Chapter I

Environmental Science: Studying the State of Our Earth

Chapter Summary

This chapter introduces the study of environmental science. It discusses key concepts used in the study of environmental science, including the systems perspective, environmental indicators, sustainability, and scientific method. The chapter establishes important foundations for chapters to come. The chapter consists of three modules:

- Module 1: Environmental Science
- Module 2: Environmental Indicators and Sustainability
- Module 3: Scientific Method

Chapter Opening Case: Earthquakes, Leakage, and Wastewater: Modern-Day Consequences of Energy Production

The chapter opening case introduces you to the costs and benefits of using hydraulic fracturing, known as fracking, to extract oil and gas. This case demonstrates how human activities that are initially perceived as causing little harm to the environment can in fact have substantial adverse effects. It also illustrates the controversial side of issues that environmental scientists explore and the difficulty in obtaining absolute answers to environmental problems and questions.

Do the Math

This chapter contains the following "Do the Math" boxes to help prepare you for calculation questions you might encounter on the exam.

- "Converting Between Hectares and Acres" (page 10)
- "Rates of Forest Clearing" (page 13)
- "Range of Electric Vehicles" (page 20)

To make sure you understand the concepts and techniques presented in these boxes, do the practice problems presented in the text as well as the additional "Practice the Math" problems that appear in Module 2 and Module 3 of this study guide.
Module 1: Environmental Science

Before You Read the Module

Focus on Learning Goals
Use the module learning goals to guide your reading. On a separate piece of paper, write down each goal and take notes to help you meet each learning goal. After studying this module, you should be able to:

- define the field of environmental science and discuss its importance.
- identify ways in which humans have altered and continue to alter our environment.

Key Terms

<table>
<thead>
<tr>
<th>Fossil fuel</th>
<th>Environmental science</th>
<th>Abiotic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fracking</td>
<td>Ecosystem</td>
<td>Environmentalism</td>
</tr>
<tr>
<td>Environment</td>
<td>Biotic</td>
<td>Environmental studies</td>
</tr>
</tbody>
</table>

While You Read the Module
Answer the following questions as you read. Use a separate sheet of paper if necessary.

Case Study: Earthquakes, Leakage, and Wastewater: Modern-Day Consequences of Energy Production

1. Name some potential negative consequences of fracking that the title of the case study foreshadows.

2. List the types of fossil fuels.

3. Describe the environmental problems associated with fossil fuels.

4. What is the least harmful fossil fuel? Why?

5. What is “fracking” short for?

6. Describe how fracking works.

7. What are the benefits of fracking?

9. Name FOUR examples of negative consequences of fracking.

10. Why is it difficult to know whether the benefits of fracking outweigh the problems?

Module 1 Environmental Science

Environmental science offers important insights into our world and how we influence it

11. How are humans dependent on Earth?

12. Consider your surroundings. What do you observe?

13. List the environmental conditions that influence life.

14. In what ways do environmental conditions influence humans?

15. Define the study of environmental science.

16. Define system.

17. Give your own example of a human-made system.

18. Give an example of a natural system.

19. Give an example of an environmental scientist’s work from small to large systems.

20. Define ecosystem and the interacting components.
21. Give an example of a biotic and an abiotic component in the environment.

22. How is environmental science different from environmentalism?

23. Figure 1.1: What does the study of environmental science include?

24. Environmental science is a subcategory of what broader field?

Humans alter natural systems

25. List key biotic and abiotic components in the natural system of a wooded area where a tree has fallen and there has been a fire.

26. Figure 1.2: Identify the different interconnecting systems that operate at different scales for scientists studying the fisheries of the North Atlantic.

27. Identify ONE example of an intentional environmental change and ONE example of an unintentional environmental change that human activities have caused.

28. Early humans are thought to have caused the extinction of large mammals. Explain why this happened. Was it intentional or unintentional?

29. How did humans cause changes to the Great Plains? Was this intentional or unintentional?

30. Identify how human well-being has improved over the last two centuries.

31. Identify how human population growth has led to unintentional environmental consequences.

32. Figure 1.3: What unintended consequences can be viewed from the 1880 and 2013 photographs?
After You Read the Module

Review Key Terms

Match the key terms on the left with the definitions on the right.

1. Fossil fuel
2. Fracking
3. Environment
4. Environmental science
5. Ecosystem
6. Biotic
7. Abiotic
8. Environmentalism
9. Environmental studies

a. The field of study that includes environmental science and additional subjects such as environmental policy, economics, literature, and ethics
b. Living
c. Nonliving
d. A social movement that seeks to protect the environment through lobbying, activism, and education
e. A particular location on Earth with interacting biotic and abiotic components
f. The field of study that looks at interactions among human systems and those found in nature
g. A fuel derived from biological material that became fossilized millions of years ago
h. The sum of all the conditions surrounding us that influence life
i. Hydraulic fracturing, a method of oil and gas extraction that uses high-pressure fluids to force open cracks in rocks deep underground

Module 2: Environmental Indicators and Sustainability

Before You Read the Module

Focus on Learning Goals

Use the module learning goals to guide your reading. On a separate piece of paper, write down each goal and take notes to help you meet each learning goal. After studying this module, you should be able to:

- identify key environmental indicators and their trends over time.
- define sustainability and explain how it can be measured using the ecological footprint.

Key Terms

Ecosystem service
Environmental indicator
Biodiversity
Genetic diversity
Species
Species diversity
Speciation
Background extinction rate
Greenhouse gases
Anthropogenic
Per capita
Development
Sustainability
Sustainable development
Biophilia
Ecological footprint
Module 2 Environmental Indicators and Sustainability

Environmental scientists use key environmental indicators to monitor natural systems for signs of stress

1. Define ecosystem services and give two examples.

2. Describe how an ecosystem service may directly and indirectly benefit people.

3. Identify how someone may measure personal health.

4. Describe the tools scientists might use to assess the health of the environment.

5. List the five global-scale environmental indicators that this textbook will focus on.

6. Table 2.1: Identify what unit(s) of measurement may be used for the environmental indicator of food production.

Biodiversity

7. Define biodiversity.

8. Identify the three levels of biodiversity.

9. Figure 2.1: Identify how the biodiversity differs among panels (a), (b), and (c).

Genetic Diversity

10. Define genetic diversity.

11. What is an advantage of high genetic diversity?
Species Diversity

12. Define species.


14. How many species have been identified and cataloged? What is the most common estimate of Earth’s number of species?

15. Define species diversity.

16. How is higher species diversity an advantage?

17. What makes an ecosystem resilient?

18. Describe how a frog species is an indicator of regional environmental health.

19. Define speciation.

20. How many species develop per year worldwide?

21. Define background extinction rate.

22. What should background extinction rate be for 2 million species?

23. What is the current extinction rate scientists believe is occurring? How many times faster is this number than the background extinction rate?

24. Identify two species that have been saved from extinction.

25. Identify a species that remains endangered and may go extinct.
Ecosystem Diversity


27. Identify the measures of land area used for biodiversity.

Food Production

28. Identify the need for food production.

29. Identify how science and technology has been used to increase the amount of food that is produced on a given area of land.

30. Figure 2.3: How has grain production changed from 1950 to 2017?

31. List the factors that influence grain production.

Average Global Surface Temperature and Carbon Dioxide Concentrations

32. How long has Earth’s temperature been relatively constant?

33. What keeps Earth’s temperature so constant?

34. Define greenhouse gases.

35. Figure 2.4: Notice the solar energy entering the heat-trapping greenhouse gases. Identify and describe how the heat moves in the diagram.

36. What gas contributes most to the warming of the atmosphere?

37. Figure 2.5: Describe the correlation of the carbon dioxide levels with the global temperatures shown on the graph.
38. Define anthropogenic.

39. What do scientists believe is the cause in the rise of atmospheric carbon dioxide?

**Human Population**

40. What is the current human population?

41. Describe how the population changes in a 24-hour time period and every five days.

42. What is Earth’s projected human population?

43. Can the planet sustain so many people?

**Resource Depletion**

44. Explain what natural resources provide.

45. Identify some of Earth’s natural resources that are finite and cannot be renewed or reused.

46. Identify some of Earth’s natural resources that are finite but can be reused or recycled.

47. Identify an example of Earth’s renewable resources. Can you think of another example?

48. Define per capita and explain how it is determined.

49. Define development.

50. Explain how development influences lifestyle.

51. Identify examples of countries that are considered developed.
52. Figure 2.7: Of the three pie charts, which shows the greatest difference in developed versus developing nations?

53. Table 2.2: Identify and explain what key global indicators you are most concerned about after the initial readings.

Sustainability can be assessed using the ecological footprint

54. Define sustainability.

The Impact of Consumption on the Environment

55. What effect does increased consumption have on the environment?

56. Describe how the overexploitation of the Great Plains occurred.

57. Figure 2.8: Compare the population from 1850-1950 to 1950-2011.

58. What are the requirements to live sustainably?

59. Define sustainable development.

60. Figure 2.9: Why is biking to work or school considered a sustainable practice?

Defining Human Needs

61. Identify what humans need to sustain life.

62. Define biophilia.

63. Figure 2.10: How is this photo a testament to biophilia?
The Ecological Footprint

64. Explain why developing countries may be less likely to implement environmental protections.

65. Explain this statement: "Using or protecting one has an effect on the others."

66. Define ecological footprint.

67. Describe the difference in land needed for someone that has a plant-based diet to someone that consumes meat. Identify which has the higher ecological footprint.

Practice the Math: Converting Between Hectares and Acres

Read “Do the Math: Converting Between Hectares and Acres” on page 10. Try “Your Turn.” For more math practice, do the following problem. Remember to show your work. Use a separate sheet of paper if necessary.

2.5 acres = 1 hectare (ha)
1 acre = 0.40 ha

Convert the following from acres to hectares.

50,000 acres = ____________ hectares

75,000 acres = ____________ hectares

150,000 acres = ____________ hectares

Practice the Math: Rates of Forest Clearing

Read “Do the Math: Rates of Forest Clearing” on page 13. Try “Your Turn.” For more math practice, do the following problem. Remember to show your work. Use a separate sheet of paper if necessary.

Environmental organizations have yielded a range of estimates of the amount of forest clearing that is occurring in the Brazilian Amazon. Convert the first two estimates into hectares per day and compare the three estimates.

- Estimate 1: 15 acres per minute
- Estimate 2: 22,000 acres per day
- Estimate 3: 8,000 ha per day
**Review Key Terms**

Match the key terms on the left with the definitions on the right.

<table>
<thead>
<tr>
<th>1. Ecosystem services</th>
<th>a. The diversity of life forms in an environment</th>
</tr>
</thead>
<tbody>
<tr>
<td>2. Environmental indicator</td>
<td>b. A measure of the genetic variation among individuals in a population</td>
</tr>
<tr>
<td>3. Biodiversity</td>
<td>c. Development that balances current human well being and economic advancement with resource management for the benefit of future generations</td>
</tr>
<tr>
<td>4. Genetic diversity</td>
<td>d. Love of life</td>
</tr>
<tr>
<td>5. Species</td>
<td>e. Improvement in human well-being through economic advancement</td>
</tr>
<tr>
<td>6. Species diversity</td>
<td>f. An indicator that describes the current state of an environmental system</td>
</tr>
<tr>
<td>7. Speciation</td>
<td>g. A group of organisms that is distinct from other groups in its morphology, behavior, or biochemical properties</td>
</tr>
<tr>
<td>8. Background extinction rate</td>
<td>h. Living on Earth in a way that allows humans to use its resources without depriving future generations of those resources</td>
</tr>
<tr>
<td>9. Greenhouse gasses</td>
<td>i. A measure of how much an individual consumes, expressed in an area of land</td>
</tr>
<tr>
<td>10. Anthropogenic</td>
<td>j. The evolution of new species</td>
</tr>
<tr>
<td>11. Per capita</td>
<td>k. The number of species in a region or in a particular type of habitat</td>
</tr>
<tr>
<td>12. Development</td>
<td>l. Derived from human activities</td>
</tr>
<tr>
<td>13. Sustainability</td>
<td>m. The average rate at which species become extinct over the long term</td>
</tr>
<tr>
<td>14. Sustainable development</td>
<td>n. Gasses in Earth's atmosphere that trap heat near the surface</td>
</tr>
<tr>
<td>15. Biophilia</td>
<td>o. The processes by which life-supporting resources such as clean water, timber, fisheries, and agricultural crops are produced</td>
</tr>
<tr>
<td>16. Ecological footprint</td>
<td>p. Amount per each person in a country or unit of population</td>
</tr>
</tbody>
</table>

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**Module 3: Scientific Method**

**Before You Read the Module**

**Focus on Learning Goals**

Use the module learning goals to guide your reading. On a separate piece of paper, write down each goal and take notes to help you meet each learning goal. After studying this module, you should be able to:

- explain the scientific method and its application to the study of environmental problems.
- describe some of the unique challenges and limitations of environmental science.
Key Terms
Scientific method
Hypothesis
Variable
Independent variable
Dependent variable
Null hypothesis
Replication
Sample size (n)
Accuracy
Precision
Uncertainty
Theory
Control group
Natural experiment

While You Read the Module

Answer the following questions as you read. Use a separate sheet of paper if necessary.

Module 3 Scientific Method

The scientific method is an important process in environmental science

The Scientific Method
1. Identify how scientists investigate the natural world.

2. Define scientific method.

3. Figure 3.1: List the steps of the scientific method.

Observing and Questioning

Forming Hypotheses
4. Define hypothesis.

5. What makes a hypothesis testable? Give an example of a testable hypothesis.

6. Define variable.

7. Explain the differences between independent and dependent variables.

8. Define null hypothesis and give an example.
Collecting Data


10. Define sample size.

11. Define accuracy.


14. Figure 3.2: Explain how the third dartboard demonstrates high accuracy and precision.

Interpreting Results

15. Contrast inductive and deductive reasoning.

Disseminating Findings

16. Explain an advantage of the dissemination of findings.

17. Define theory.

18. Describe natural law and give an example.

Scientific Method in Action: The Chlorpyrifos Investigation

19. Figure 3.3: Using the steps of the scientific method, describe each part of The Chlorpyrifos Investigation.

The Hypothesis

Testing the Hypothesis

20. Define control group.
The Results

Controlled Experiment and Natural Experiments


22. Describe the differences between a controlled experiment and a natural experiment.

23. Figure 3.4: Identify why this forest is a good example of a natural experiment.

24. Identify the reason a natural experiment is difficult to interpret.

25. Why did researchers need to use a natural experiment to study the effect of chlorpyrifos on human brains?

Science and Progress

26. Describe the decision by the U.S. Environmental Protection Agency regarding chlorpyrifos.

Environmental science presents unique challenges

27. List the challenges and limitations that are found in environmental science studies that are not in other scientific disciplines.

Lack of Baseline Data


Subjectivity

29. Describe how the choice between using a paper or plastic bag at a grocery store is subjective.

Interactions

30. Explain how human preferences and behaviors affect environmental systems, using the example of decreasing gas consumption through fuel-efficient vehicles.
Human Well-Being

31. Identify the circumstances under which people are less likely to be concerned about the state of the natural environment.

32. Figure 3.6: Describe the working conditions presented in the photo.

Working Toward Sustainability: Reducing Food Waste

33. Describe the negative environmental impact of producing food.

34. Describe the purpose of the U.S. Department of Agriculture.

35. Explain how much food is wasted and why.

36. Explain the “food waste challenge” put forth from the USDA and the U.S. Environmental Protection Agency.

37. Identify the food loss and waste goal.

Practice the Math: Range of Electric Vehicles

Read “Do the Math: Range of Electric Vehicles” on page 20. Try “Your Turn.” For more math practice, do the following problem. Remember to show your work.

The mileage ranges of three electric vehicles are 115 miles, 82 miles, and 124 miles, while the mileage ranges of three hybrid cars are 540 miles, 602 miles, and 574 miles.

(a) Which type of vehicle has the longer driving range?

(b) How many miles on average is the longer driving range?
After You Read the Module

Review Key Terms

Match the key terms on the left with the definitions on the right.

1. Scientific method
2. Hypothesis
3. Variable
4. Independent variable
5. Dependent variable
6. Null hypothesis
7. Replication
8. Sample size (n)
9. Accuracy
10. Precision
11. Uncertainty
12. Theory
13. Control group
14. Natural experiment

a. A prediction that there is no difference between the groups or conditions that are being compared
b. An objective method to explore the natural world, draw inferences from it, and predict the outcome of certain events, processes, or changes
c. An estimate of how much a measured or calculated value differs from a true value
d. The data collection procedure of taking repeated measurements
e. A natural event that acts as an experimental treatment in an ecosystem
f. A hypothesis that has been repeatedly tested and confirmed by multiple groups of researchers and has reached wide acceptance
g. A variable that is not dependent on other factors
h. In a scientific investigation, a group that experiences exactly the same conditions as the experimental group, except for the single variable under study
i. How close a measured value is to the actual or true value
j. The number of times a measurement is replicated in data collection
k. A testable conjecture about how something works
l. How close the repeated measurements of a sample are to one another
m. Any categories, conditions, factors, or traits that differ in the natural world or in experimental situations
n. A variable that is dependent on other factors
Chapter 1 Review Exercises

Check Your Understanding

Review “Learning Goals Revisited” on page 28 of your textbook. Compare the notes you took while reading each module. Complete these exercises to review the chapter. Use a separate sheet of paper if necessary.

1. What disciplines are incorporated into the study of environmental science?

2. List the five key global-scale environmental indicators.

3. Describe the following: genetic diversity, species diversity, and ecosystem diversity.

4. Give an example of an anthropogenic activity.

5. Currently, what is the size of the human population?

6. What is a person's ecological footprint?

7. List the steps in the scientific method.
Practice for Free-Response Questions

Complete this exercise to build and practice the skills you will need to answer free-response questions on the exam. Use a separate sheet of paper if necessary.

Humans manipulate the environment more than any other species. Complete the table below to identify how human activities have affected the environment and to identify relevant environmental indicators that can help us evaluate the current state of the system.

<table>
<thead>
<tr>
<th>Human Activity</th>
<th>Environmental Impact</th>
<th>Environmental Indicator</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increased numbers of human population</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Land use changes/increased urbanization/agriculture</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increased rate of species extinctions</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Food production</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Burning fossil fuels</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overfishing</td>
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<td></td>
</tr>
</tbody>
</table>
Review and Reflect

Complete these activities to solidify your knowledge of the chapter concepts and key terms. Use a separate sheet of paper if necessary.

1. Review your key terms table for each module.
   (a) Which words did you already know? Which were new to you?
   (b) Write a new sentence using each key term.
   (c) Create a set of flash cards that includes each key term. Use the cards to review terms that were new or challenging.
   (d) When you feel comfortable with the new or challenging terms, review all of the cards, including those with familiar terms.
   (e) Save your cards to review before an exam.

2. What are the challenging concepts from this chapter?
   (a) Identify any concepts you found particularly challenging in this chapter.
   (b) Create a list of topics you need to review in preparation for an exam.

3. What questions do you have about concepts in the chapter?
   (a) Note any further questions you might have about material in the chapter.
   (b) Work with a partner to discuss these questions and ask your teacher for help as needed.

4. Write five possible multiple-choice questions based on this chapter. Work with a partner to quiz each other in preparation for an exam.