for potential interaction

Community interactions

Ecologists call relationships between species in a community **interspecific interactions**

Examples are competition, predation, herbivory, symbiosis (parasitism, mutualism, and commensalism), and facilitation

Interspecific interactions can affect the survival and reproduction of each species, and the effects can be summarized as positive (+), negative (–), or no effect (0)

Competition

Interspecific competition (–/– interaction) occurs

when species compete for a resource in short supply

Competitive Exclusion

Strong competition can lead to **competitive exclusion**, local elimination of a competing species

The competitive exclusion principle states that two species competing for the same limiting resources cannot coexist in the same place

Ecological Niches and Natural Selection

The total of a species' use of biotic and abiotic resources is called the species' **ecological niche**

An ecological niche can also be thought of as an organism's ecological role

Ecologically similar species can coexist in a community if there are one or more significant differences in their niches

Resource partitioning is differentiation of ecological niches, enabling similar species to coexist in a community

A species' fundamental niche is the niche potentially occupied by that species

A species' realized niche is the niche actually occupied by that species

As a result of competition, a species' fundamental niche may differ from its realized niche

- For example, the presence of one barnacle species limits the realized niche of another species

Character Displacement

Character displacement is a tendency for characteristics to be more divergent in sympatric populations of two species than in allopatric populations of the same two species

An example is variation in beak size between populations of two species of Galápagos finches

Predation

Predation (+/– interaction) refers to interaction where one species, the predator, kills and eats the other, the prey

Some feeding adaptations of predators are claws, teeth, fangs, stingers, and poison

Prey display various defensive adaptations

Behavioral defenses include hiding, fleeing, forming herds or schools, self-defense, and alarm calls

Animals also have morphological and physiological defense adaptations

Cryptic coloration, or camouflage, makes prey difficult to spot

Animals with effective chemical defense often exhibit bright warning coloration, called **aposematic coloration**

Predators are particularly cautious in dealing with prey that display such coloration

In some cases, a prey species may gain significant protection by mimicking the appearance of another species

In **Batesian mimicry**, a palatable or harmless species mimics an unpalatable or harmful model

In **Müllerian mimicry**, two or more unpalatable species resemble each other

Herbivory

Herbivory (+/– interaction) refers to an interaction in which an herbivore eats parts of a plant or alga

It has led to evolution of plant mechanical and chemical defenses and adaptations by herbivores

Symbiosis

Symbiosis is a relationship where two or more species live in direct and intimate contact with one another

Parasitism

In **parasitism** (+/– interaction), one organism, the **parasite**, derives nourishment from another organism, its **host**, which is harmed in the process

Parasites that live within the body of their host are called **endoparasites**

Parasites that live on the external surface of a host are **ectoparasites**

Many parasites have a complex life cycle involving a number of hosts

Some parasites change the behavior of the host to increase their own fitness

Mutualism

Mutualistic symbiosis, or **mutualism** (+/+ interaction), is an interspecific interaction that benefits both species

A mutualism can be

- Obligate, where one species cannot survive without the other
- Facultative, where both species can survive alone

Commensalism

In **commensalism** (+/0 interaction), one species benefits and the other is neither harmed nor helped

Commensal interactions are hard to document in nature because any close association likely affects both species

Facilitation

Facilitation (+/+ or 0/+) describes an interaction where one species can have positive effects on another species without direct and intimate contact

Diversity and trophic structure characterize biological communities

In general, a few species in a community exert strong control on that community's structure

Two fundamental features of community structure are species diversity and feeding relationships

Species Diversity

Species diversity of a community is the variety of organisms that make up the community

It has two components: species richness and relative abundance

- **Species richness** is the total number of different species in the community
- **Relative abundance** is the proportion each species represents of the total individuals in the community

Two communities can have the same species richness but a different relative abundance

Diversity can be compared using a diversity index

Shannon diversity index (*H*)

$$H = -(p_A \ln p_A + p_B \ln p_B + p_C \ln p_C + \ldots)$$

where A, B, C . . . are the species, *p* is the relative abundance of each species, and ln is the natural logarithm

Determining the number and abundance of species in a community is difficult, especially for small organisms

Molecular tools can be used to help determine microbial diversity

Diversity and Community Stability

Ecologists manipulate diversity in experimental communities to study the potential benefits of diversity

Communities with higher diversity are

- More productive and more stable in their productivity
- Better able to withstand and recover from environmental stresses
- More resistant to **invasive species**, organisms that become established outside their native range

Trophic Structure

Trophic structure is the feeding relationships between organisms in a community

It is a key factor in community dynamics

Food chains link trophic levels from producers to top carnivores

Food Webs

A **food web** is a branching food chain with complex trophic interactions

- Species may play a role at more than one trophic level
- Food webs can be simplified by
  - Grouping species with similar trophic relationships into broad functional groups
  - Isolating a portion of a community that interacts very little with the rest of the community

Limits on Food Chain Length

Each food chain in a food web is usually only a few links long

Two hypotheses attempt to explain food chain length: the energetic hypothesis and the dynamic stability hypothesis

The **energetic hypothesis** suggests that length is limited by inefficient energy transfer

- For example, a producer level consisting of 100 kg of plant material can support about 10 kg of herbivore **biomass** (the total mass of all individuals in a population)

The **dynamic stability hypothesis** proposes that long food chains are less stable than short ones

Most data support the energetic hypothesis

Species with a Large Impact

Certain species have a very large impact on community structure

Such species are highly abundant or play a pivotal role in community dynamics

Dominant Species

Dominant species are those that are most abundant or have the highest biomass

Dominant species exert powerful control over the occurrence and distribution of other species

One hypothesis suggests that dominant species are most competitive in exploiting resources

Another hypothesis is that they are most successful at avoiding predators

Invasive species, typically introduced to a new environment by humans, often lack predators or disease

Keystone Species and Ecosystem Engineers

Keystone species exert strong control on a community by their ecological roles, or niches

In contrast to dominant species, they are not necessarily abundant in a community

Ecosystem engineers (or “foundation species”)

cause physical changes in the environment that

affect community structure

For example, beaver dams can transform

landscapes on a very large scale

Bottom-Up and Top-Down Controls

The **bottom-up model** of community organization proposes a unidirectional influence from lower to higher trophic levels

In this case, presence or absence of mineral nutrients determines community structure, including abundance of primary producers

The **top-down model**, also called the trophic cascade model, proposes that control comes from the trophic level above

In this case, predators control herbivores, which in turn control primary producers

Biomanipulation can help restore polluted communities

In a Finnish lake, blooms of cyanobacteria (primary producers) occurred when zooplankton (primary consumers) were eaten by large populations of roach fish (secondary consumers)

The addition of pike perch (tertiary consumers) controlled roach populations, allowed zooplankton to increase and ended cyanobacterial blooms

Disturbance influences species diversity and composition

Decades ago, most ecologists favored the view that communities are in a state of equilibrium

This view was supported by F. E. Clements who suggested that species in a climax community function as a superorganism

Other ecologists, including A. G. Tansley and H. A. Gleason, challenged whether communities were at equilibrium

Recent evidence of change has led to a **nonequilibrium model**, which describes communities as constantly changing after being buffeted by disturbances

A **disturbance** is an event that changes a community, removes organisms from it, and alters resource availability

Characterizing Disturbance

Fire is a significant disturbance in most terrestrial ecosystems

A high level of disturbance is the result of a high intensity and high frequency of disturbance

The **intermediate disturbance hypothesis** suggests that moderate levels of disturbance can foster greater diversity than either high or low levels of disturbance

High levels of disturbance exclude many slow-growing species

Low levels of disturbance allow dominant species to exclude less competitive species

Ecological Succession

Ecological succession is the sequence of community and ecosystem changes after a disturbance

Primary succession occurs where no soil exists when succession begins

Secondary succession begins in an area where soil remains after a disturbance

Early-arriving species and later-arriving species may be linked in one of three processes

- Early arrivals may facilitate appearance of later species by making the environment favorable
- They may inhibit establishment of later species
- They may tolerate later species but have no impact on their establishment

Human Disturbance

Humans have the greatest impact on biological communities worldwide

Human disturbance to communities usually reduces species diversity

Biogeographic factors affect community biodiversity

Latitude and area are two key factors that affect a community's species diversity

Latitudinal Gradients

Species richness is especially great in the tropics and generally declines along an equatorial-polar gradient

Two key factors in equatorial-polar gradients of species richness are probably evolutionary history and climate

Temperate and polar communities have started over repeatedly following glaciations

The greater age of tropical environments may account for the greater species richness

In the tropics, the growing season is longer such that biological time is faster

Climate is likely the primary cause of the latitudinal gradient in biodiversity

Two main climatic factors correlated with biodiversity are solar energy and water availability

They can be considered together by measuring a community’s rate of evapotranspiration

Evapotranspiration is evaporation of water from soil plus transpiration of water from plants

Area Effects

The **species-area curve** quantifies the idea that, all other factors being equal, a larger geographic area has more species

A species-area curve of North American breeding birds supports this idea

Island Equilibrium Model

Species richness on islands depends on island size, distance from the mainland, immigration, and extinction

The equilibrium model of island biogeography maintains that species richness on an ecological island levels off at a dynamic equilibrium point