3

Evolution, Biodiversity, and Population Ecology

Chapter Objectives

This chapter will help students:

Explain the process of natural selection and cite evidence for this process

Describe the ways in which evolution influences biodiversity

Discuss reasons for species extinction and mass extinction

events

List the levels of ecological organization

Outline the characteristics of populations that help predict population growth

Assess logistic growth, carrying capacity, limiting factors, and other fundamental concepts in population ecology

Identify efforts and challenges involved in the conservation of biodiversity

Lecture Outline

I. Central Case: Striking Gold in a Costa Rican Cloud Forest

A. Local residents in Costa Rica's mountainous Monteverde region told of an elusive golden toad that appeared only in the early rainy season.

B. In 1964, Dr. Jay M. Savage and his colleagues encountered hundreds of these golden toads, which had never been formally discovered, during an expedition.

C. The newly discovered species went extinct 25 years later when global climate change caused drying of the forest.

II. Evolution as the Wellspring of Earth's Biodiversity

1. A **species** is a particular type of organism that shares certain characteristics and can breed with one another and produce fertile offspring.

2. A **population** is a group of individuals of a particular species

that live in a particular area.

3. Biological **evolution** consists of genetic change in organisms across generations.

4. **Natural selection** is the process by which inherited characteristics that enhance survival and reproduction are passed on more frequently to future generations, altering the genetic makeup of populations through time.

A. Natural selection shapes organisms and diversity.

1. In 1858, **Charles Darwin** and **Alfred Russell Wallace** each independently proposed the concept of natural selection as a mechanism for evolution and as a way to explain the great variety of living things.

a. Individuals of the same species vary in their characteristics.
b. Organisms produce more offspring than can possibly survive.
c. Some offspring may be more likely than others to survive and reproduce.

d. Characteristics that give certain individuals an advantage in surviving and reproducing might be inherited by their offspring.

e. These characteristics would tend to become more prevalent in the population in future generations.

2. A trait or characteristic that promotes success is called an **adaptive trait**, or an **adaptation**.

B. Natural selection acts on genetic variation.

1. Accidental changes in DNA are called **mutations** and can give rise to genetic variation among individuals. If a mutation occurs in a sperm or egg cell, it may be passed on to the next generation.

2. Most mutations have little effect; some are deadly; others are beneficial.

3. When organisms reproduce sexually they mix, or recombine, their genetic material so that a portion of each parent's genes contribute to the genes of the offspring.

C. Selective pressures from the environment influence adaptation.

1. Closely related species living in different environments may evolve differently as a result of different selective pressures.

2. Environments change over time and traits that produce success at one time or location may not do so at another.

3. Natural selection helps to elaborate and diversify traits that may lead to new species and new types or organisms.

D. Evidence of natural selection is all around us.

1. This process of selection conducted under human direction is termed **artificial selection**.

2. Many of our domestic pets and food crops are a result of this process.

E. Evolution generates biological diversity.

1. **Biological diversity**, or **biodiversity**, refers to the variety of life across all levels of biological organization, including the diversity of species and their genes, the diversity of populations within a community, and the diversity of communities within an ecosystem.

2. Scientists have described about 1.8 million species but estimate that 100 million may exist.

F. **Speciation** produces new types of organisms.

1. When populations of the same species are kept separate, their individuals no longer come in contact, so their genes no longer mix.

2. If there is no contact, the mutations that occur in one population cannot spread to the other.

3. Eventually the populations may diverge enough so that even if they come together again they may not be able to interbreed and have become different species.

G. Populations can be separated in many ways.

1. Geographic isolation, or allotropic speciation – caused by such issues as ice sheet movement, mountain range building, climate change and similar events – is considered to be the main mode of species formation.

2. Other mechanisms such as hybridization or different feeding and mating characteristics can also result in speciation.

H. We can infer the history of life's diversification by comparing organisms.

1. Scientists represent the history of divergence on diagrams called **phylogenic trees**. They illustrate hypotheses of how

divergence took place by looking at similarities among genes or external characteristics of organisms.

2. By mapping traits such as flights, swimming, or vocalization on the trees according to which organisms possess them, biologists can infer evolutionary histories.

I. The fossil record teaches us about life's long history.

1. Hard parts of organisms are often preserved after death when sediments are compressed into rock and minerals replace the organic material, leaving behind a **fossil**. Dating these sediments allows scientists to produce a **fossil record**.

2. The fossil record shows an evolution of life on Earth over a period of at least 3.5 billion years with a generally increasing number of species over time.

3. The species living today are a small fraction of those that ever existed, many of which disappeared during episodes of mass extinction.

J. Speciation and extinction together determine Earth's biodiversity.

1. The disappearance of a species is called **extinction**.

2. The fossil record indicates an average existence of a species on Earth to be 1-10 million years.

3. Human impact appears to be speeding up extinctions.

K. Some species are more vulnerable to extinction than others.

1. Generally, extinction occurs when environmental conditions change rapidly or severely enough that a species cannot genetically adapt to the change.

2. Some species are vulnerable because they are **endemic**, occurring in only a single place on the planet.

L. Earth has seen several episodes of mass extinction.

1. There have been five **mass extinction events** at widely spaced intervals in Earth's history. Each wiped out anywhere from 50 to 95% of Earth's species each time.

2. The best known of these occurred 65 million years ago and brought an end to the dinosaurs, but it was not the largest.

M. The sixth mass extinction is upon us.

1. Many biologists conclude that human activities have caused an extinction rate that is 100-1,000 times greater than the historic background rate.

2. Amphibians, such as the golden toad, are disappearing at a higher rate than other organisms, with 170 species having

disappeared in the last few decades and 30% of their species in danger of extinction.

III. Levels of Ecological Organization

1. **Ecology** is the study of interactions among organisms and between organisms and their environments.

A. We study ecology at several levels.

1. Life occurs in a hierarchy of levels, from the atoms, molecules, and cells up through the **biosphere**, which is the cumulative total of living things on Earth and the areas they inhabit.
2. At the level of the organism, ecology describes the relationships between the organism and its physical environment.
3. **Population ecology** examines the dynamics of population change and the factors that affect its distribution and abundance.
4. **Communities** are made up of multiple interacting species that live in the same area. **Community ecology** focuses on species diversity and interactions among species.
5. **Ecosystems** encompass communities and the abiotic (nonliving) material, and forces with which their members interact. **Ecosystem ecology** reveals patterns, such as the flows of energy and nutrients, by studying living and non-living components of systems.

B. Each organism has habitat needs.

1. The specific environment in which an organism lives is its **habitat,** which consists of living and non-living elements around it.
2. Each organism thrives in certain habitats and not others, leading to non-random patterns of **habitat use**.
3. Mobile organisms can choose where to live by **habitat selection**. For non-mobile organisms whose young disperse and settle passively, habitat uses result from success in some and failures in others.
4. The habitat needs of many organisms often conflict with those of humans who want to alter or develop habitats for human use.

C. Niche and specialization are key concepts in ecology.

1. A species' **niche** reflects its use of resources and its functional role in a community.
2. Species with very specific requirements are said to be **specialists**.
3. Those with broad tolerances, able to use a wide array of habitats or resources, are **generalists**.

IV. Population Ecology

A. Populations exhibit characteristics that help predict their dynamics.

1. **Population size** is the number of individual organisms present at a given time.
2. **Population density** is the number of individuals in a population, per unit area. This is often the major consideration for success or failure of mating or food competition.
3. **Population distribution**, or **population dispersion**, is the spatial arrangement of organisms within a particular area. Ecologists define three types: random, uniform, and clumped.
4. A population's **sex ratio** is its proportion of males to females.
5. **Age distribution**, or **age structure**, describes the relative numbers of organisms of each age within a population.
6. Birth and death rates measure the number of births and deaths per 1,000 individuals for a given time period.
7. The likelihood of death varies with age; this can be graphically shown in **survivorship curves**.

B. Populations may grow, shrink, or remain stable.

1. **Demographers,** scientists who study human populations, use mathematical concepts to study population changes.
2. Population growth or decline is determined by four factors: births, deaths, **immigration** into an area, and **emigration** away from an area.
3. The **natural rate of population growth** is determined by subtracting the death rate from the birth rate.
4. The **population growth rate** equals the crude birth rate plus the immigration rate, minus the crude death rate plus the emigration rate.

C. Unregulated populations increase by exponential growth.

1. When a population increases by a fixed percentage each year, it is said to undergo **exponential growth**.

D. Limiting factors restrain population growth.

1. Every population is eventually contained by **limiting factors**, which are physical, chemical, and biological characteristics of the environment.
2. The interaction of the limiting factors determines the **carrying capacity**.
3. The **logistic growth curve**, an S-shaped curve, shows a population that increases sharply at first and then levels off as it is affected by limiting factors.

E. The influence of some factors on population depends on population density.

1. The influence of **density-dependent** factors waxes and wanes according to population density.
2. **Density-independent** factors are not affected by population density.

F. Carrying capacities can change.

1. Limiting factors are diverse and complex, and help keep population levels below carrying capacity.
2. Some organisms can alter their environment to reduce environmental resistance and increase carrying capacity.
3. Humans have appropriated immense proportions of the planet's resources and in the process have reduced the carrying capacities for many other organisms.

G. Reproductive strategies vary among species.

1. Species that devote large amounts of energy and resources to caring for a few offspring are said to be **K-selected**, because their populations tend to stabilize over time at or near their carrying capacity.
2. Species that are **r-selected** have high biotic potential and devote their energy and resources to producing as many offspring as possible in a relatively short time.
3. K is an abbreviation for carrying capacity, and species that are K-selected species are ones that tend to stabilize over time at or near the carrying capacity.

H. Changes in populations influence the composition of communities.

V. Conserving of Biodiversity

A. Social and economic factors affect species and communities.

1. Early European immigrants and their descendants viewed Costa Rica's forests as an obstacle to agricultural and timber development.
2. Since 1945, Costa Rica's population quadrupled and pressures on land increased.

B. Costa Rica took steps to protect its environment.

1. Beginning in 1970, Costa Rica began protecting its land resources. Today over a quarter of the country's area lies within national parks or other protected reserves.
2. Tourists now visit Costa Rica for **ecotourism**.

VI. Conclusion

A. Natural selection, speciation, and extinction help determine Earth's biodiversity.

B. Many biologists believe that human activities are playing a role in biodiversity loss.

Key Terms for Chapter 3

adaptation
adaptive trait
age distribution
age structure
artificial selection
biodiversity
biological diversity
biosphere
carrying capacity
communities
community ecology
Darwin, Charles
demographers
density dependent factor
density independent factor
ecology
ecosystem ecology
ecosystems
ecotourism
emigration
endemic evolution
exponential growth
extinction
fossil
fossil record
generalists
habitat
habitat use
habitat selection
immigration
K-selected limiting
factors logistic
growth curve
mass extinction events
mutations
natural selection
natural rate of population growth
niche
phylogenetic trees
population density
population dispersion
population distribution
population ecology
population growth rate
population size
r-selected
sex ratio
specialists
speciation
species
survivorship curves
Wallace, Alfred Russell