Unit 4

Ecosystems

Background

Introduction

The abundance of a species and species diversity affect how natural resources are processed within an ecosystem. This pattern of processing contributes to functional and compositional characteristics of an ecosystem. But many ecosystems around the world are currently experiencing significant changes in species composition, abundance, and diversity due to the influence of human activity. These changes have, more often than not, led to a reduction in species diversity. Changes in species composition, species richness, and/or functional type affect the efficiency with which resources are processed within an ecosystem, raising the issue of whether the biogeochemical functioning of an ecosystem will be impaired by a loss of species or the introduction of a new species.

Essential Questions

Why do ecosystems like Tropical Rainforests have such immense diversity?

What have scientists discovered that determines how many individuals of a species can be supported within an ecosystem?

How does science restore the diversity to areas where human activity has interfered with the natural structure of a habit/ecosystem?

Content

Unit 4 addresses two fundamental questions that ecologists seek to answer: Why is there so much diversity within ecosystems and why are so many species in such abundance? Today ecosystems are shaped and characterized by complex interactions among social, economic, institutional, and environmental variables. The effects of anthropogenic habitat loss or degradation on the numbers and types of species in an ecosystem are still unfolding.

The video introduces us to Stuart Davies, director of the Center for Tropical Forest Science (Smithsonian Tropical Research Institution), who studies tropical rain forests, one of the most diverse biomes on Earth. Davies and his research team are conducting a worldwide tree census in an attempt to discover how such a wide range of species competing for the same resources can successfully co-exist. These scientists are trying to understand this by studying energy flow and biogeochemical cycling concepts, niche evolution and partitioning in forests, and the role of predators and pathogens in maintaining diversity (Janzen-Connell effects) and species abundance. The second case study focuses on the rise and fall of different populations in a riparian habitat as a result of a wolf re-introduction project in a temperate ecosystem. Robert Crabtree, chief scientist and founder of The Yellowstone Ecological Research Center, untangles the cascading effect in Yellowstone National Park after the wolf was removed and 70 years later reintroduced. By looking at the balance that exists between species, both scientists wish to learn how to manage and protect any ecosystem from becoming permanently and irreversibly destroyed.

Background

Learning Goals

During this session you will have an opportunity to build understandings of the following.

a. Knowledge

   i. Global circulation patterns and geography create the basic conditions that determine abundance and diversity.

   ii. Decomposers are more important than organisms at any trophic level when it comes to flow of energy through a food chain or food web.

   iii. Bioaccumulation of a toxin in the lower trophic levels can lead to biomagnifications in a predator.

   iv. Living organisms have the capacity to produce populations of infinite size, but environments and resources are finite (carrying capacity).

   v. Organisms with a narrow niche are the most sensitive to environmental changes.

   vi. A disruption of ecosystem interactions impacts the natural selection process.

b. Skills

   i. Ability to recognize the mechanism responsible for the elevated absorption of carbon by land ecosystems.

   ii. Ability to understand how to "harvest" a population without disrupting its natural growth rate.

c. Dispositions

   i. Alteration of ecosystem interaction has a direct impact on social, economic, and political systems.

   ii. Human alteration of ecosystem interactions through direct harvesting, pollution, atmospheric changes, and other factors is threatening current global stability, and, if not addressed, ecosystems will be irreversibly affected.

Key Concepts

Bioaccumulation

Biome

CO_2 fertilization

Co-evolution

Competitive exclusion principal

K-selected

Primary production (gross/net)

Succession

Latitudinal biodiversity gradient

Life history strategy

Mimicry

Nitrogen fixation/denitrification

Niche (fundamental/realized)

Niche partitioning

R-selected

Trophic level

FACILITATOR: These concepts correspond roughly to the sections of the unit. There are a number of other concepts that could be included. It is best to start with the author's major ideas and then ask for input from the study group for other concepts they would include.

Background

Misconceptions about Ecosystems

Although misconceptions can be a result of a misunderstanding or misinformation, some have their beginnings in the attitudes held by people with a personal interest. Misconceptions are scientifically inaccurate assumptions or explanations of facts that are gathered by an individual through his/her experiences or perceived experiences. Misconceptions involving ecological phenomena are particularly important to overcome because ecology teaches individuals how they are affected by, and have an effect on, the ecosystems. Ironically, we are simultaneously the most potent forces within most ecosystems and yet nearly oblivious to the ecological effects of our daily lifestyles. There has never been a time when a deep understanding of ecosystems and our roles within them has been more critical.

Below is a list of common misconceptions about ecosystems. The facilitator should lead a discussion on how the following misconceptions might have come to be. Participants should look at public or private factors such as attitude, personal motive, lack of information, and total ignorance.

- Ecosystems are not an organized whole, but a collection of organisms.
- Forest fires are harmful to terrestrial ecosystems and should not be allowed to burn.
- An organism cannot change trophic levels.
- An animal that is high on the food web preys on all populations below it.
- The top of the web has the most energy.
- Characteristics of a population are created according to the needs of the individual or according to a predetermined grand plan.
- Characteristics are passed on by the bigger, stronger organisms.
- Species live together in an ecosystem because they have compatible needs and behaviors.
- A change in the prey population has no effect on the predator.

Getting Ready (45 minutes)

Activity One: Assessing Prior Knowledge, Questions, and Related Experiences

FACILITATOR: Distribute index cards to the study group. On the first card, participants should indicate something they know about ecosystems. On the second, they write one question they have about ecosystems. And on the third card, they should describe a direct experience that they have had that relates to ecosystems. For example an individual might write:

The pond in my neighborhood is an aquatic ecosystem.

Is my neighborhood part of a larger ecosystem?

I enjoyed scuba diving on coral reefs.

Getting Ready

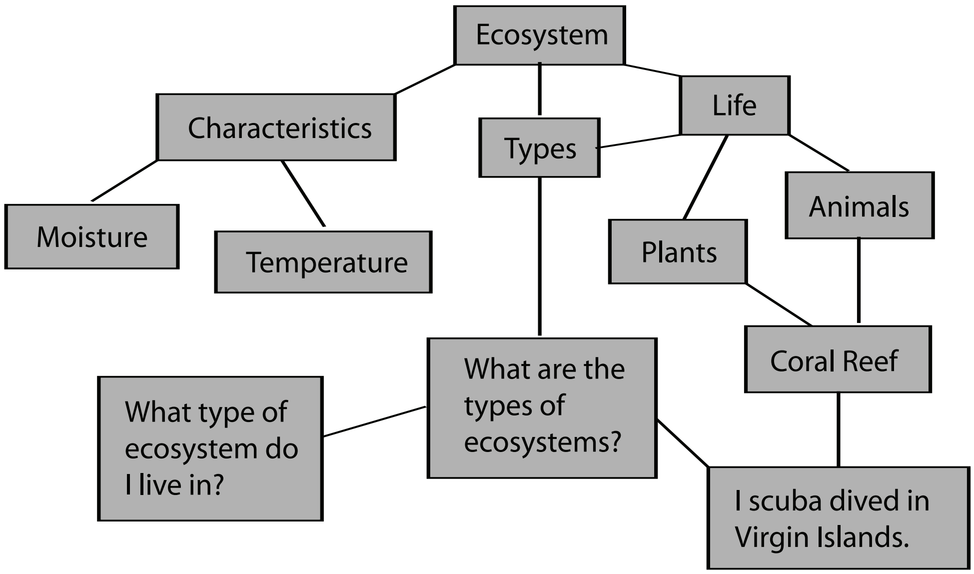

Figure 4.1 An example of a study groups' idea collection, with major subjects identified and the addition of the major focus ideas from the video. This activity links individual pre-existing knowledge with that of other members of the group and the unit content.

Activity Two: Current Events & Editorial Cartoons

Participants will share an article that they have found that relates to the week's topic. All members of the group will share their headlines for the articles. The leader should ask a few people to summarize their articles and ask for comments from others with related articles. As the group discusses the articles, a participant should record key concepts and make a list. (Participants may choose to bring in a cartoon or an editorial related to the week's topic instead of an article.)

Activity Three: Ecology Lab Simulation

During this activity, the participants will use the Interactive Lab: Ecosystems (www.learner.org/channel/courses/envsci/interactives/ecosystems) to construct a computer-simulated food web that will put Plants B and C in a growth pattern that is normal for an imaginary habitat. For this particular ecosystem, Plant B and C population numbers typically cycle in an inversely proportionate relationship—when one type is at its highest, the other is at its lowest; in between, the numbers are equal. The cycle continues to repeat over and over. The pattern is similar to a series of continuous infinity (∞∞∞) symbols. In this habitat, Plant A exists only when it is transported in the feces of a specific species of migrating birds, Cedar Waxwings. Plant A, being an opportunist, easily out-competes Plants B and C if natural controls are not in place and Plant C can quickly become extinct as a result of competitive exclusion.

Under normal circumstances, Plant A populations never become a significant competitor because the deer populations tend to favor Plant A over Plants B and C. For the past five years, a disease has been keeping the deer populations below normal numbers and, consequently, Plant A has predominated. Now the deer populations are healthy again.

The objective in this simulation is to construct a food web that restores Plants B and C to their normal population cycles and excludes Plant A sometime after Day 70.

Getting Ready

FACILITATOR

1. Divide participants into groups depending on the number of computers available in the room. Show them where to find the Ecology Lab simulation module. Have the participants click on the "Tableau" drop down menu and select plants.
2. Announce that all trophic levels must be used and no species may be excluded via competitive exclusion until after Day 70. The inverse relationship between Plants B and C must exist until the end of the simulation run through Day 100.
3. If participants are having trouble finding a web, give hints that will allow them to find a food web to achieve the Plant B to C growth pattern. The following is one example: Plants A and B would be preyed on by all five possible predators and Plant C would have no predation. The herbivore predators are as follows: Herbivore A is prey to the top predator; Herbivore B is prey to Omnivore A; and Herbivore C is prey to the top predator. Out of the two omnivores only Omnivore A is preyed on by the top predator. Omnivore B has no predators.
4. Have the participants use the above scenario but another feeding relationship. What happens when Omnivore B preys on Omnivore A? Is this a more stabilized food web?

Discussion Questions

1. Following Plant A's extinction, what other species will eventually disappear at approximately 85 days? Why did this happen?
2. Predict what would happen if the deer were removed from this food web. How are the producers affected? What other cascades occur?
3. In this food web, which species has the highest population number? What happens if it is removed from the food web?
4. In this food web, which has the biggest impact on the food web, removal of Herbivore B (the snail) or Herbivore C (the deer)? Does population size or individual size have the greatest impact? Explain your answer.

Video (45 minutes)

Activity Four: Watch the Video

As you watch the video, think about the following focus questions.

1. What is the function of the Center for Tropical Forest Science (CTFS)?
2. Why are the trees given the title of "engineers" of the tropical rain forest?
3. What is the Barrows Colorado Island (BCI Plot) CTFS project and what are some of the significant findings about diversity and abundance in ecosystems such as BCI?
4. Why does a high density species suffer greater mortality rates than rare density species?
5. What is the focus of Robert Crabtree's research project in Yellowstone National Forest?
6. What were some of the Park's initial management strategies during the early 1900s to help preserve this national resource?

7. What was the cascade effect of the elimination of the Park's wolf population after 1926? Consider the following in your answer: willow, beaver, and elk populations.
8. Food chains and webs can be shaped from the "top down" or from the "bottom up." Which of these two categories best describes the wolf reintroduction project of 1995 and 1996?
9. What are the "hot spots" in Yellowstone and how are they important to the wolf reintroduction research project?
10. What is meant by "escape height" and what additional parameters are used to measure the cascade effects of the wolf reintroduction process?

Activity Five: Discuss the Video

Discuss the following questions about the video.

1. Why do tropical rainforests have such immense diversity? How do they maintain their diversity?
2. What role do tropical forests play in stabilizing climate and atmosphere? Can we take advantage of and enhance their ability to store carbon? Why is this important?
3. How can the data from a tropical rainforest that explains species diversity and abundance be helpful in managing and protecting temperate forests such as those in Yellowstone National Park or any other ecosystem on planet Earth?

FACILITATOR: Refer back to the misconception section and Activity One: Assessing Prior Knowledge. Has the video contributed to the participants' new understanding of concepts? Are there any changes the participants would make in the arrangement of their cards from Activity One?

Going Further (60 minutes)

Activity Six: Determination of Species Diversity and Abundance Using Owl Pellet Data

Background Information

In this activity, barn owl pellet data are used to determine an ecosystem's degree of biodiversity. The barn owl (tyto alba) swallows small birds and rodents whole, and the resulting pellets generally contain the complete skeletons of the owl's prey. While carnivorous mammals, such as bobcats and wolves, have teeth to grind up bones and claws and a digestive tract adapted to pass these ground parts, owls do not have teeth for grinding and cannot safely pass whole bones and claws through their digestive tract. Instead, these materials form a bolus (or pellet), which is surrounded by the hair or feathers of their prey and orally expelled. Barn owls can expel one to two pellets per day. Scientists take advantage of this adaptation by examining the pellet's contents. Since barn owls are not very selective feeders, these pellets can be used to estimate the diversity of available prey within their feeding range. The contents are also a direct indicator of what an owl has fed on—information that is crucial for species management and protection.

There are many genera of prey that occur in both the Northwest (Washington, Oregon) and Southeast (Mississippi, Alabama, Louisiana), as well as several that are exclusive to one of these areas. The owl pellet table seen below contains 14 mammalian prey types that account for approximately 95 percent of the prey found in each of the two habitats. Other prey consists of birds, bats, insects, crayfish, and small reptiles.

Going Further

Procedure

The facilitator should copy Table 4.1, Owl Prey Data, for all participants in the group and explain the background information about owl pellets and how they relate to the video and the text. (If possible, it would be interesting to have some owl pellets available so participants could see the general appearance and samples of remnant prey.) Depending on time, the facilitator may provide the chart below with all of the data and calculations or give the participants a chart in which they have to do the biomass calculations: genera, group, and regional totals. The facilitator may want to have students work in groups to divide up the tasks.

Table 4.1 Owl Prey Data and Calculations

	Northwest United States				Southwest United States			
Prey: Groups and Genera	No. per 50 pellets[1]	Prey Weight[2], grams	Total genera biomass, grams	Total group biomass, grams	No. per 50 pellets[1]	Prey Weight[2], grams	Total genera biomass, grams	Total group biomass
Pocket Gopher Thomomys	7	150	1,050	1,050	**		0	0
Rat				450				1,890
Sigmodon	**				11	100	1,100	
Oryzomys	**				8	80	640	
Rattus	3	150	450		1	150	150	
Vole Microtus	12	40	480	480	8	40	320	320
Mice				386				402
Peromyscus	4	22	88		6	22	132	
Mus	7	18	126		11	18	198	
Reithrodontomys	6	12	72		6	12	72	
Perognathus	4	25	100		**			
Mole				110				165
Scapanus	2	55	110		**			
Scalopus	**				3	55	165	
Shrew				24				192
Blarina	**				7	20	140	
Cryptotis	**				11	4	44	
Sorex	6	4	24		2	4	8	
Other Prey				162				148
Bats	4	7	28		2	7	14	
Birds	6	15	90		4	15	60	
Insects	4	1	4		4	1	4	
Crayfish	4	5	20		2	5	10	
Small Reptiles	1	20	20		3	20	60	
Total Habitat Biomass / 50 pellets / region					2,662			3,117

Notes:

1. Assume each owl expels two pellets per day. Assume there is one owl per sample area. Data represents 25 feeding days.
2. Prey weight is the average for each species.

** Does not occur

Going Further

Questions about Data

Which type of prey contributed the most by number for each region?

Did the same prey type contribute the most by number for both regions?

Which prey type contributed the most in biomass for each region? Did this same prey type contribute the most in biomass for both regions?

If an owl needs 100 grams of food per day, how many Sorex does it need to capture? How many Sigmodon?

Assume an owl eats 100 grams of insects and one 100 gram rat. Which prey contributed the most to the owl's diet? Explain.

Is quantity or quality of prey more important? Why?

Diversity and Stability

Both the video and the text have emphasized that increased diversity leads to increased stability. If a predator has only one prey type available in its habitat, then a decline in that prey will lead to a decline in the predator. If the prey is eradicated through disease or over hunting, then the predator will have to relocate and find a substitute food source or it may become extinct. On the other hand, if a predator feeds equally on all available prey types, a decline in one or two may create only small problems for the predator due to the presence the remaining prey types.

As demonstrated in the video, diversity increases as one nears the equator. Alaskan owls feed almost exclusively on lemmings. As seen in the data chart above, the owls in the southwestern states have over 12 different prey types while those that live on the equator typically feed on 15 to 20 prey types that range in size from insects to opossums.

Construct Two Food Webs

Participants should be able to put together a food web that has three to four trophic levels. Within each working group the participants will construct a web for each of the two regions. The facilitator should have the groups put the food webs on large newsprint and post them around the room when complete. The first group will present their food webs. Subsequent groups will point out the differences in their webs from webs constructed by the other participants.

Discussion

Which region has the most complex food web?

Which region has the most stability?

Would a crash in the shrew (Blarina, Cryptotis, Sorex) population seriously affect either region? Why?

Would a crash in the vole (Microtus) population seriously affect either region? Why?

Some owls produce 2 pellets per day. Assume each pellet represents 80 grams of biomass. Also assume that one 40 gram vole can cause 50 cents of crop damage to a farm per season. If a barn owl family of seven (2 adults and 5 young) lives on a farm for 12 weeks and feeds exclusively on voles, how much will the farmer save in crop damages?

Going Further

Activity Seven: Return to Essential Questions

The facilitator should draw the attention of the participants back to the essential questions posed in the Background Section of this unit guide. Discuss how the participants' ideas may have changed in regard to the questions. Discuss the most logical and complete answers to the questions.

Activity Eight: Discuss Supplementary Classroom Activities

If the participants in the study group are teachers, the facilitator should draw the participants' attention to supplementary classroom activities located at the end of this guide. Discuss how teachers would implement these activities in their classrooms and how they would relate them to the topics in this unit.

Between Sessions

Next Week's Topic Overview

In Unit 5, "Human Population Dynamics," the key themes are the fundamental principles of population dynamics and the environmental consequences of population growth. Sub-topics will examine areas of concern such as threats to health, baby booms and busts, human life span, and population migrations.

On-line Simulation

After reading Unit 5, complete the lessons for Interactive Lab: Demographics for next week and bring a half page summary of your experience and results.

Read for Next Session

For the next session, be sure to read the Unit 5 Professional Development Guide background section. Consider the essential questions as you read the text. The misconceptions section will give you some insight into what misunderstandings people may have about population dynamics. Consider discussing the topic with your friends or students and discussing common misconceptions.

Current Events

Bring in a current event article or cartoon related to population dynamics.

Supplementary Classroom Activity 1

Ecosystems

Objectives

1. Students will learn about species that are native to their backyard.
2. Students will understand that a small habitat can contain wide biodiversity of plant life.
3. Students will learn that individual ecosystems contain diversity within each species population.

Materials

Undisturbed or unmanaged part of a school grounds or a local park

Plastic bags for carrying leaf specimens

Tree and shrub field guides

Procedure

1. Choose a site that is relatively undisturbed. Determine beforehand that the area does not contain any poisonous plants.
2. At the site, ask students to collect as many different leaf types (representing distinct species) as they can. If the area has several distinct habitats, have different groups sample different areas: meadow, riparian, wet land, or forest. Students should note whether the leaf is simple or compound and its arrangement around the twig (alternate, opposite, or whorled).
3. Back in the classroom, make a list of the leaves. Set up a dichotomous key. First divide by simple or compound, next divide those two categories into alternate, opposite, and whorled. Then students should use such characteristics as leaf shape, leaf edges, veination patterns, color, hairiness, etc. to separate even further. If time permits, they can name by genus and species.
4. Allow students to observe other collections to see if there are any species that are not contained in their samples.
5. Lead a discussion about their findings in an attempt to assess the plant biodiversity of their community or city as a whole.
6. Choose one or two of the most commonly occurring species in the collections.
7. Ask the students to look for differences within the same species. This activity will help them understand the second level of biodiversity—that each ecosystem will contain evidence of diversity within each species.

Adaptations

In addition to selecting the leaves, students should bring drawing pads and pencils in order to sketch insects in this ecosystem. As with the leaves, they should identify as many of the species they've drawn as possible. They can also look for evidence of other organisms by searching for tracks or scat.

Supplementary Classroom Activity 1

Discussion

1. Valleys such as Death Valley, the Mississippi River Valley, and the Hudson River Valley are homes to a wide variety of plants and animals. Discuss how abrupt changes in elevation make vastly different habitats possible.
2. The popular opinion is that pre-Columbian Native American culture was much more "in tune" with nature than modern American culture. Is this true?
3. Ansel Adams made his fame, in part, through his photographs of the Yosemite Valley. Discuss why so many artists find inspiration in using natural scenes in their artwork. What creative, artistic, or inspiring qualities does nature possess?
4. Yosemite National Park attracts around five million visitors per year, making it one of the most visited places on Earth. Such a large number of visitors cannot help but cause damage to this wilderness area. For the sake of preservation, should human travel in wilderness areas be restricted by law? Why or why not?
5. John Muir, the founder of the Sierra Club, said, "Any fool can destroy a tree. It cannot run away." He was referring to loggers, who he believed would rather make a profit from the wilderness than preserve and enjoy it. Create a list of businesses that could use the wilderness areas of America without destroying them—while still making a profit. Explain your ideas in each case.

Supplementary Classroom Activity 2

Planning a Park

New National Park

National parks in any part of the United States are created by an act of Congress. Behind every national park is a story about how it was founded. Have your students visit the Web site of the U.S. National Park Service to locate information about the history, habitats, and natural features of a nearby national park. When their research is complete, divide your students into planning groups and challenge each group to develop a proposal for establishing a new national park in your state or county.

You may ask students to begin this project by examining a state population map and finding areas where population is low. Then ask them to determine what unique features the new park will offer. They can create a map of the natural features of their park, name it, and establish wildlife habitats for various species within its borders. Finally, ask students to write up a rationale for creating a new national park in a specific location and adding it to the existing parks system.

Notes