

Ecosystem Ecology Lecture Outline

I. Ecosystems

- A. Many global environmental problems have emerged recently.
 - 1. Examples: global warming, acid rain, the ozone hole, anaerobic “dead zones,” algal blooms, and so forth.
 - 2. Problems develop when humans change the chemical and physical characteristics of the environment.
- B. Ecosystems consist of all the organisms that live in an area, as well as the nonbiological components.
 - 1. Ecosystems are composed of multiple communities along with their physical and chemical environment.
 - 2. Relevant abiotic components are nutrients, air, water, sunlight, soil, temperature.
 - 3. Flows of energy and exchanges of nutrients link the biotic and abiotic components.
 - 4. The focus of ecosystem studies is to understand:
 - a. How molecules cycle between the abiotic and biotic environments.
 - b. How energy in sunlight dissipates as it flows through an ecosystem.

II. Energy Flow and Trophic Structure

- A. All ecosystems have four components that are linked by the flow of energy. (**Fig. 54.1**)
 - 1. Primary producers
 - a. They use solar or chemical energy to manufacture their own food.
 - b. They form the basis of ecosystems by transforming energy in sunlight or reduced inorganic compounds into the chemical energy stored in sugars.
 - c. All producers are autotrophs.
 - 2. Consumers
 - a. They include all organisms that eat other organisms.
 - b. Herbivores eat plants.
 - c. Carnivores eat animals.
 - 3. Decomposers
 - a. They obtain energy by feeding on the dead remains of other organisms.
 - b. They may also feed on the waste products of other organisms.
 - 4. The abiotic environment
 - a. It includes the soil, climate, atmosphere, and so forth.
 - b. It can also include things as fine as the particulates and solutes in water.
- B. Global Patterns in Productivity
 - 1. How does net primary productivity vary among ecosystems? Look at the summary of NPP data from around the globe (**Fig. 54.2**), or look at NPP data as organized by biome. (**Fig. 54.3**)

2. Tropical rain forests have the highest productivity, whereas desert and arctic regions have the lowest. Marine productivity is the highest along coasts.
3. The overall productivity of terrestrial ecosystems is limited by a combination of temperature and the availability of water and sunlight. (**Fig. 54.4**)
4. The overall productivity of marine ecosystems is limited by the availability of nutrients.
5. Experiment: Biologists show that large increases occur in the concentration of chlorophyll *a* in surface waters over a two-week interval after fertilization with iron. (**Fig. 54.5**)

C. Trophic Structure

1. Organisms that obtain their energy from the same type of source occupy the same trophic level.
 - a. Each feeding level represents a trophic level.
 - b. Example: All plant-eating organisms occupy the same trophic level. (**Fig. 54.7**)
 - c. Primary producers, primary consumers, and secondary consumers all define the trophic structure of an ecosystem.
 - d. Organisms at the top trophic level are not eaten by any other organisms.
2. Ecosystems share a characteristic pattern of productivity at each trophic level.
 - a. Productivity declines from one trophic level to the next.
 - b. Productivity is highest at the lowest trophic level.

D. Food Chains and Food Webs

1. A food chain describes the species occupying each trophic level in a particular ecosystem. (**Fig. 54.7**)
2. Food chains are usually embedded in more complex food webs because multiple species are present at several trophic levels. (**Fig. 54.8**)
3. Food chains and webs are the most basic ways to describe the structure of an ecosystem.
4. Schoener found that the maximum number of links in any food chain or web ranged from 1 to 6.

E. Hypotheses to Explain Why Ecosystems Don't Have 8, 9, 10, or More Trophic Levels

1. Energy transfer may limit food-chain length.
 - a. As energy is transferred up the food chain, a large fraction is always lost.
 - b. By the time energy reaches the top trophic level, there may not be enough left to support an additional group of consumers. (**Fig. 54.9**)
 - c. This hypothesis predicts that there should be more trophic levels in ecosystems with higher productivity or higher energy-transfer efficiency.
 - d. To date, research has not supported this prediction.
2. Long food chains may be more fragile. (**Fig. 54.10**)
 - a. Long food chains are easily disrupted by environmental disturbances.
 - b. Therefore, they tend to be eliminated.

- c. Mathematical models show that long food chains take longer to return to their previous state following a disturbance.
 - d. Long food chains are unlikely to persist in a variable environment.
 - e. This hypothesis also predicts that food chains should be longer in more stable environments.
 - f. Some data support this prediction, but other data have challenged it.
3. Food-chain length may depend on environmental complexity.
- a. Food-chain length may be a function of an ecosystem's physical structure.
 - b. Three-dimensional ecosystems should have longer food chains than two-dimensional ones.
 - c. Data support the idea that dimensionality does influence food-web structure.
 - d. The mechanism for this pattern remains unknown, however.
- F. There is no simple answer to the question of what limits food chains. Each of the hypotheses listed here may all have a limiting impact on food chains, and their interrelationship may be the key.
- G. Analyzing Energy Flow: A Case History
- 1. Researchers extensively measured how energy flows through a forest ecosystem.
 - a. They found that 0.8% of the light was captured by photosynthesis. **(Fig. 54.11)**
 - b. Plants used 55% of this energy for growth and 45% for maintenance (lost as respiration).
 - 2. In chipmunks, 80.7% of energy intake goes to maintenance, 17.7% is excreted, and only 1.6% goes into the production of new tissue (secondary production). **(Fig. 54.12)**

III. Biogeochemical Cycles

- A. Energy is not the only quantity that is transferred when one organism eats another.
 - 1. Nutrients also cycle through ecosystems.
 - 2. The path an element takes as it moves from abiotic systems through living organisms and back again is referred to as its biogeochemical cycle.
- B. Humans are now disrupting biogeochemical cycles on a global scale.
- C. Researchers study three basic aspects of biogeochemical cycling:
 - 1. The nature and size of the pools or reservoirs where elements are stored for a period of time
 - 2. The rate of movement between pools and the factors that influence these rates
 - 3. How different biogeochemical cycles interact
- D. Biogeochemical Cycles in Ecosystems **(Fig. 54.13)**
 - 1. Summary of the process
 - a. Nutrients are taken up from the soil by plants and incorporated into plant tissue.

- b. If the plant is eaten, the nutrients pass to the animal members of the ecosystem.
 - c. If the plant dies, the nutrients and plant biomass in them become litter, or dead biomass.
 - d. Once ingested by an animal, nutrients are excreted in fecal matter or urine, taken up by a parasite or predator, or enter the dead biomass pool when the individual dies.
 - e. Decomposers break down the nutrients in plant litter, animal excretions, and dead animal bodies.
 - f. The nutrients then become part of the organic matter of soil. Soil organic matter is a complex mixture of partially decomposed detritus.
 - g. The nutrients in soil organic matter are converted to an inorganic form.
 - h. The nutrients are now once again available for uptake by plants.
2. A key feature in the process is that nutrients are reused.
- a. This reuse is not total.
 - (1) Nutrients do leave the ecosystem whenever plant or animal biomass is removed.
 - (2) Examples: flowing water, wind, soil erosion
 - b. This is often called nutrient recycling.

E. Factors Controlling the Rate of Nutrient Cycling in Ecosystems

- 1. Decomposition of detritus usually limits the overall rate of nutrient movement the most.
- 2. The decomposition rate is influenced by two factors:
 - a. Abiotic conditions
 - (1) These include temperature and precipitation.
 - (2) Example: accumulations of detritus in boreal versus tropical forests (**Fig. 54.14**)
 - b. Quality of detritus as a nutrient source for the decomposers
 - (1) Decomposers can be limited by the presence of large compounds that are difficult to digest.
 - (2) The growth of decomposers is also inhibited if detritus is low in nitrogen.

F. Factors Influencing the Rate at which Nutrients Are Exported from Ecosystems

- 1. Nutrient availability has a profound effect on productivity.
- 2. The rate of nutrient loss is an important characteristic of any ecosystem.
- 3. Many human activities accelerate nutrient loss.
- 4. Researchers tested the effect of vegetation removal on nutrient cycling. (**Fig. 54.15**)
 - a. Experiment:
 - (1) They compared nutrient loss in a vegetated and devegetated site over the course of 4 years.

- (2) Before removing the vegetation, they documented that 90% of the nutrients in the ecosystems were in soil organic matter, with an additional 9.5% in plant biomass.
- (3) After the vegetation was removed, they monitored the concentrations of nutrients in the streams exiting the two watersheds.
- b. Results: Nutrient losses were typically 10 times as high in the devegetated site versus the control site.
- c. Conclusions:
 - (1) Devegetation has a huge impact on nutrient export.
 - (2) Without plants to recycle them, nutrients are quickly washed out of the soil and lost to the ecosystem.
 - (3) Devegetated areas are much less productive than intact, vegetated sites.

G. Global Biogeochemical Cycles

1. When nutrients leave one ecosystem, they enter another.
2. The movement of nutrients among ecosystems links local biogeochemical cycles into one massive global system.
3. The global water cycle (**Fig. 54.16**)
 - a. Water typically evaporates from the ocean and then precipitates back into the ocean. The key here is that evaporation exceeds precipitation—a net gain of water into the atmosphere.
 - b. This vapor moves over land and precipitates. The cycle is completed by water that moves from land to the oceans via streams and groundwater.
4. The global carbon cycle (**Fig. 54.17**)
 - a. The global carbon cycle involves the rapid movement of carbon between terrestrial ecosystems, the oceans, and the atmosphere.
 - b. The ocean is the largest pool or reservoir of carbon.
 - c. Carbon moves in and out of the atmospheric pool at exceptionally high frequencies.
 - d. Carbon frequently moves through atmospheric pools through organisms.
 - e. In both terrestrial and aquatic systems, photosynthesis is responsible for taking carbon from the atmosphere and incorporating it into tissue.
 - f. Respiration releases carbon from living organisms back into the atmosphere.
 - g. Humans have changed the carbon cycle. (**Fig. 54.18**)
 - (1) Burning fossil fuels
 - (2) Land-use changes (e.g., deforestation)
 - (3) The use of fire
 - h. CO₂ is a greenhouse gas because it traps heat that has been radiated from Earth and keeps it from being lost to space.
5. The global nitrogen cycle (**Fig. 54.19**)
 - a. A key aspect is that plants are able to use nitrogen only in the form of NH₄⁺ or NO₃⁻.
 - b. The vast pool of molecular nitrogen (N₂) in the air is unavailable to plants.

- c. Nitrogen is added to ecosystems in a usable form only when it is “fixed.”
 - (1) This means it is converted from N_2 into either NH_4^+ or NO_3^- .
 - (2) This can be accomplished by lightening reactions in the atmosphere or by enzymes in bacteria that live in the soil and oceans.
 - d. Humans have altered this cycle.
 - (1) Nitrogen fixation from human sources is now about equal to that from natural sources. (**Fig. 54.20**)
 - (2) Human-fixed nitrogen comes from industrially produced fertilizers, the release of nitric oxide during fossil fuel combustion, and the cultivation of crops.
 - e. Adding nitrogen to terrestrial ecosystems usually increases productivity.
 - (1) This can be beneficial in some cases.
 - (2) However, it can also be very detrimental.
 - (a) Nitrogen runoff can also be very harmful to aquatic systems.
 - (b) Nitrogen inputs can lead to a significant loss of biodiversity.
- H. Some of our most pressing environmental problems result from recent and massive alterations in biogeochemical cycles. Even local changes can have large-scale consequences.

III. Human Impacts on Ecosystems

- A. Residents of industrialized countries, though relatively few in number, have a disproportionately large impact on biogeochemical cycles because they use so much energy, water, food, and other resources. (**Fig. 54.21**)
- B. Global Warming
 - 1. In 1998, researchers summarized the studies and data available on global warming and concluded that current evidence suggests a “discernible human influence on climate.”
 - 2. In 2001 the new report stated that “there is new and stronger evidence that most of the warming observed over the last 50 years is attributable to human activities.”
 - 3. The panel has taken the position that the rise in concentrations of greenhouse gases are at least partially—if not primarily—responsible for global warming.
 - 4. Example: Warming ocean temperatures have reduced the number of copepod species and their respective ranges. (**Fig. 54.22**)
- C. Productivity Increases
 - 1. If grassland habitats are fertilized with nitrogen, productivity increases but species richness declines over time.
 - 2. Nitrate ions derived from fertilizers are washing into the Gulf of Mexico. This has stimulated the growth of planktonic organisms, whose subsequent decomposition has used up available oxygen and triggered the formation of anaerobic “dead zones.”
 - 3. Increased nitrate runoff from fertilizers has also cause toxic algal blooms.

4. Massive phosphate runoff in the 1960s and 1970s resulted in explosive growth in cyanobacteria, large die-off, and eventual lake eutrophication—the conversion of a lake to a highly productive ecosystem with rapid decomposition, low oxygen levels, and rapid filling with decomposing organic matter.