Instructor's Guide for

Introduction to Environmental Science

by

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W. H. Freeman and Company
San Francisco

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Introduction

This Instructor's Guide is designed to accompany Introduction to Environmental Science. In writing that text, we made special efforts to produce a book that would stimulate its intended audience, an audience that typically not only represents a wide diversity of interests, but also many of whose members experience anxiety about the traditional physical and biological sciences.

We recognize that, at different colleges and universities, our text will be used by teachers from a wide range of disciplines, including biology, ecology, chemistry, geology, geography, physics, and meteorology. This mirrors the fact that, nationwide, there is no single departmental (or even interdepartmental) home for introductory environmental-science courses. We therefore included in our text a wide variety of topics--more topics than usually can be covered in a single semester course. This gives you flexibility in selecting a sequence of chapters that best matches your course syllabus. Alternatively, you may wish to redesign your course to correspond more closely to our topic coverage.

The chapters in this Instructor's Guide parallel the chapters in the text. For each chapter we provide the following aids:

1. A statement of learning objectives.

2. Answers to the questions and suggestions about the projects that appear at the end of the chapter. (Where appropriate, we have indicated the page in the text where an answer appears.)

3. Five discussion questions useful for small group meetings.

4. Twenty or more multiple-choice questions for all except chapters 1 and 20. We have indicated the correct answer by an asterisk and the page on which the question is answered.)

Our formulation of the questions in this Instructor's Guide and in the text reflects our interest in communicating effectively with students. We test not merely for recall of key facts but more importantly for comprehension of basic concepts and issues.

As appropriate, we point out how a particular chapter fits within the context of the three themes that subdivide the text (Concepts of Ecology; Environment Quality

and Management; Fundamental Problems: Population, Food, and Energy). We also point out linkages between chapters. These notations will allow you to select those chapters most appropriate for your course; the remaining chapters may then be covered as assigned reading.

We have included two appendixes to assist you in teaching your course. Appendix I on visual aids includes a list of rental sources and films that we have used in our course. Appendix II contains a list of private organizations and governmental departments and agencies that are valuable information sources.

For those who find the use of visual aids in the classroom to be especially helpful, we have selected a group of particularly important illustrations and graphs from the text to be made into transparency masters. A set of these masters can be obtained from W. H. Freeman and Company.

We wish you and your students much success with your introductory environmental-science course and we hope that you find this Instructor's Guide useful. We welcome any suggestions that you may have for the future editions of the text and the guide.

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Green Bay, Wisconsin
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Contents

Chapter 1

People and Nature in Conflict

Chapter Objectives

In this introductory chapter, we introduce several themes that are developed in subsequent chapters. These themes include the historical roots of environmental problems, the impact of our growing demands for diminishing resources, and our efforts to cope with environmental issues. But, our primary objective in this chapter is to spur the students' interest in environmental science by demonstrating how he or she is personally affected by environmental problems. Hopefully, our discussion will motivate the student to learn more about environmental science.

Discussion Questions

1. List some of the ways deterioration of environmental quality affects your personal life.

2. Are resource depletion and pollution of the environment inevitable consequences of our way of life?

3. Discuss some of the ways increasing population pressures affect you now and in the future.

4. In view of the serious implications of environmental problems, why do we have just cause to be somewhat optimistic about the future?

5. Have you voluntarily altered any aspects of your lifestyle in a personal effort to alleviate environmental problems?

Chapter 2

Ecosystems: The Flow of Energy and Materials

Chapter Objectives

This chapter is intended to give students a basic foundation in ecological principles relating to movement of energy and materials within and between ecosystems. After reading the chapter students should be able to:

- list the major components of an ecosystem
- trace the flow of energy through a food web
- compare energy flow in grazing and detritus food webs
- describe the causes of low ecological efficiencies
- evaluate the consequences of human efforts to overcome food chain inefficiencies
- describe the implications of monoculture in light of food web stability
- trace the movement of carbon, phosphorus, nitrogen, and oxygen
- describe the interactions of various cycles with each other and with energy flow
- describe the general effects of human activity on transfer rates of materials and energy

This chapter is designed to give only the basic rudiments of the flow of energy and materials so that students have the basic ecological underpinnings for understanding the causes of and evaluating the solutions to environmental problems discussed throughout the text. For those who wish to provide their students with a greater in-depth presentation and/or different examples, the three texts listed in the selected readings plus the Annual Reviews of Ecology and Systematics are appropriate resources. Another useful text is the second edition (1979) of General Ecology by S.M. McNaughton and L.L. Wolf.

This chapter provides part of the ecological foundation for many chapters in this text. An understanding of the movement of energy and materials is important to comprehend the concept and significance of food chain accumulation of pollutants as discussed in Chapter 7 (water pollution), Chapter 17 (pesticides), and Chapter 18 (radioactive wastes). The concept of pollution as a change in transfer rates of materials and/or energy is central to an understanding of the causes, consequences, and strategies for control of pollutants as discussed throughout Part II of the text. The discussion of inefficiencies in food webs establishes the foundation for comprehending the limitations on food production as described in Chapter 17.

Chapter Outline

Components of Ecosystems
Movement of Energy
- Food Webs
- Causes of Low Efficiencies
- Consequences of Low Efficiencies
- The Stability of Food Webs

Movement of Materials
- The Carbon Cycle
- The Phosphorus Cycle
- The Nitrogen Cycle
- The Oxygen Cycle

Transfer Rates and Human Activity
Transfer Rates and Pollution
Conclusions

Answers and Suggestions for Questions and Projects

1. See glossary.

2. The major biotic and abiotic components are listed on pages 7-8. The kind and number of organisms affect energy flow. In turn, the physical environmental conditions affect the kind and numbers of organisms. Students could compare ecosystems such as a desert and a forest to come up with specific examples of organisms and limiting environmental factors.

3. See pages 11 and 13.

4. We recommend that the class visits both terrestrial and aquatic ecosystems to be able to compare both types of ecosystems. Students should be encouraged to consider not only the larger, easily seen plants and animals, but also more inconspicuous organisms such as algae, mosses, zooplankton and insects.

5. This exercise is intended to get students to think further than "food comes from the supermarket or from the restaurant." Once the plant or animal source has been identified, the geographical sources of the food will be important to note. Is the locale generally self-sufficient in food or does it have to be imported from other regions? What types of food have to be imported?

6. Only the grain, not the entire plant is feed to the chickens. The energy costs of plowing, planting, cultivation, harvesting and the application of fertilizers and herbicides have not been considered. Assuming the chickens are grown in confinement, energy is needed to maintain proper temperature, to bring in the corn, and to dispose of wastes.

7. Growing livestock in confinement (such as feedlots) reduces energy expended in movement. By providing shelter and perhaps heat in winter, less energy is used in maintaining body temperature. Early detection and treatment of disease also reduce energy losses in livestock.

8. See pages 18-19, 22-23.

9. Seeds are storehouses of nutrients such as starch, fats, and proteins for the germinating seedling, thus they would be the highest in digestible content. Wood contains primarily cellulose, lignin and other complex materials that are very poorly digestible, thus wood is the least digestible. As foilage matures, the proportion of digestible nutrients to undigestible fiber increases. In order of decreasing digestibility, the sequence is seeds, young foilage, mature foilage, and woods.

10. The "10 percent rule" states that only 10 percent of the energy is transferred from one trophic level to the next. As a consequence, the amount of energy at each succeeding trophic level declines by 90%. As a consequence, each trophic level can support only a limited number of consumers.

11. American farmers produce so much grain that there is more than enough to feed to livestock. American per capita income is high enough that they can afford the cost of putting meat on their table.

12. See pages 18-19.

13. If an animal can switch to lower trophic levels, there is a greater amount of energy available. Moreover, the animal has a greater diversity of food sources. Both are advantages, particularly when food resources are scarce.

14. See pages 23-24.

15. See pages 25, 35.

16. See page 31.

17. Microorganisms play essential roles in nutrient cycling. They are important in the decay process that releases nutrients into the environment for uptake again by plants. Moreover, some microbes such as nitrogen-fixing bacteria and blue-green algae play vital roles in changing the nutrients from one inorganic form to another.

18. See page 36.

19. A major subcycle of most substances (such as carbon and phosphorus) involves food webs. Generally plants pick up the substance from the environment (carbon in the form of carbon dioxide from the atmosphere and phosphorus in the form of phosphate from the soil) and incorporate these substances into their tissues. As plants are eaten by herbivores that are subsequently consumed by carnivores, these materials move through food webs. Detritus feeders release these substances back into the environment in a form similar to that in which they were originally taken up by plants. In the case of carbon, cellular respiration by all living organisms release carbon back to the atmosphere, usually in the form of carbon dioxide.

20. Two categories may be considered here. One category includes those cases where the input is greater than the output. The excessive washing of phosphates and nitrates into a lake from surrounding agricultural lands is an example. The second category is where output exceeds input. The consequences of mining is an appropriate example.

21. Examples of natural pollutants include volcanic ash, ash from fires, pollen, and toxins released by overgrowths of blue-green algae.

22. Ask students to compare their lists. Are there some materials that some students consider to be essential, but other students believe them to be luxuries? What are the criteria used for categorizing a material as an essential or as a luxury?

Discussion Questions

1. Describe why there must be a continual input of energy into an ecosystem.

2. Describe and weigh the economic and ecological advantages and disadvantages of crop monoculture.

3. Devise a strategy to overcome the ecological inefficiencies in food webs. Describe the difficulties in successfully implementing this strategy.

4. Describe the major ways that human activities have affected the carbon cycle.

5. List the major ways that the phosphorus cycle differs from the carbon cycle. Describe how these differences affect the strategies of pollution control for each substance.

Multiple Choice Questions for Chapter 2

2-1. An organism that occupies the 4th trophic level in a grazing food chain can best be described as:
(a) a detritus feeder
(b) a green plant
(c) an animal that eats plants
*(d) an animal that eats other animals (p. 10)

2-2. Photosynthesis:
(a) is normally 40 percent efficient
*(b) is a sequence of reactions that produces high energy sugars from low-energy substances (p. 10)
(c) involves the direct activities of herbivores
(d) all of the above are correct
(e) none of the above is correct

2-3. Detritus food webs:
(a) are a means of recycling materials
(b) are particularly important in wetlands such as marshes
(c) ultimately depend upon the sun as a source of energy
*(d) all of the above are correct (p. 11, 13, 25)
(e) none of the above is correct

2-4. Food webs:
(a) can consist of either detritus or grazing pathways
(b) are interlocking food chains
(c) are more difficult to disturb than single food chains
*(d) all of the above are correct (p. 10, 11, 23)
(e) none of the above is correct

2-5. Not all energy available at one trophic level is transferred to the next trophic level because:
(a) when food is burned in the body, some is lost as heat
(b) not all food ingested is digested
(c) not all available food is consumed
*(d) all of the above are correct (p. 16-18)
(e) none of the above is correct

2-6. The pyramid of energy illustrates:
(a) the 10 percent rule
(b) the earth can support only a limited number of consumers
(c) one of the consequences of cellular respiration
*(d) all of the above are correct (p. 13, 16, 17)
(e) none of the above is correct

2-7. Ecological efficiency:
*(a) is the annual increase in consumer biomass divided by the annual increase in prey biomass (p. 13)
(b) is a measure of the efficiency of cycling phosphorus through an ecosystem
(c) can be as high as 100% in some detritus food webs
(d) results in an increase in weedy species

2-8. The general figure given for ecological efficiencies is:
(a) 1 percent
*(b) 10 percent (p. 16)
(c) 50 percent
(d) 80 percent

2-9. One important aspect of grazing food chain dynamics is that as one gets higher up the chain:
(a) there is a greater amount of available energy
(b) the carnivores are more efficient than the herbivores
*(c) fewer animals can occupy that trophic level (p. 18)
(d) all of the above are correct
(e) none of the above is correct

2-10. Cellular respiration is a process that:
(a) occurs continuously in all living organisms
(b) involves the loss of some energy as heat energy
(c) occurs in the carbon cycle
*(d) all of the above are correct (p. 17, 25)
(e) none of the above is correct

2-11. By becoming a complete herbivore rather than functioning as both a carnivore and a herbivore, we:
(a) would not be able to support a population that is even much smaller than the present world population
(b) would still have the same total amount of food energy available to us
(c) would not need to take precautions about obtaining proper protein nutrition
(d) all of the above are correct
*(e) none of the above is correct (p. 19)

2-12. The substitution of plant protein for animal protein such as with soybeans for meat represents an attempt to:
(a) decrease the world's need for fertilizers
*(b) increase the world's food carrying capacity for people (p. 19)
(c) increase the chances of overfishing
(d) decrease the world's need for calories

2-13. The problem of southern corn blight had a potential for much greater severity because:
(a) the blight was caused by a carnivorous insect
*(b) 80 percent of the corn grown did not possess the genetic make-up that made it resistant to the blight (p. 24)
(c) there were too many checks and balances
(d) the southern states did not use enough weed-killer

2-14. Plants are important in the functioning of ecosystems because:
*(a) they pump nutrients out of the soil (p. 28)
(b) they significantly warm up the soil in spring
(c) they transform food energy into light energy
(d) they are 90 percent efficient in energy transformations

2-15. The carbon cycle:
(a) has been modified by the burning of fossil fuels
(b) involves the processes of respiration and photosynthesis
(c) includes the formation of limestone and dolomite
*(d) all of the above are correct (p. 25-26)
(e) none of the above is correct

2-16. The movement of carbon within an ecosystem can best be described as:
(a) a downhill one-way street
(b) a process that occurs only within organisms
*(c) a set of interlocking subcycles (p. 25)
(d) a process that is independent of the activities of adjacent ecosystems

2-17. Pollution:
(a) is only human induced
(b) is an event that began with the industrial revolution
*(c) is a change in the transfer rates of materials or energy (p. 37)
(d) all of the above are correct
(e) none of the above is correct

2-18. Biological fixation:
*(a) is carried out by specialized forms of bacteria and blue-green algae (p. 31)
(b) is an important process in phosphorus cycle
(c) combines oxygen gas with nitrogen gas to form nitrates
(d) all of the above are correct
(e) none of the above is correct

2-19. In the phosphorus cycle:
(a) soil erosion is rarely an important factor
*(b) phosphorus enters food webs via plant roots (p. 28)
(c) human activities have had little effect
(d) all of the above are correct
(e) none of the above is correct

2-20. In the oxygen cycle:
(a) the Haber process plays a significant role
*(b) human activities have not significantly changed atmospheric oxygen levels (p. 36)
(c) oxygen combines with few other substances
(d) all of the above are correct
(e) none of the above is correct

Chapter 3

Ecosystems and Environmental Change

Chapter Objectives

This chapter is intended to give students a basic foundation in ecological principles relating to limiting factors, succession, and adaptation. After reading the chapter students should be able to:

- diagram a limiting factor curve
- describe the implications of pollution for organisms in the context of tolerance limits
- describe the difficulties in determining the tolerance limits of an organism for a particular substance
- distinguish between primary succession and secondary succession
- trace the sequence of changes in the types of organisms and the nature of the physical environment that occur during secondary succession
- describe the implications of wide-spread human reversal of succession
- identify the limitations on succession
- describe the process of natural selection
- describe the importance of adaptations
- compare the relative significance of adaptations by learning for different types of animals
- identify the most important human adaptations
- describe the limits to adaptations and their significance for the future of humankind

This chapter is designed to present only the fundamental concepts of limiting factors, succession, and adaptations so that students have a basic ecological foundation for understanding the causes of and evaluating the solutions to environmental problems discussed throughout the text. For those who wish to provide their students with a greater in-depth presentation and/or different examples, the three texts listed in the selected readings plus the Annual Reviews of Ecology and Systematics are appropriate resources.

Chapter Outline

Limiting Factors
- Tolerance Limits
- Toxic and Hazardous Materials
- Determining Limiting Factors
- The Consequences of Limiting Factors

Ecological Succession
- Secondary Succession
- The Effects of Human Activities on Succession

Limitations on Succession
Adaptation
Natural Selection
The Significance of Adaptations
Adaptation by Learning
Some Human Adaptations
Limits to Adaptations
Conclusions

Answers and Suggestions for Questions and Projects

1. See glossary.

2. See page 43.

3. Pages 44-45 provide the scientific background to use in describing a local example.

4. In many instances the physical conditions are beyond the tolerance limits of the population. Temperatures are too high or too low. Soil moisture conditions are too wet or too dry. In other cases, the physical conditions are within the population's tolerance limits but not near enough to the optimum to be successful in population interactions. For example, physical conditions may limit their competitive ability or increase their susceptibility to predators and parasites.

5. See page 47. These substances produce maladies for which we have few or no cures. Cancer is the second leading cause of death in the United States. Cancer patients often face a long, painful period before their death. Mutagens and tetratogens may produce debilitating deformities so that victims are completely dependent upon others. Many victims are stillborn. There is little way to predict whom the maladies will strike and what form they will take. This unpredictibility coupled with pain and suffering that has to be endured by the victims and their families raises a tremendous fear that often produces a loud outcry.

6. See page 48.

7. See page 49.

8. See pages 54-55.

9. A visit to several field sites would help students to prepare their lists.

10. Any factor that causes localized stress can produce this pattern. These include fire, high winds such as tornadoes, or floods. Over past decades much emphasis has been placed on fire prevention. Moreover many dams have been built to reduce flood damage. Hence to maintain a diversity of successional habitats,