

Week 4

AP Environmental Science

Homework bundle for this week

本周作业合集

exercises.lol

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2. The Living World: Biodiversity

Starter Quiz · 课前小测

AP Environmental Science

Name: _____ Score: _____

1. **Biodiversity** is...

- ☐ the variety of life at all levels
- ☐ the number of people
- ☐ the amount of rain
- ☐ a single species

2. **Ecosystem services** are...

- ☐ the benefits people get from nature
- ☐ jobs at a zoo
- ☐ a type of pollution
- ☐ a kind of law

3. Island biogeography says the number of species on an island is a balance between...

- ☐ new species arriving and species going extinct
- ☐ rain and sunshine
- ☐ day and night
- ☐ summer and winter

4. **Ecological tolerance** is...

- ☐ the range of conditions a species can survive in
- ☐ how patient an animal is
- ☐ the number of species
- ☐ the age of an ecosystem

5. A natural **disruption** is...

- ☐ a natural event that disturbs an ecosystem
- ☐ a human factory
- ☐ a new species being born
- ☐ the normal daily cycle

6. The variety of genes within a single species is called _____ diversity.

7. Nature controlling floods, water quality, or climate is a _____ service.

8. An island closer to the mainland usually receives more new species.

- ☐ True ☐ False

9. Outside its _____ range, a species cannot survive.

10. A rare, unpredictable event like a meteor strike is a _____ disruption.

1. the variety of life at all levels

Biodiversity is the variety of life — genes, species, and ecosystems.

2. the benefits people get from nature

Ecosystem services are the many free benefits — food, clean water, climate control — that nature provides.

3. new species arriving and species going extinct

Species number balances **immigration** (arrivals) against **extinction** (losses) on the island.

4. the range of conditions a species can survive in

Ecological tolerance is the range of conditions (like temperature) a species can survive.

5. a natural event that disturbs an ecosystem

A natural **disruption** — fire, storm, flood, disease — disturbs an ecosystem’s balance.

6. genetic

Genetic diversity is the variety of alleles within a species — the raw material for adapting.

7. regulating

Regulating services are ways nature controls conditions — flood control, pollination, climate.

8. True

Closer islands are easier to reach, so more species immigrate to them.

9. tolerance

Beyond the **tolerance** range, conditions are too extreme and the species dies out there.

10. random

A **random** disruption strikes rarely and without warning.

2.1 Introduction to Biodiversity

Name: _____ Class: _____ Date: _____ **Total: 11 marks**

KEY WORDS biodiversity 生物多样性 • species richness 物种丰富度 • evenness 均匀度
• resilience 恢复力 • resilient 有韧性的

Objective

Build the skills to answer exam questions on **biodiversity**.

You must be able to:

- distinguish **species richness** 物种丰富度 and **evenness** 均匀度
- explain why higher biodiversity increases **resilience** 恢复力
- describe genetic, species, and habitat diversity

1 Worked examples

Study these first. Each one shows the method for a question type used later — follow the steps and you can do the Practice and Exam-style questions yourself.

■ Types of diversity

Biodiversity has three levels: **genetic** (variety of genes), **species** (variety of species), and **habitat/ecosystem** (variety of habitats).

■ Richness and evenness

- **Species richness** — the **number** of different species.
- **Species evenness** — how **evenly** individuals are spread among species.

A community with many species in similar numbers has high diversity.

■ Resilience

Higher biodiversity gives an ecosystem more **resilience** — it recovers better from disturbances because other species can fill lost roles.

■ A worked comparison

Community A has 10 species in equal numbers; community B has 10 species where one dominates. A has higher **evenness** and therefore higher diversity.

2 Practice

Now apply the methods above.

2.1 What is species richness? [1]

2.2 What is species evenness? [1]

2.3 Name the three levels of biodiversity. [3]

3 Exam-style questions

3.1 A community with high species evenness has individuals [1]

- A all of one species
- B spread fairly evenly among species
- C with no genetic variation
- D in a single habitat

3.2 Two communities each have 8 species. In community X one species makes up 90% of individuals; community Y is even.

(a) Which has higher diversity? [1]

(b) Explain your answer using richness and evenness. [2]

3.3 Explain why higher biodiversity makes an ecosystem more resilient. [2]

Solutions

2.1 The number of different species.

2.2 How evenly individuals are distributed among the species.

2.3 Genetic, species, and habitat/ecosystem diversity.

3.1 B — spread fairly evenly among species.

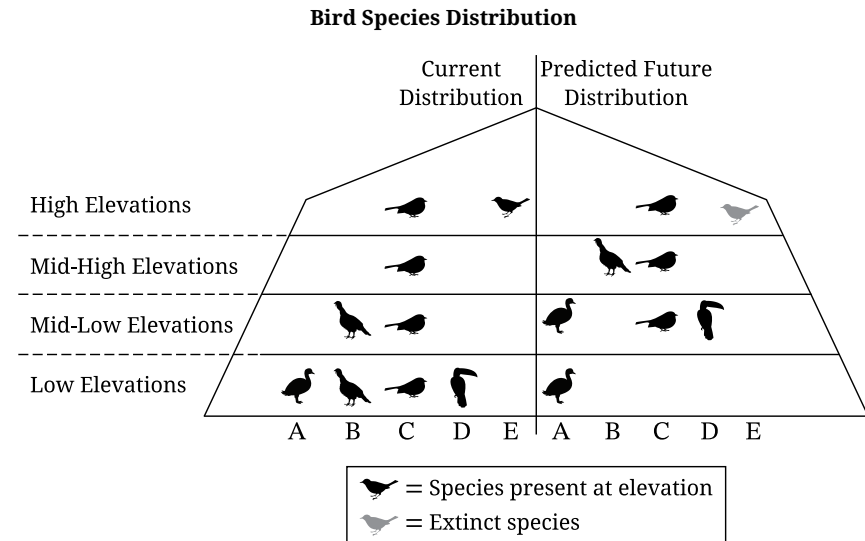
3.2 (a) Community Y. (b) Both have the same richness (8 species), but Y has higher evenness (no single dominant species), so Y is more diverse.

3.3 With more species filling more roles, if one is lost others can compensate, so the ecosystem keeps functioning and recovers from disturbance.

The following information applies to parts A, B, C, D, and E.

Climate change can affect both terrestrial and marine organisms. Researchers studying the effect of climate change on bird distribution mapped elevation zones at which five bird species lived within a tropical mountain range. Birds are distributed in part according to climate-related adaptations. Researchers modeled where the birds would most likely live in the future based on climate change predictions.

The results of this study are shown in the following diagram. Each unique shape in the diagram represents a different bird species, labeled A through E. Current distribution is shown on the left side of the figure, and predicted future distribution is shown on the right.



The following information applies to parts F, G, and H.

Some organisms such as birds can move in response to environmental changes, while other organisms such as corals cannot. Researchers studying the effect of climate change on marine organisms conducted two experiments involving photosynthetic algae that have a symbiotic relationship with corals.

In Experiment 1, the researchers placed photosynthetic algal colonies living in corals in three different saltwater tanks. The temperature of Tank 1 was set to 27°C, the average temperature at which most corals live. Water circulation in each tank mimicked natural ocean currents. After 30 days, the researchers counted the number of bleached corals. The tank setups are shown in the following list.

- Tank 1: 27°C and no sediment
- Tank 2: 32°C and no sediment
- Tank 3: 37°C and no sediment

In Experiment 2, the researchers used the same photosynthetic algae living in corals but modified the conditions of the tanks as shown in the following list. Water circulation kept the sediment in the tanks suspended. After 30 days, the researchers counted the number of bleached corals.

- Tank 1: 27°C and no sediment
- Tank 2: 27°C and moderate sediment
- Tank 3: 27°C and high sediment

1. Respond to parts A, B, C, D, E, F, G, H, I, and J.

Part A

Based on the information in the diagram, **identify** the elevation zone that has the highest species richness for the current distribution.

Part B

Describe a climate condition at high elevations that is different than it is at low elevations.

Part C

A predator at low elevations currently feeds on Species C and D. Based on the information in the diagram, **describe** what could happen to the predator species in the future in response to the predicted changes in the prey community.

Part D

Species C is considered a generalist, while Species E is considered a specialist. **Explain** why Species C and E are predicted to respond differently to climate change.

Part E

Based on the information in the diagram, **explain** why the bird community at low elevations in the future would be less likely to recover from natural disruptions than the current low-elevation bird community.

Part F

Identify the independent variable in Experiment 1.

Part G

Identify a likely scientific question for Experiment 1.

Part H

In Experiment 2 the temperature of the tanks was held constant, while the amount of sediment was varied. **Explain** how this modification could affect the results of this experiment.

Part I

Changes in climate also affect Arctic ecosystems. One impact of climate change is the loss of ice and snow in polar regions. **Describe** a positive feedback loop that results from the loss of ice and snow in polar regions.

Part J

Describe one problem that Arctic species, such as polar bears or ringed seals, face because of warming in polar regions.

Chickadees are a K-selected species of bird that eat insects and spiders. Spiders consume insects, and many insects consume plants as shown in the following food chain.

Plants → Insects → Spiders

Chickadee habitat includes forests and residential yards. Residential yards often contain nonnative plants, which do not naturally exist in an area, but were introduced by humans.

Scientists measured the average number of insects and spiders as related to the percentage of nonnative plants (Figure 1). The scientists also measured the chickadees' average population growth rate (Figure 2) to determine the impact of nonnative plants on chickadee populations.

Figure 1. Percentage of Nonnative Plants and Average Number of Individual Spiders and Insects

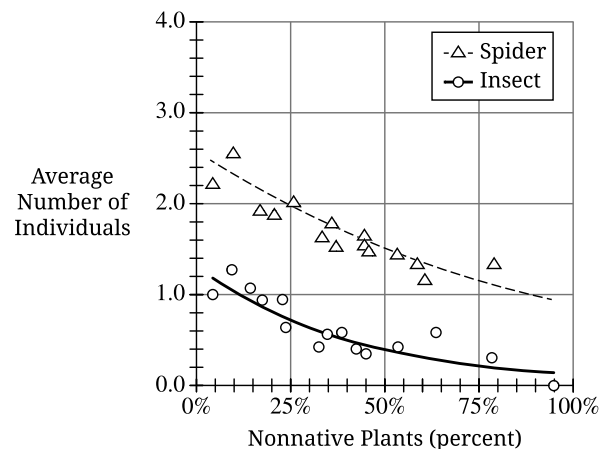
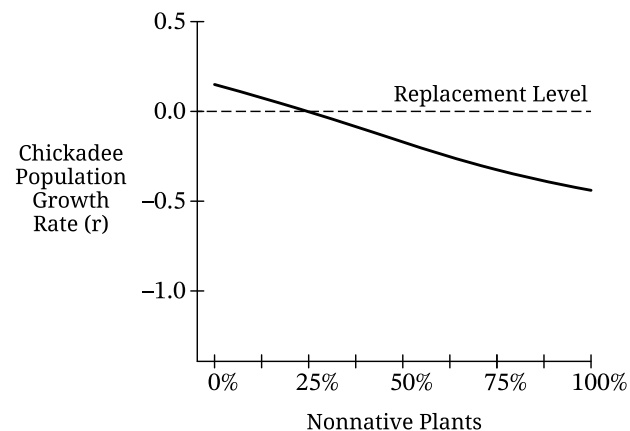


Figure 2. Chickadee Population Average Growth Rate and Percentage of Nonnative

1. Respond to parts A, B, C, D, E, F, G, and H, and all subparts.

- A. Describe** one reproductive strategy used by a K-selected species such as the chickadee.
- B.** Based on the information provided, **explain** how a decrease in spider populations could affect a lower trophic level.
- C.** Based on the data in Figure 1, **identify** the number of spiders per sample at 25% nonnative plants.
- D.** Based on the data in Figure 1, **describe** the trend in the number of insects per sample in relation to the percentage of nonnative plants.
- E.** Scientists hypothesized that the population of chickadees would be stable or growing with fewer than 25% nonnative plants. **Describe** one way that the data in Figure 2 support this hypothesis.
- F.** Insect biodiversity is important to maintain ecosystem health. A group of students was interested in learning about factors that affect ant biodiversity. They located two study sites near their school: a frequently mowed urban park and an unmowed grassland. The students used traps designed to collect ants. They loaded 10 of these traps with the same food and placed them randomly at different locations within each site. Students collected the traps after 24 hours and counted the number of different ant species in each trap to determine species richness.
- Identify** a likely scientific question for the students' investigation of ant diversity.
 - Identify** the dependent variable in the students' investigation.
- G.** The data from the student investigation of ant diversity are shown in the following table. An "X" in the table indicates that the species was present at that site.

Ant Species Present in an Urban Park and Unmowed Grassland

Site	Species A	Species B	Species C	Species D	Species E	Species F
Urban park	X			X	X	
Grassland	X	X	X	X		X

- Explain** why the ant community of the unmowed grassland would be more likely to recover from a disturbance, such as a flood or fire, than the ant community in the mowed urban park would.
 - Explain** how the results of the investigation could have been altered if students had measured ant biodiversity at a paved playground rather than in the grassland.
- H.** Habitat fragmentation has impacts on a variety of species. Paved roads can lead to habitat fragmentation.
- Describe** one effect that a paved road in a forest can have on animal species such as deer or bears.

There is a natural climate phenomenon that occurs in the equatorial Pacific Ocean because of periodic fluctuations in sea surface conditions and atmospheric circulation. This phenomenon happens every few years, resulting in shifts in temperature and precipitation in many parts of the world.

Figure 1 shows temperature and precipitation patterns associated with one phase of this phenomenon in the equatorial Pacific Ocean. Figure 2 shows the associated temperature and precipitation patterns that occur over North America.

Figure 1. Effects of Changes in Sea Surface Conditions in Equatorial Pacific Ocean

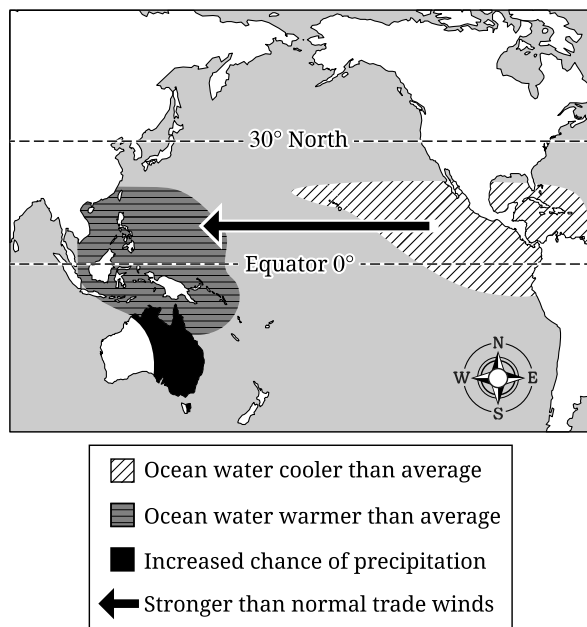
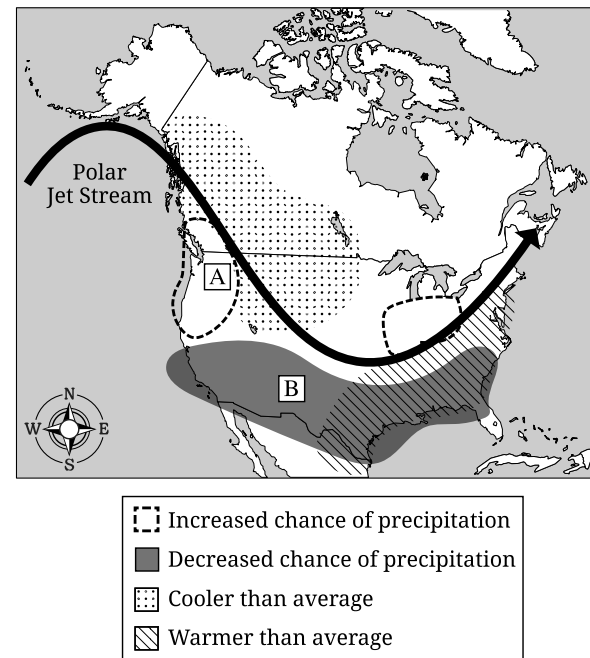


Figure 2. Polar Jet Stream and Climate Conditions in North America



1. Respond to parts A, B, C, D, E, F, G, H, and I, and all subparts.

- A. Based on the data in the graph, **identify** the number of Common Tern breeding pairs in 1995.
- B. Based on the data in the graph, **describe** the trend in the number of Common Tern breeding pairs from 1995 to 2008.
- C. A group of students hypothesized that sea level rise will lead to an increase in Common Tern populations. **Describe** one way that the data in the graph refute this hypothesis.
- D. **Explain** how climate change can lead to sea level rise.
- E. Wading birds are a group of large-bodied birds that inhabit coastal wetlands all over the world. Researchers monitored the number of wading bird species at four coastal locations experiencing rising sea levels over a 5-year period. The data are shown in the following table.

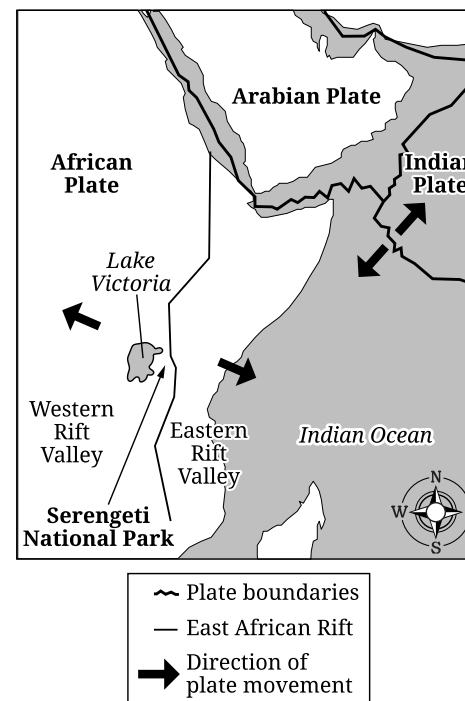
Sea Level Rise and Number of Wading Bird Species at Four Coastal Locations

Year	Increase in Sea Level (m)	Location A	Location B	Location C	Location D
1	0.05	1	5	3	4
2	0.08	2	4	3	6
3	0.10	6	7	5	5
4	0.12	5	7	7	7
5	0.15	7	8	9	8

- i. **Identify** a hypothesis that researchers are likely investigating in the wading bird study.
- ii. **Identify** the dependent variable in this study.
- F. One year after the completion of the study of wading bird species described in Part E, locations A and B experienced an increase in the concentration of PCBs, known to be a persistent organic pollutant, running off into the water. If the researchers repeated their study, **explain** how this environmental change could affect the results of the study.
- G. **Describe** a regulating ecosystem service that can be provided by wetlands.
- H. Since 1990, there has been an increase in urbanization around the coastal wetlands that wading bird communities inhabit. Most of these bird species eat fish and locate prey visually while walking through shallow water. An increase in sediment was discovered in a wetland located near an urban area. **Explain** how increased sediment might lead to a change in the size of the wading bird populations.
- I. **Describe** an environmental problem, other than an increase in sediment, that can occur in wetlands that is associated with increased urbanization and development.

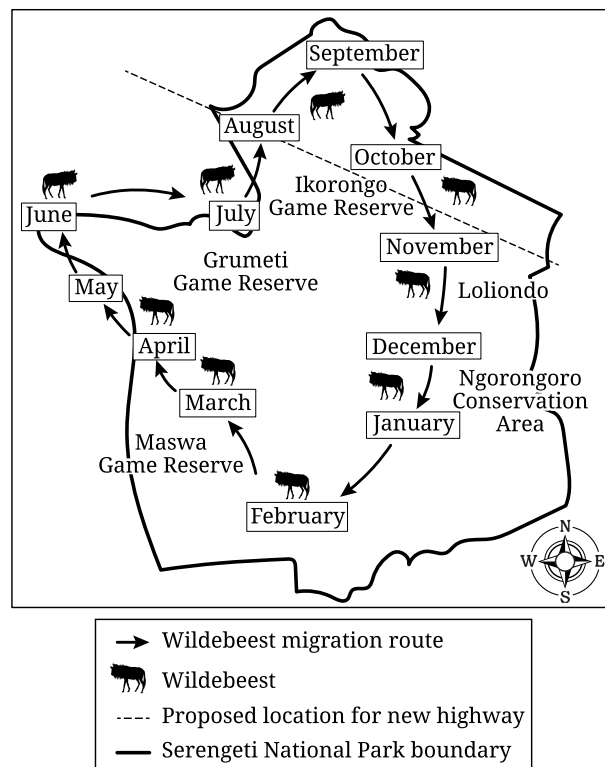
Serengeti National Park is located in Tanzania, Africa. The park is located in a valley along a tectonic plate boundary called the East African Rift. Figure 1 shows the East African Rift and other plate boundaries near the east coast of Africa.

Figure 1. Tectonic Plate Movement near East Coast of Africa



Serengeti National Park contains a variety of tropical habitats but is dominated by wideopen lands that include a variety of grass species with scattered trees and shrubs. Most grass growth occurs after the March through May rainy season. Many of the park's herbivores, such as wildebeest and zebra, migrate through the park in an annual cycle following the growth of new grass (Figure 2).

Figure 2. Annual Migration of Wildebeest in Serengeti National Park



ENVIRONMENTAL SCIENCE

SECTION II

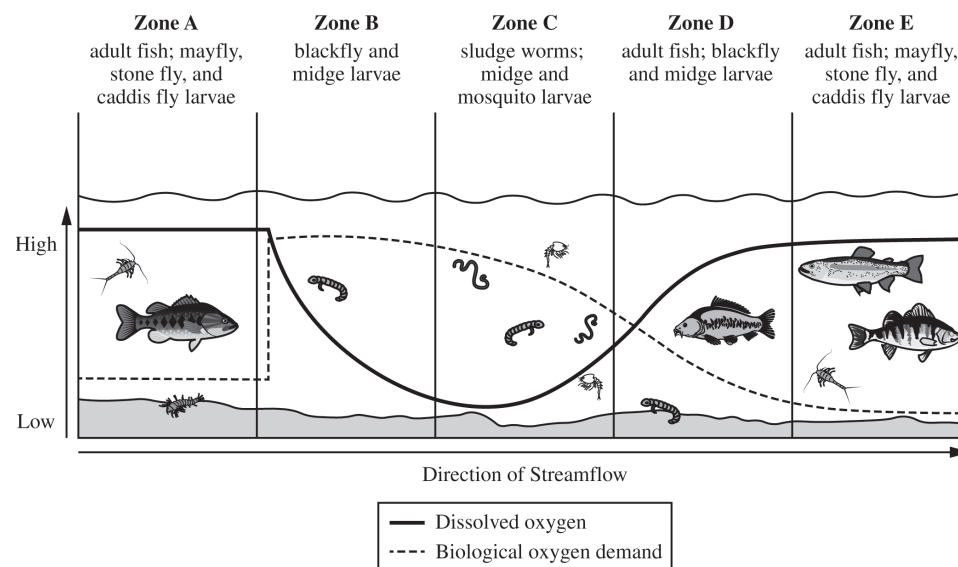
Time—1 hour and 10 minutes

3 Questions

Directions: Answer all three questions, which are weighted equally; the suggested time is about 22 minutes for answering each question. Write all your answers in the Free Response booklet. Where calculations are required, clearly show how you arrived at your answer. Where explanation or discussion is required, support your answers with relevant information and/or specific examples. You may plan your answers in this orange booklet, but no credit will be given for anything written in this booklet. **You will only earn credit for what you write in the separate Free Response booklet.**

1. Researchers are studying the stream ecosystem shown in the following diagram. They have identified five different zones based on the dissolved oxygen levels and biological oxygen demand as the water flows downstream. Biological oxygen demand is the amount of oxygen needed by bacteria and other microorganisms to break down organic material in water. Some of the most common fish and macroinvertebrate species found in each zone are listed in the diagram.

Dissolved Oxygen and Biological Oxygen Demand in a Stream Ecosystem



- (a) Based on the information in the diagram, **identify** the zone with the lowest level of dissolved oxygen..
- (b) Based on the information in the diagram, **describe** the relationship between biological oxygen demand and dissolved oxygen.
- (c) Based on the information in the diagram, **identify** the zone where there is most likely point-source water pollution discharged into the stream.

The research team is interested in investigating the relationship between dissolved oxygen levels and macroinvertebrate species richness in the stream. Researchers counted the number of macroinvertebrate species in zones A, B, and C during the summer months. The researchers selected zone A to serve as the control in the investigation.

- (d) **Identify** the dependent variable in the researchers' investigation.
- (e) **Identify** a testable hypothesis for the researchers' investigation.
- (f) **Describe** the reason the researchers selected zone A to serve as the control in the investigation.

The researchers decided to repeat their data collection during the winter months.

- (g) **Explain** how the modification to collect data in the winter months could alter the results of the investigation.

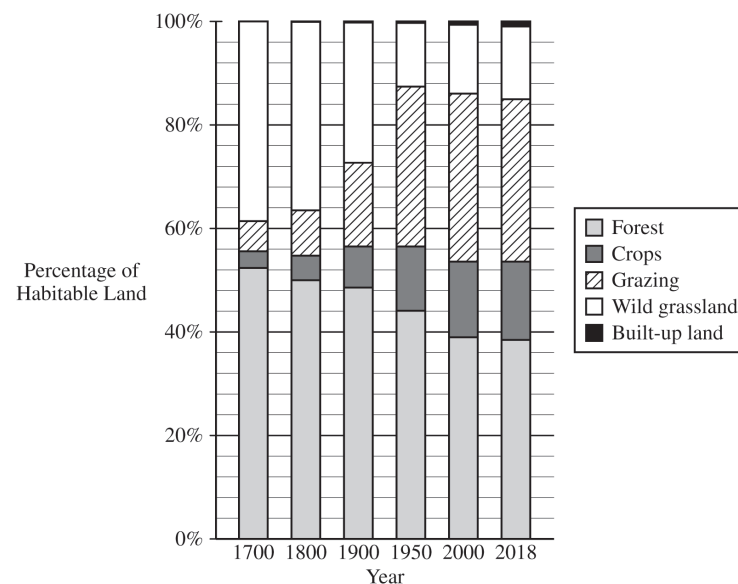
Stream ecosystems are affected by point-source organic pollution in a variety of ways.

- (h) **Describe** the effect that the introduction of raw sewage into the stream could have on the population of bacteria in the stream.
- (i) **Identify** an abiotic factor other than dissolved oxygen and organic pollution that could also influence the population size of bacteria in the stream.
- (j) **Explain** how persistent organic pollutants can affect higher trophic levels in an aquatic food web.

Begin your response to this question at the top of a new page in the separate Free Response booklet and fill in the appropriate circle at the top of each page to indicate the question number.

2. The following graph shows how global uses of habitable land have changed since 1700.

Land Use Changes on Earth, 1700–2018



- (a) Based on the data in the graph, **identify** the year with the highest percentage of forest.
- (b) Based on the data in the graph, **describe** the relationship between the land use changes in the wild grasslands and grazing from 1700 to 1950.
- (c) **Identify** an environmental problem associated with overgrazing by livestock.
- (d) A student hypothesized that the change in the percentage of forest from 1700 to 2018 has decreased atmospheric carbon dioxide concentrations. **Explain** whether the hypothesis is supported or refuted based on the data in the graph.
- Urban environments have accounted for an increasing percentage of land use within the last few decades.
- (e) **Describe** a water-related environmental problem associated with urbanization.
- (f) **Describe** a potential response to mitigate the environmental problem identified in part (e).

Farmers who own large sections of cropland notice that bobcats, a medium-sized predatory forest cat, were present many years ago but are now virtually absent in the area. Instead, smaller mammal species now inhabit the area. Over time, the farmers have cleared nearly all of the forest on their property and converted it to farmland.

(g) **Explain** why there are fewer bobcats present on the farmland now compared to several decades ago.

The small mammal species are considered pests by the farmers. The farmers partner with a conservation group to increase the number of bobcats in the area. As a solution, the conservation group will introduce bobcats onto the few isolated patches of the original forested habitat left in the area. They can introduce only a small number of bobcats in each patch.

(h) **Describe** a disadvantage of introducing only a small population of bobcats.

(i) **Propose** a solution to improve the chances that the bobcat reintroductions will be successful in reestablishing wild populations.

(j) **Justify** the solution proposed in part (i) by describing an additional advantage, other than reestablishing the bobcat population near the farms.

Begin your response to this question at the top of a new page in the separate Free Response booklet and fill in the appropriate circle at the top of each page to indicate the question number.

ENVIRONMENTAL SCIENCE**SECTION II****Time—1 hour and 10 minutes****3 Questions**

Directions: Answer all three questions, which are weighted equally; the suggested time is about 22 minutes for answering each question. Write all your answers in the Free Response booklet. Where calculations are required, clearly show how you arrived at your answer. Where explanation or discussion is required, support your answers with relevant information and/or specific examples. You may plan your answers in this orange booklet, but no credit will be given for anything written in this booklet. **You will only earn credit for what you write in the separate Free Response booklet.**

1. Researchers interested in sustainability developed three new varieties of genetically modified green beans designed to produce higher yields in arid regions. Four plots (A–D) were set up on a floodplain of a river to grow beans. Plots A, B, and C were each planted with seeds of different types of genetically modified strains of green beans. Plot D was planted with seeds of unmodified green beans. Each plot was given equal amounts of fertilizer, which contains phosphorus and nitrogen, and water and was irrigated using spray irrigation for one hour per day. Throughout the growing season, researchers measured the amount of green beans harvested within each plot. The plots with genetically modified beans had higher crop yields than the plot with unmodified beans.

(a) **Identify** the control group in this experiment.

(b) **Identify** the scientific question for the investigation.

(c) Researchers repeated the experiment by modifying the length of time for the spray irrigation to 20 minutes per day. **Explain** how the results of the experiment could be altered with this modification.

Researchers also monitored the amount of sediment and fertilizer washing into the river from each plot in the original study. The soil temperature was also measured in each plot at the same depth and at the same time each day approximately 0.05 meters below the surface of the soil.

Genetically Modified Green Bean Experimental Results

Plot	Sediment Runoff (mg/L)	Phosphorus Runoff (mg/L)	Nitrogen Runoff (mg/L)	Soil Temperature (°C)
A (Type 1 GMO beans)	2.4	0.11	1.07	18.6
B (Type 2 GMO beans)	2.1	0.02	0.56	18.3
C (Type 3 GMO beans)	0.9	0.04	0.68	18.3
D (Unmodified beans)	3.5	0.15	1.24	17.6

(d) Based on the data in the table, **identify** the plot with the lowest soil temperature.

(e) **Describe** how sediment runoff and fertilizer runoff compare between the unmodified green beans and the genetically modified green beans.

- (f) The Type 2 GMO beans in Plot B were developed to grow more quickly than the unmodified beans in Plot D. Researchers have hypothesized that the Type 2 beans would use fertilizer more completely than the other varieties. Based on the data in the table and the experimental design, **explain** whether the researchers' hypothesis was supported or refuted.

Once the experiment was concluded, the researchers burned the plots to remove the crops that had been planted. After a few years, the researchers returned to the plots and observed a variety of plants, insects, and bird species living there.

- (g) **Describe** the ecological process that occurred on the plots after the crops were burned.

A survey indicated that one of the plots had twice the plant diversity that the other plots had. Over the next five years, the river occasionally flooded the plots, killing off many of the species that inhabited the plots.

- (h) After each flooding event, the plot with twice the plant diversity returned to its prior level of biodiversity more quickly than the other plots did. **Explain** why a community with more plant diversity will recover more quickly from the flooding.

- (i) After the last flooding event, a beetle not previously known in the area appeared in one of the plots with less plant diversity. Over a period of a few months, the new beetle population increased, whereas the existing beetle species in the plot had declining populations. **Explain** why the new beetle species could be better able to successfully populate this plot than the existing beetle species could.

- (j) **Describe** one realistic method to prevent the new beetle from spreading beyond the experimental plot.

Begin your response to this question at the top of a new page in the separate Free Response booklet and fill in the appropriate circle at the top of each page to indicate the question number.

3. Habitat destruction and fragmentation can have many different effects on species.

- (a) **Describe** a characteristic of a specialist species that would make the specialist species more likely to be negatively affected by habitat fragmentation than a generalist species.

A rapidly growing suburban municipality purchases nearby forested land and proposes a newly planned housing development, which would involve clear-cutting much of the area for the construction of single-family homes. While evaluating the land, the development committee discovers that development will encroach upon the habitat of a wood thrush population. The wood thrush is a solitary, territorial bird whose preferred habitat consists of large, intact densely forested areas. Wood thrush populations are also threatened by cowbirds. A cowbird lays her egg in an existing nest of a wood thrush. After the cowbird egg hatches, the cowbird pushes the unhatched wood thrush eggs out. The wood thrush parents raise the cowbird hatchling as their own.

- (b) **Identify** the symbiotic relationship between the wood thrush and the cowbird.

- (c) **Describe** one ecological advantage of leaving areas of undeveloped forest in the development plan as compared to clear-cutting the property.

- (d) **Propose** a solution that will minimize the effect of development on the resident population of wood thrush while still meeting the municipality's need for a housing development.

- (e) A male wood thrush needs a minimum of 800 m^2 of territory for reproduction. The municipal development committee has set a biodiversity preservation target of 275 male wood thrush territories. **Calculate** the area that must be set aside to support the goal of 275 male thrush territories. **Show** your work.

- (f) A real estate developer wants to build houses on the property. The plan will support 1,000 lots with a lot size of $1,100 \text{ m}^2$. The developer has proposed setting aside land equal to 10% of the size of each lot it sells. **Calculate** the maximum number of male wood thrush territories that could be created under this proposal. **Show** your work.

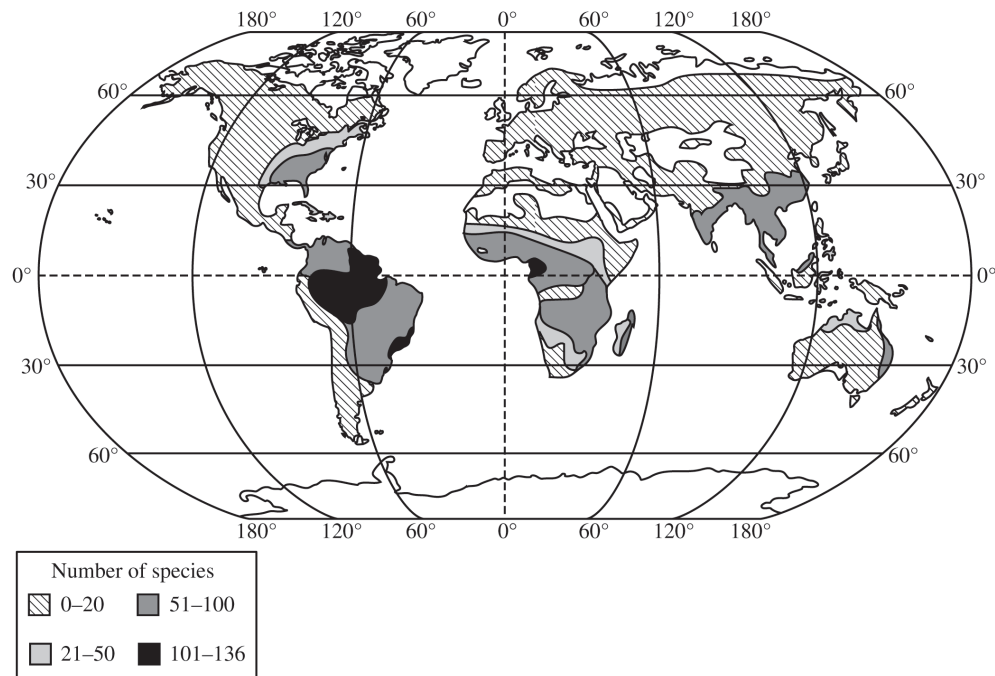
- (g) **Calculate** the percentage of each of the 1,000 lots that would need to be set aside in order to support the goal of 275 male wood thrush territories. **Show** your work.

Begin your response to this question at the top of a new page in the separate Free Response booklet and fill in the appropriate circle at the top of each page to indicate the question number.

STOP

END OF EXAM

GLOBAL AMPHIBIAN SPECIES RICHNESS



2. Biodiversity around the world is changing as a result of anthropogenic influences.

(a) The map represents species richness of amphibians around the globe. Use the map to answer the following questions.

- Identify** the latitudinal range with the greatest amphibian species richness.
 - Identify** what biome this range most likely represents.
 - Describe** one reason amphibian species richness would tend to be highest in this region.
- (b) There are many environmental threats facing amphibians today, such as deforestation. **Describe** one possible anthropogenic reason for deforestation.
- (c) Many factors influence biodiversity.
- Explain** how the species richness of an ecosystem influences its response to environmental stressors.
 - Explain** why amphibian biodiversity is declining globally, other than from deforestation.
- (d) Currently, wildlife species are going extinct at an alarming rate. To combat this threat, governments around the world have enacted legislation and signed treaties to protect species threatened by extinction.

- Identify** one specific piece of legislation that has been designed to protect species threatened by extinction.
 - Explain** how the requirements of the legislation identified in part (d)(i) specifically protect species threatened by extinction.
- (e) A town is considering selling an undeveloped parcel of land along its border for residential developments. The square parcel of land consists of approximately 30% wetland and 70% pasture. The wetland runs through the middle of the property for its entire width and is home to three native frog species.
- Propose** a viable solution that will result in the protection of the native frog species while still allowing for maximum profit of the property development.
 - Justify** the solution proposed in (e)(i) by describing a potential advantage of the plan, other than frog protection.

Begin your response to this question at the top of a new page in the separate Free Response booklet and fill in the appropriate circle at the top of each page to indicate the question number.

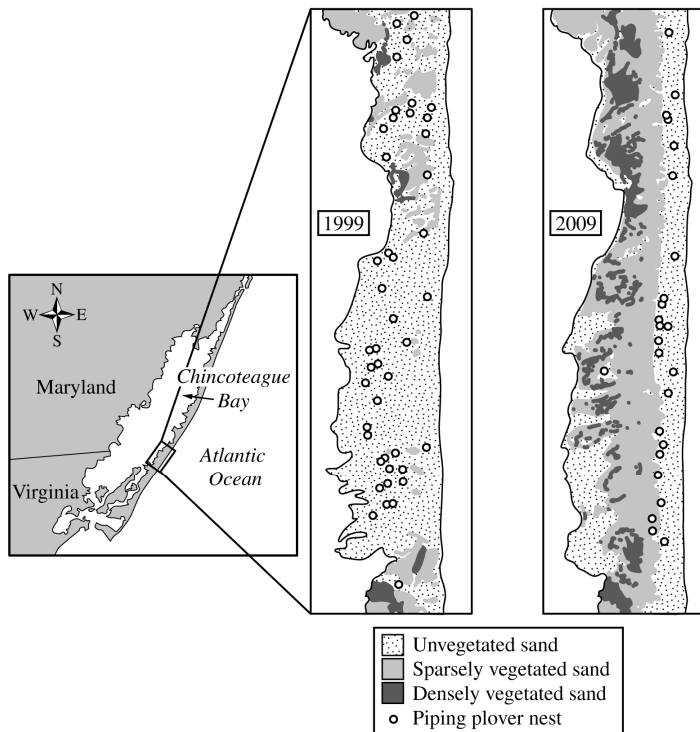
ENVIRONMENTAL SCIENCE**SECTION II****Time—1 hour and 30 minutes****4 Questions**

Directions: Answer all four questions, which are weighted equally; the suggested time is about 22 minutes for answering each question. Write all your answers on the pages following the questions in this book. Where calculations are required, clearly show how you arrived at your answer. Where explanation or discussion is required, support your answers with relevant information and/or specific examples.

1. The piping plover is a globally threatened species, with perhaps as few as 2,000 nesting pairs remaining in the Atlantic population of these migratory shorebirds. Plovers were nearly hunted to extinction in the nineteenth century.

Plovers prefer to nest and search for food on open sandy beaches between sparsely vegetated sand dunes. Washovers, where sand is washed up from the beach and buries vegetated areas during big storms, are also important to plovers because they provide moist and undisturbed habitat for plover adults and their chicks. Ecologists with the Elliott Oceanographic Institute mapped the distribution of plover nests during two seasonal surveys of nesting sites over a ten-year period on Assateague Island. This is a barrier island, a long, narrow island running parallel to the Atlantic coast of Virginia.

SPRING PIPING PLOVER NESTING SITES
ON ASSATEAGUE ISLAND, VIRGINIA



- (a) Use the maps provided to answer the following questions.
- Identify** the preferred nesting habitat for piping plovers.
 - Describe** the change in the number of piping plover nests on Assateague Island between 1999 and 2009.
 - Describe** one likely reason for the change in the number of piping plover nests between 1999 and 2009.
- (b) Coastal species are affected by more than just natural events.
- Special beach restrictions can help piping plovers during nesting season. **Describe** one restriction that could reasonably be implemented to help prevent the destruction of plover nests by human actions.
 - In addition to providing habitat for piping plovers, barrier islands (and closely related landforms) are important for other reasons. **Explain** one way that these features help to preserve and protect the environment in coastal regions.
 - Identify** one human action that directly threatens coastal habitats and **describe** one impact on species, other than the piping plover, that use the habitat.

Approximately 40% of the United States population resides in coastal areas, such as areas near Assateague Island, where sea level rise and shoreline erosion is occurring.

- Identify** one economic impact on coastal communities that has resulted from rising sea levels.
- Describe** TWO methods that may be used locally to protect coastal communities from rising sea levels.

4. Dams are built by humans for various purposes including hydroelectric power generation and control of downstream flooding.
- (a) **Explain** how electricity is generated at a hydroelectric dam.
 - (b) **Identify** TWO economic benefits, other than hydroelectric power generation and control of downstream flooding, associated with dams.
 - (c) **Describe** one ecological benefit of seasonal flooding of the floodplain of a free-flowing river.
 - (d) Some dams have been removed from rivers.
 - (i) **Explain** how removal of a dam can benefit fish populations.
 - (ii) **Describe** one negative environmental consequence of removing a dam from a river (other than effects on fish populations).
 - (e) Dams are also built by beavers, a keystone species in some North American ecosystems.
 - (i) **Define** keystone species.
 - (ii) **Describe** how dams built by beavers can make beavers a keystone species in some ecosystems.

STOP
END OF EXAM

ENVIRONMENTAL SCIENCE
SECTION II
Time—90 minutes
4 Questions

Directions: Answer all four questions, which are weighted equally; the suggested time is about 22 minutes for answering each question. Write all your answers on the pages following the questions in this book. Where calculations are required, clearly show how you arrived at your answer. Where explanation or discussion is required, support your answers with relevant information and/or specific examples.

1. Read the following article from the *Fremont New Tribune*.

Fremont New Tribune

May 2, 2016

As another winter concludes, biologists are alarmed by the continued spread of white nose syndrome (WNS) in bats. WNS is a fungal disease that is decimating bat populations across eastern North American forests, with mortality rates reaching up to 100 percent at many sites. WNS has been found in at least 25 states in the United States and 5 Canadian provinces.

The fungus (*Pseudogymnoascus destructans*) grows well in cool conditions such as those found in caves and has been observed as white patches on the muzzles, noses, ears, and wings of many cave-dwelling bats. WNS has caused significant population declines for several bat species, including once-numerous species such as the little brown bat (*Myotis lucifugus*).

Little brown bats hunt using echolocation by emitting up to 200 high-frequency calls per second when pursuing their prey. When healthy, the little brown bat can live up to ten years and have one or two offspring (called pups) each year.

"Little brown bats provide tremendous value to the United States economy every year by the essential services they provide to farmers and other people. We need to understand how this deadly disease spreads and attempt to help reduce its impact on the little brown bat and other bat species," said Dr. Duke Serach of the Fremont office of the United States Fish and Wildlife Service. Dr. Serach concluded with, "It may yet be possible to save the little brown bats, but the remaining population will be alarmingly small."

- (a) Diseases can devastate populations; however, most diseases do not drive their host to extinction. **Provide** one explanation for why diseases seldom cause extinction.
- (b) Dr. Serach suggests that even if the impact of WNS on little brown bat populations can be reduced and the extinction of the species avoided, the bat populations are likely to remain alarmingly small.
- (i) **Describe** TWO threats (other than WNS) to the survival of the bat species if the total number of bats becomes very small.
- (ii) If the little brown bat species does not become extinct and can potentially recover, the rate of recovery is likely to be slow. **Discuss** one aspect of bat biology that might slow the recovery of little brown bat populations to pre-WNS numbers.
- (c) Bats are found in ecosystems around the world. **Describe** TWO ways in which other organisms in an ecosystem could be affected by a decline in a bat population.
- (d) The Eastern deciduous forest in which the little brown bats live is an important ecosystem. **Identify** TWO ecosystem services that forests provide, and **explain** how each service benefits human society.
- WNS is an emerging disease in bats. Humans are also subject to emerging diseases, such as Ebola. A recent study suggests that the number of emerging infectious diseases affecting human populations has been steadily increasing in recent decades.
- (e) **Provide** a likely reason for the increase in emerging infectious diseases affecting human populations. Include an explanation for the reason you provided.

2.2 Ecosystem Services

Name: _____ Class: _____ Date: _____

Total: 11 marks

KEY WORDS ecosystem services 生态系统服务

Objective

Build the skills to answer exam questions on **ecosystem services**.

You must be able to:

- classify **ecosystem services** 生态系统服务 (provisioning, regulating, supporting, cultural)
- give examples of each
- explain their value to humans

1 Worked examples

Study these first. Each one shows the method for a question type used later — follow the steps and you can do the Practice and Exam-style questions yourself.

■ Four types of ecosystem service

- **Provisioning** — products: food, water, timber, medicine.
- **Regulating** — control: climate regulation, water purification, pollination, flood control.
- **Supporting** — underlying processes: nutrient cycling, soil formation.
- **Cultural** — non-material: recreation, tourism, spiritual value.

■ Classifying a service

Ask what the ecosystem provides. Clean water = **regulating** (purification) or **provisioning** (the water itself); nutrient cycling = **supporting**; a national park visit = **cultural**.

■ Value to humans

Ecosystem services are worth trillions of dollars — replacing them artificially (e.g. water treatment for lost wetlands) is expensive, so protecting ecosystems is cost-effective.

■ A worked example

Bees pollinating crops is a **regulating** service worth billions to agriculture; losing pollinators would raise food costs sharply.

2 Practice

Now apply the methods above.

2.1 Name the four types of ecosystem service. [2]

2.2 Classify “pollination of crops”. [1]

2.3 Give one provisioning service. [1]

3 Exam-style questions

3.1 Water purification by a wetland is which type of service? [1]

- A provisioning
- B regulating
- C supporting
- D cultural

3.2 A forest provides timber, stores carbon, and is used for hiking.

(a) Classify each of these three services. [3]

(b) Explain why ecosystem services have economic value. [1]

3.3 Explain why protecting a wetland can be cheaper than replacing its services artificially. [2]

Solutions

2.1 Provisioning, regulating, supporting, cultural.

2.2 Regulating.

2.3 Any one: food, water, timber, medicine.

3.1 B — regulating.

3.2 (a) Timber = provisioning; carbon storage = regulating; hiking = cultural. (b) They provide things people would otherwise have to pay to produce or replace.

3.3 The wetland naturally purifies water for free; replacing it with a treatment plant costs money to build and run, so conserving it is cheaper.

Name:

AP Environmental Science: 2025 Set 2

1. Respond to parts A, B, C, D, E, F, G, H, and I, and all subparts.

- A. Based on the data in the graph, **identify** the number of Common Tern breeding pairs in 1995.
- B. Based on the data in the graph, **describe** the trend in the number of Common Tern breeding pairs from 1995 to 2008.
- C. A group of students hypothesized that sea level rise will lead to an increase in Common Tern populations. **Describe** one way that the data in the graph refute this hypothesis.
- D. **Explain** how climate change can lead to sea level rise.
- E. Wading birds are a group of large-bodied birds that inhabit coastal wetlands all over the world. Researchers monitored the number of wading bird species at four coastal locations experiencing rising sea levels over a 5-year period. The data are shown in the following table.

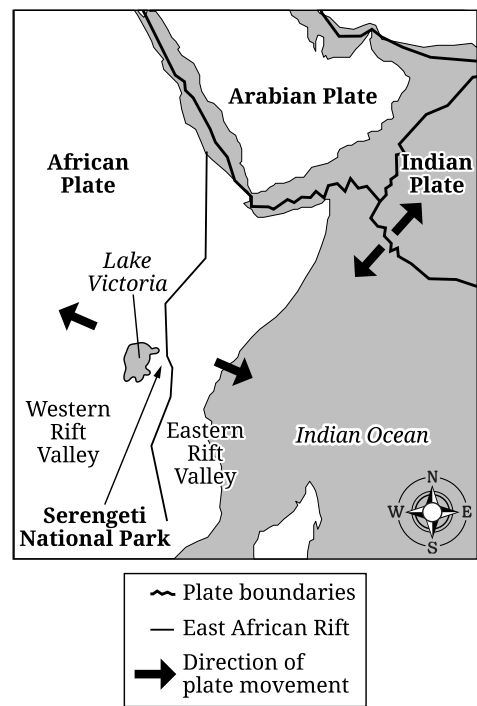
Sea Level Rise and Number of Wading Bird Species at Four Coastal Locations

Year	Increase in Sea Level (m)	Location A	Location B	Location C	Location D
1	0.05	1	5	3	4
2	0.08	2	4	3	6
3	0.10	6	7	5	5
4	0.12	5	7	7	7
5	0.15	7	8	9	8

- i. **Identify** a hypothesis that researchers are likely investigating in the wading bird study.
- ii. **Identify** the dependent variable in this study.
- F. One year after the completion of the study of wading bird species described in Part E, locations A and B experienced an increase in the concentration of PCBs, known to be a persistent organic pollutant, running off into the water.
- If the researchers repeated their study, **explain** how this environmental change could affect the results of the study.
- G. **Describe** a regulating ecosystem service that can be provided by wetlands.
- H. Since 1990, there has been an increase in urbanization around the coastal wetlands that wading bird communities inhabit. Most of these bird species eat fish and locate prey visually while walking through shallow water. An increase in sediment was discovered in a wetland located near an urban area.
- Explain** how increased sediment might lead to a change in the size of the wading bird populations.
- I. **Describe** an environmental problem, other than an increase in sediment, that can occur in wetlands that is associated with increased urbanization and development.

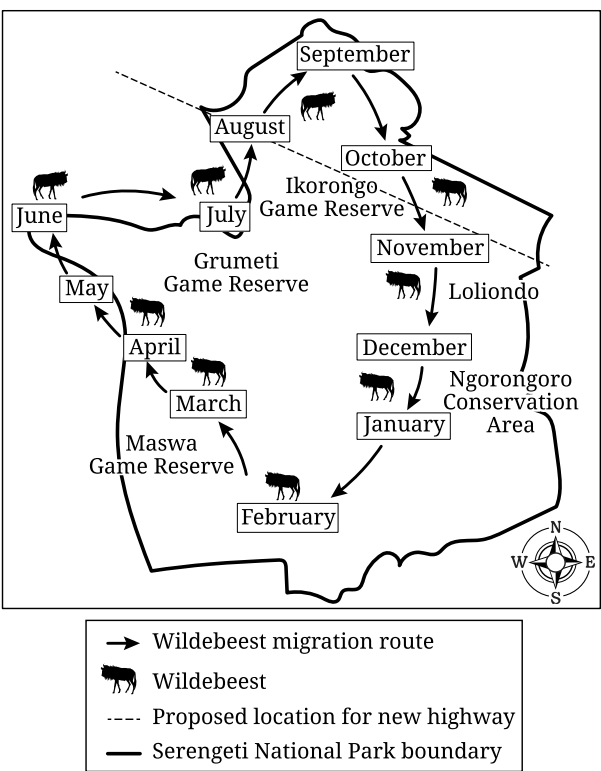
Serengeti National Park is located in Tanzania, Africa. The park is located in a valley along a tectonic plate boundary called the East African Rift. Figure 1 shows the East African Rift and other plate boundaries near the east coast of Africa.

Figure 1. Tectonic Plate Movement near East Coast of Africa



Serengeti National Park contains a variety of tropical habitats but is dominated by wideopen lands that include a variety of grass species with scattered trees and shrubs. Most grass growth occurs after the March through May rainy season. Many of the park's herbivores, such as wildebeest and zebra, migrate through the park in an annual cycle following the growth of new grass (Figure 2).

Figure 2. Annual Migration of Wildebeest in Serengeti National Park



3. Earth's climate has changed over time by the addition of greenhouse gasses to the atmosphere. One approach to mitigate climate change is the use of nuclear power, rather than coal-burning power plants, for electricity generation.

(a) **Identify** a fuel used in a nuclear power plant.

(b) **Describe** a negative environmental impact on nearby bodies of water that is caused by using water for cooling in nuclear power plants.

(c) In 2021, 4.1×10^{12} kilowatt hours (kWh) of commercial electricity was generated in the United States. Nuclear power accounted for 18.9% of the total commercial electricity. **Calculate** the amount of electricity in kWh generated by nuclear power in the United States in 2021. **Show** your work.

Another approach to reduce greenhouse gas emissions is to switch from coal-burning power plants to natural gas power plants.

(d) In addition to reducing greenhouse gas emissions, **describe** how switching from coal-burning power plants to natural gas power plants will improve air quality.

Researchers have proposed large-scale tree planting as a solution to reduce the effects of fossil fuel combustion on global climate change.

(e) **Justify** the proposed solution by explaining an additional advantage, other than the reduction of atmospheric greenhouse gases.

(f) 7.4×10^7 cubic meters of natural gas were extracted from a large deposit in 2020. An average of 4.76 kWh of electricity can be generated from each cubic meter of natural gas combusted. In 2020, an average home consumed 10,715 kWh of electricity. **Calculate** how many homes could have been provided with electricity by natural gas extracted from the large deposit in 2020. **Show** your work.

(g) In 2021, 8.99×10^{11} kWh of electricity was generated through the combustion of coal. One kilogram of carbon dioxide is produced per kWh of electricity generated by combusting coal, while 0.42 kilograms of carbon dioxide is produced by combusting natural gas. **Calculate** how much less carbon dioxide would have been produced in 2021 if all coal-burning power plants were replaced with natural gas-burning power plants. **Show** your work.

Begin your response to this question at the top of a new page in the separate Free Response booklet and fill in the appropriate circle at the top of each page to indicate the question number.

STOP

END OF EXAM

ENVIRONMENTAL SCIENCE

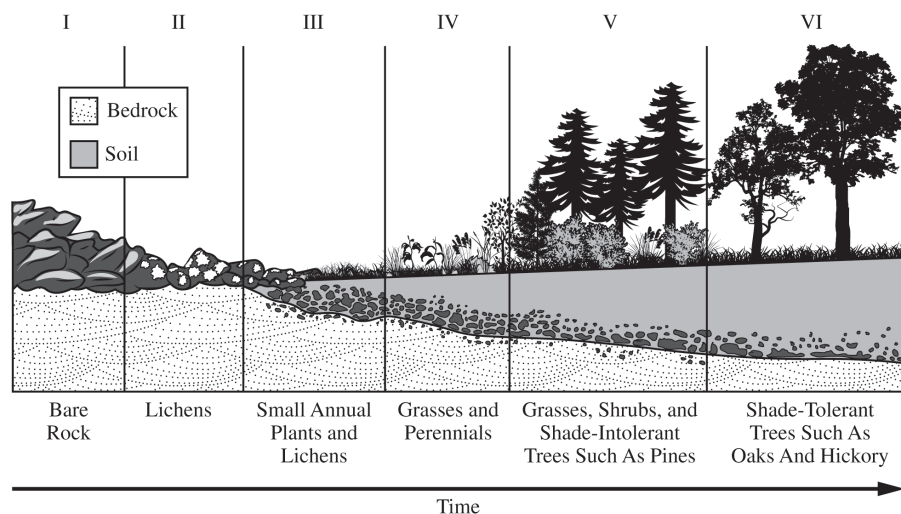
SECTION II

Time—1 hour and 10 minutes

3 Questions

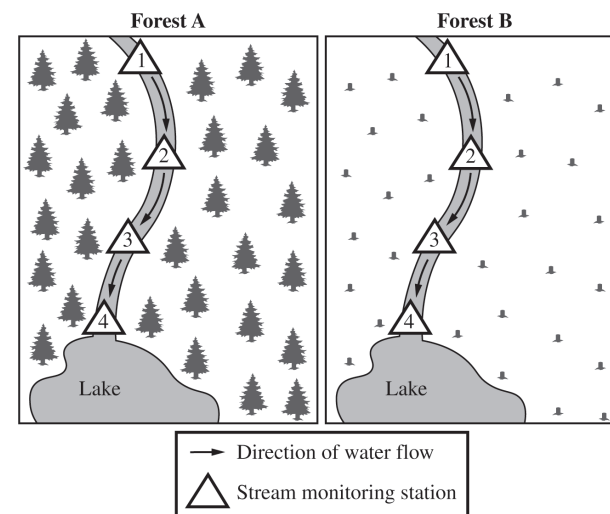
Directions: Answer all three questions, which are weighted equally; the suggested time is about 22 minutes for answering each question. Write all your answers in the Free Response booklet. Where calculations are required, clearly show how you arrived at your answer. Where explanation or discussion is required, support your answers with relevant information and/or specific examples. You may plan your answers in this orange booklet, but no credit will be given for anything written in this booklet. **You will only earn credit for what you write in the separate Free Response booklet.**

1. The following diagram shows how an area changed over time. The dominant vegetation in each stage is labeled in the diagram. Each roman numeral represents a stage in the ecological process.



- Identify** the ecological change over time illustrated in the diagram.
- Identify** the stage in which pioneer species first appear.
- Describe** how soil forms from stage II to stage III.
- Identify** a cultural ecosystem service that may be provided by a mature forest.

Researchers are interested in investigating the effect of the removal of trees on the water quality of nearby waterways. To conduct their experiment, the researchers locate two identical forest watersheds, both with a river running through them. Forest A is an intact forest and forest B is a clear-cut forest. Four stream monitoring stations are set up in each forest study area. Each station monitors a variety of water quality indicators, including water temperature, at various locations along the river. The experimental setup is shown in the following diagrams. The arrows shown in the rivers represent the direction of water flow. The triangles in the river show the location of the stream monitoring stations.



- Identify** a testable hypothesis being investigated by the researchers.
- Identify** the independent variable in the experiment.
- Describe** the purpose of forest A in the experiment.
- Explain** why the water temperature might change because of clear-cutting trees in forest B.

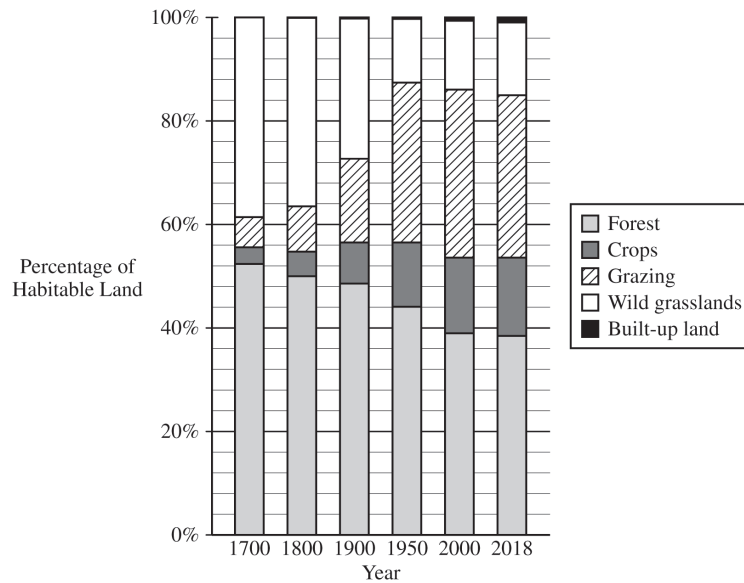
After the experiment was completed, land developers constructed a golf course in the clear-cut area of forest B. To prepare the land, developers removed any remaining stumps and newly grown trees and began planting and fertilizing new grass. The researchers are interested in the effect the golf course may have on the water quality of the river. To monitor the river in forest B, the researchers repeated the experiment once the golf course had been constructed.

- Explain** why an indicator of water quality other than temperature could be altered by the golf course in forest B.
- Explain** how the aquatic organisms living in the lake illustrated in the diagram of forest B are likely to be affected by the new golf course.

Begin your response to this question at the top of a new page in the separate Free Response booklet and fill in the appropriate circle at the top of each page to indicate the question number.

2. The following graph shows how global uses of habitable land have changed since 1700.

Land Use Changes on Earth, 1700–2018



- (a) Based on the data in the graph, **identify** the year with the highest percentage of forest.
- (b) Based on the data in the graph, **describe** the relationship between the land use changes in the wild grasslands and grazing from 1700 to 1950.
- (c) **Identify** an environmental problem associated with overgrazing by livestock.
- (d) A student hypothesized that the change in the percentage of forest from 1700 to 2018 has decreased atmospheric carbon dioxide concentrations. **Explain** whether the hypothesis is supported or refuted based on the data in the graph.

Urban environments have accounted for an increasing percentage of land use within the last few decades.

- (e) **Describe** a water-related environmental problem associated with urbanization.
- (f) **Describe** a potential response to mitigate the environmental problem identified in part (e).

Farmers who own large sections of cropland notice that bobcats, a medium-sized predatory forest cat, were present many years ago but are now virtually absent in the area. Instead, smaller mammal species now inhabit the area. Over time, the farmers have cleared nearly all of the forest on their property and converted it to farmland.

- (g) **Explain** why there are fewer bobcats present on the farmland now compared to several decades ago.

The small mammal species are considered pests by the farmers. The farmers partner with a conservation group to increase the number of bobcats in the area. As a solution, the conservation group will introduce bobcats onto the few isolated patches of the original forested habitat left in the area. They can introduce only a small number of bobcats in each patch.

- (h) **Describe** a disadvantage of introducing only a small population of bobcats.

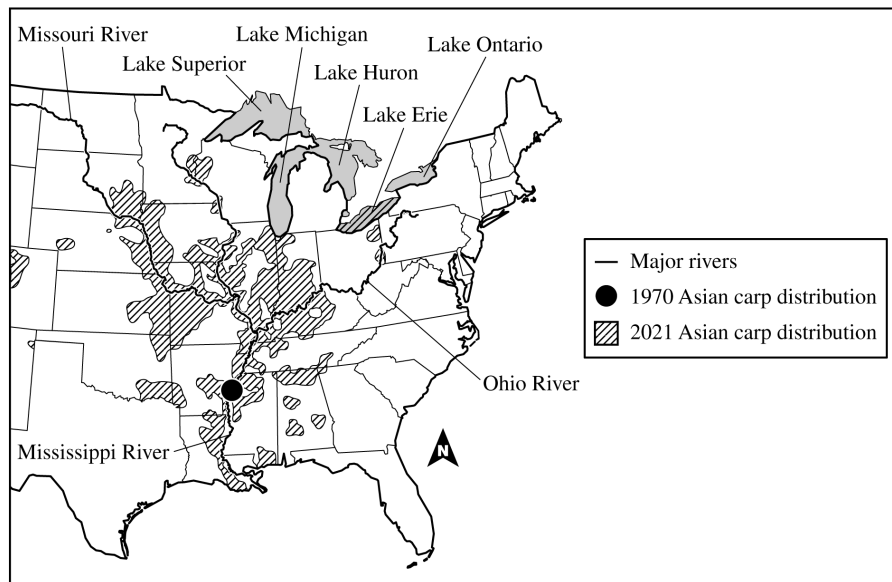
- (i) **Propose** a solution to improve the chances that the bobcat reintroductions will be successful in reestablishing wild populations.

- (j) **Justify** the solution proposed in part (i) by describing an additional advantage, other than reestablishing the bobcat population near the farms.

Begin your response to this question at the top of a new page in the separate Free Response booklet and fill in the appropriate circle at the top of each page to indicate the question number.

2. Asian carp were first introduced in the southern United States in the 1970s by fish farmers wanting to control algal growth in fish ponds. Asian carp can eat up to 40% of their body weight in algae each day, and a female carp can produce up to 1 million eggs every year.

Distribution of the Asian Carp in the United States



- (a) Based on the information given, **identify** a body of water invaded by Asian carp that is labeled on the map.
- (b) Based on the information shown in the map, **describe** the change in the distribution of Asian carp since their introduction in the 1970s.

The Great Lakes are a group of five major freshwater inland lakes that all share the same watershed.

- (c) **Describe** one impact the introduction of Asian carp could have on the ecosystem services provided by the Great Lakes region.
- (d) **Propose** a realistic solution to help reduce the spread of the Asian carp from their current distribution.
- (e) **Justify** the solution proposed in part (d) by providing an additional advantage.

The following is an example of a simple food chain in the Great Lakes.

Algae → Zooplankton → Macroinvertebrates → Yellow perch → Rainbow trout

- (f) **Identify** the primary consumer in the Great Lakes food chain.
- (g) **Describe** what the arrows in the aquatic food chain represent.

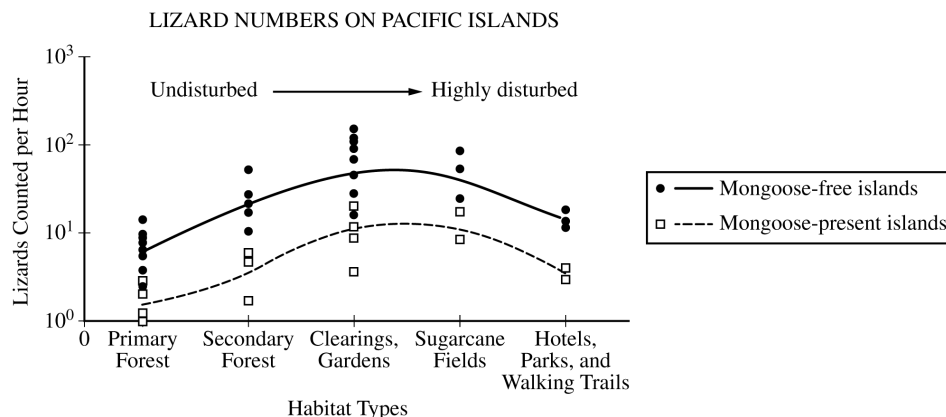
- (h) **Describe** one possible effect of the introduction of the Asian carp on the Great Lakes food chain.

The blue pike, a fish that was endemic to the Great Lakes, was commercially fished from the late 1800s until their population crashed in 1958. In 1970, the species was declared to be extinct.

- (i) **Describe** one way that overfishing of blue pike illustrates the tragedy of the commons.
- (j) One potential solution to reduce overfishing is to use aquaculture. **Describe** one disadvantage of this solution.

Begin your response to this question at the top of a new page in the separate Free Response booklet and fill in the appropriate circle at the top of each page to indicate the question number.

2. Biologists collected data on the abundance of lizards on several Pacific islands with and without mongoose populations. The surveys were conducted at different locations on the islands by counting the number of lizards observed per hour and included habitats with both undisturbed areas and anthropogenically disturbed areas.



- (a) The graph shows data collected by biologists on lizard numbers on several Pacific islands.
- Based on the data in the graph, **identify** the habitat type with the greatest number of lizards.
 - Based on the data in the graph, **describe** the relationship between the lizard numbers observed on islands with and without mongoose populations.
- Globally, islands vary in size, location, and habitat.
- (b) Based on the theory of island biogeography, **describe** the characteristics of an island with the greatest species diversity.
- (c) Island ecosystems are often threatened by invasive species, such as the mongoose populations studied in the survey.
- Describe** one environmental problem caused by invasive animal species.
 - Invasive species are often pests. **Make a claim** that proposes one way to control pest species.
 - Justify** the solution proposed in (c)(ii) by providing an additional benefit of the solution.
- (d) Islands provide humans with many ecosystem services. However, humans may alter ecosystems when they obtain these services. Large-scale commercial sugarcane farming on the Pacific islands has led to significant ecological damage.
- Identify** a provisioning ecosystem service provided by primary forests.
 - Based on the data in the graph, **explain** how replacing primary forests with sugarcane fields may have affected the number of lizards counted on the mongoose-free Pacific islands.
 - The long-term use of monocultures in commercial sugarcane farming is one cause of the ecological damage. **Describe** one problem associated with monocultures.

One solution to the ecological damage of monocultures is to use a form of crop rotation using legumes.

- (e) **Describe** an advantage of crop rotation using legumes on soil fertility.

3. Habitat destruction and fragmentation can have many different effects on species.

- (a) **Describe** a characteristic of a specialist species that would make the specialist species more likely to be negatively affected by habitat fragmentation than a generalist species.

A rapidly growing suburban municipality purchases nearby forested land and proposes a newly planned housing development, which would involve clear-cutting much of the area for the construction of single-family homes. While evaluating the land, the development committee discovers that development will encroach upon the habitat of a wood thrush population. The wood thrush is a solitary, territorial bird whose preferred habitat consists of large, intact densely forested areas. Wood thrush populations are also threatened by cowbirds. A cowbird lays her egg in an existing nest of a wood thrush. After the cowbird egg hatches, the cowbird pushes the unhatched wood thrush eggs out. The wood thrush parents raise the cowbird hatchling as their own.

- (b) **Identify** the symbiotic relationship between the wood thrush and the cowbird.
- (c) **Describe** one ecological advantage of leaving areas of undeveloped forest in the development plan as compared to clear-cutting the property.
- (d) **Propose** a solution that will minimize the effect of development on the resident population of wood thrush while still meeting the municipality's need for a housing development.
- (e) A male wood thrush needs a minimum of 800 m^2 of territory for reproduction. The municipal development committee has set a biodiversity preservation target of 275 male wood thrush territories. **Calculate** the area that must be set aside to support the goal of 275 male thrush territories. **Show your work.**
- (f) A real estate developer wants to build houses on the property. The plan will support 1,000 lots with a lot size of $1,100 \text{ m}^2$. The developer has proposed setting aside land equal to 10% of the size of each lot it sells. **Calculate** the maximum number of male wood thrush territories that could be created under this proposal. **Show your work.**
- (g) **Calculate** the percentage of each of the 1,000 lots that would need to be set aside in order to support the goal of 275 male wood thrush territories. **Show your work.**

Begin your response to this question at the top of a new page in the separate Free Response booklet and fill in the appropriate circle at the top of each page to indicate the question number.

STOP

END OF EXAM

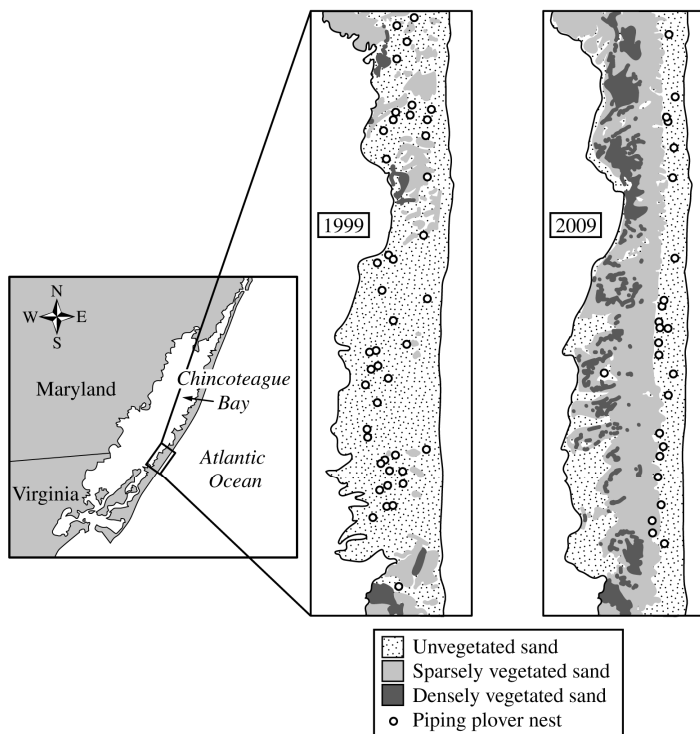
ENVIRONMENTAL SCIENCE**SECTION II****Time—1 hour and 30 minutes****4 Questions**

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1. The piping plover is a globally threatened species, with perhaps as few as 2,000 nesting pairs remaining in the Atlantic population of these migratory shorebirds. Plovers were nearly hunted to extinction in the nineteenth century.

Plovers prefer to nest and search for food on open sandy beaches between sparsely vegetated sand dunes. Washovers, where sand is washed up from the beach and buries vegetated areas during big storms, are also important to plovers because they provide moist and undisturbed habitat for plover adults and their chicks. Ecologists with the Elliott Oceanographic Institute mapped the distribution of plover nests during two seasonal surveys of nesting sites over a ten-year period on Assateague Island. This is a barrier island, a long, narrow island running parallel to the Atlantic coast of Virginia.

SPRING PIPING PLOVER NESTING SITES
ON ASSATEAGUE ISLAND, VIRGINIA



- (a) Use the maps provided to answer the following questions.
- Identify** the preferred nesting habitat for piping plovers.
 - Describe** the change in the number of piping plover nests on Assateague Island between 1999 and 2009.
 - Describe** one likely reason for the change in the number of piping plover nests between 1999 and 2009.
- (b) Coastal species are affected by more than just natural events.
- Special beach restrictions can help piping plovers during nesting season. **Describe** one restriction that could reasonably be implemented to help prevent the destruction of plover nests by human actions.
 - In addition to providing habitat for piping plovers, barrier islands (and closely related landforms) are important for other reasons. **Explain** one way that these features help to preserve and protect the environment in coastal regions.
 - Identify** one human action that directly threatens coastal habitats and **describe** one impact on species, other than the piping plover, that use the habitat.

Approximately 40% of the United States population resides in coastal areas, such as areas near Assateague Island, where sea level rise and shoreline erosion is occurring.

- Identify** one economic impact on coastal communities that has resulted from rising sea levels.
- Describe** TWO methods that may be used locally to protect coastal communities from rising sea levels.

2. As conventional sources of crude oil are depleted, unconventional sources such as oil sands (also known as tar sands) are being utilized. Oils sands contain bitumen, which can be processed into a synthetic crude oil. A region of boreal forest in Alberta, Canada, that covers a deposit of oil sands will be cut and removed during the process of bitumen extraction. It is estimated that the deposit contains 73 billion barrels of recoverable bitumen. The rate of extraction from the deposit will be approximately 1 million barrels of bitumen per day.

- (a) **Identify** one ecological benefit, other than providing habitat, that is provided by forests.
- (b) **Identify** one economic benefit that is provided by forests.
- (c) **Describe** TWO environmental consequences, other than those related to the loss of boreal forest habitat, that result from the extraction of bitumen or the transportation of synthetic oil to customers.
- (d) Assuming the above extraction rate, **calculate** how many days will be needed to extract the recoverable volume of bitumen from the oil sands.
- (e) **Calculate** how many years will be needed to fully extract the recoverable volume of bitumen from the oil sands.
- (f) Monthly production of synthetic crude oil is 30 million barrels. Producing one barrel of synthetic crude oil uses two barrels of heated freshwater. **Calculate** the number of barrels of freshwater needed each year to supply this demand.

ENVIRONMENTAL SCIENCE**SECTION II****Time—1 hour and 30 minutes****4 Questions**

Directions: Answer all four questions, which are weighted equally; the suggested time is about 22 minutes for answering each question. Write all your answers on the pages following the questions in this book. Where calculations are required, clearly show how you arrived at your answer. Where explanation or discussion is required, support your answers with relevant information and/or specific examples.

1. Read the following article from the *Fremont Daily Times* and answer the questions that follow.

Fremont Daily Times**May 1, 2018****GREEN IS THE NEW SCHOOL COLOR AT FREMONT HIGH SCHOOL!**

A group of students from Fremont High School addressed the city council last night and proposed that one of the existing buildings at Fremont High School, which was built in 1970, be renovated to take advantage of recent advances in green technology. Currently the heat for the school is provided by fossil fuel combustion. The students said that the redesigned building would reduce the school's carbon footprint, which is a measure of the amount of carbon dioxide and other carbon compounds released by various human activities. Incorporating specific features that conserve energy and utilize

renewable energy sources can help reduce the carbon footprint.

Councilperson Gail Fassler praised the idea, saying that the project could conserve local water resources, reduce the need for consuming new resources, and act as a “shining beacon” of sustainability for the greater Fremont community. Fassler suggested the project could even incorporate a living green roof as an additional sustainable feature. The council approved the initial site planning request and urged students to report back when the project was under way.

- (a) The students want to reduce the school's carbon footprint.
 - (i) **Define** carbon footprint.
 - (ii) **Identify** one way the school's heating system is likely adding to the school's carbon footprint.
 - (iii) **Describe** one realistic way to reduce the contribution of the heating system to the school's carbon footprint.
- (b) **Identify** TWO environmental benefits of a living green roof, such as that suggested by Councilperson Fassler.
- (c) **Describe** TWO practices the cafeteria's food service could use to decrease the environmental impacts of Fremont High School.
- (d) **Discuss** TWO benefits of using native plants for landscaping at Fremont High School.
- (e) During the renovation, the carpeting must be replaced. **Discuss** one environmental benefit of using flooring made of plant material, such as cork or bamboo, instead of carpet made of synthetic fibers.

ENVIRONMENTAL SCIENCE

SECTION II

Time—90 minutes

4 Questions

Directions: Answer all four questions, which are weighted equally; the suggested time is about 22 minutes for answering each question. Write all your answers on the pages following the questions in this book. Where calculations are required, clearly show how you arrived at your answer. Where explanation or discussion is required, support your answers with relevant information and/or specific examples.

1. Read the following article from the *Fremont Daily Times* and answer the questions that follow.

Fremont Daily Times

Scientists Discuss Threats from Plastic Pollution

In testimony before the United States Senate Committee on Environment and Public Works, Dr. Duke Ewoldsen, an eminent toxicologist, discussed a new water pollutant that threatens aquatic life: microbeads. Ewoldsen noted that while posing a different threat than more conventional water pollutants such as nitrates, phosphates and PCBs, tiny beads of plastic contained in many products, especially cosmetics, now threaten plankton and small fish that ingest the particles because they mistake

them for food. The microbeads cannot be digested and can fill or block the digestive tracts of the fish, leading to starvation. In addition, surfaces of these small spheres can adsorb organic pollutants such as PCBs and dioxin.

When asked about steps to reduce this threat, Ewoldsen noted that the beads are so small that they are not easily removed by wastewater treatment plants and thus often enter aquatic ecosystems in wastewater discharges.

- (a) **Describe** TWO effects that ingesting microbeads has on aquatic organisms.
- (b) Dr. Ewoldsen states that nitrates pose different threats to aquatic ecosystems than microbeads do. **Describe** how nitrate levels can negatively affect water quality in some aquatic ecosystems.
- (c) While wastewater treatment plants are ineffective at removing microbeads, they are very effective at removing large pieces of plastic waste and other pollutants.
 - (i) **Identify** one way large pieces of plastic are removed from wastewater during primary treatment.
 - (ii) Prior to discharge, wastewater is often disinfected. **Identify** one technique commonly used to disinfect wastewater.
 - (iii) Sludge or biosolids produced during the wastewater treatment process can be spread on agricultural fields. **Identify** one advantage and one disadvantage of this practice.
- (d) Coastal ecosystems are threatened by other human activities in addition to wastewater disposal. Mangrove swamps are one such threatened ecosystem.
 - (i) **Provide** one reason why mangrove trees are being removed by humans.
 - (ii) **Identify** one ecosystem service provided by intact mangrove ecosystems.

ENVIRONMENTAL SCIENCE

SECTION II

Time—90 minutes

4 Questions

Directions: Answer all four questions, which are weighted equally; the suggested time is about 22 minutes for answering each question. Write all your answers on the pages following the questions in this book. Where calculations are required, clearly show how you arrived at your answer. Where explanation or discussion is required, support your answers with relevant information and/or specific examples.

1. Read the following article from the *Fremont New Tribune*.

Fremont New Tribune

May 2, 2016

As another winter concludes, biologists are alarmed by the continued spread of white nose syndrome (WNS) in bats. WNS is a fungal disease that is decimating bat populations across eastern North American forests, with mortality rates reaching up to 100 percent at many sites. WNS has been found in at least 25 states in the United States and 5 Canadian provinces.

The fungus (*Pseudogymnoascus destructans*) grows well in cool conditions such as those found in caves and has been observed as white patches on the muzzles, noses, ears, and wings of many cave-dwelling bats. WNS has caused significant population declines for several bat species, including once-numerous species such as the little brown bat (*Myotis lucifugus*).

Little brown bats hunt using echolocation by emitting up to 200 high-frequency calls per second when pursuing their prey. When healthy, the little brown bat can live up to ten years and have one or two offspring (called pups) each year.

"Little brown bats provide tremendous value to the United States economy every year by the essential services they provide to farmers and other people. We need to understand how this deadly disease spreads and attempt to help reduce its impact on the little brown bat and other bat species," said Dr. Duke Serach of the Fremont office of the United States Fish and Wildlife Service. Dr. Serach concluded with, "It may yet be possible to save the little brown bats, but the remaining population will be alarmingly small."

- (a) Diseases can devastate populations; however, most diseases do not drive their host to extinction. **Provide** one explanation for why diseases seldom cause extinction.
- (b) Dr. Serach suggests that even if the impact of WNS on little brown bat populations can be reduced and the extinction of the species avoided, the bat populations are likely to remain alarmingly small.
- (i) **Describe** TWO threats (other than WNS) to the survival of the bat species if the total number of bats becomes very small.
- (ii) If the little brown bat species does not become extinct and can potentially recover, the rate of recovery is likely to be slow. **Discuss** one aspect of bat biology that might slow the recovery of little brown bat populations to pre-WNS numbers.
- (c) Bats are found in ecosystems around the world. **Describe** TWO ways in which other organisms in an ecosystem could be affected by a decline in a bat population.
- (d) The Eastern deciduous forest in which the little brown bats live is an important ecosystem. **Identify** TWO ecosystem services that forests provide, and **explain** how each service benefits human society.
- WNS is an emerging disease in bats. Humans are also subject to emerging diseases, such as Ebola. A recent study suggests that the number of emerging infectious diseases affecting human populations has been steadily increasing in recent decades.
- (e) **Provide** a likely reason for the increase in emerging infectious diseases affecting human populations. Include an explanation for the reason you provided.

2.3 Island Biogeography

Name: _____ Class: _____ Date: _____

Total: 9 marks

KEY WORDS migration 迁徙 • island biogeography 岛屿生物地理学

Objective

Build the skills to answer exam questions on **island biogeography**.

You must be able to:

- explain how **island size** and **distance** affect species number
- apply the theory to habitat fragments
- reason about immigration and extinction

1 Worked examples

Study these first. Each one shows the method for a question type used later — follow the steps and you can do the Practice and Exam-style questions yourself.

■ Island biogeography

The number of species on an island balances **immigration** (new species arriving) against **extinction** (species dying out).

■ Size effect

Larger islands support **more** species — more habitat, larger populations (lower extinction). Small islands hold fewer species.

■ Distance effect

Islands **closer** to a mainland receive **more** immigrants, so they hold more species; **far** islands receive fewer.

■ Applying to habitat fragments

Fragments of habitat (from roads, farms) act like islands. **Large, connected** fragments keep more species than **small, isolated** ones — a key idea for reserve design.

2 Practice

Now apply the methods above.

2.1 Do larger islands hold more or fewer species? [1]

2.2 Do islands closer to the mainland receive more or fewer immigrants? [1]

2.3 The number of species balances immigration against what? [1]

3 Exam-style questions

3.1 An island far from the mainland is expected to have [1]

- **A** more species (more immigration)
 - **B** fewer species (less immigration)
 - **C** no extinction
 - **D** unlimited species
-

3.2 A forest is split into one large fragment and several small ones.

(a) Which fragment will likely keep more species? [1]

(b) Explain using island biogeography. [2]

3.3 Explain why connecting habitat fragments with wildlife corridors helps preserve species. [2]

Solutions

2.1 More species.

2.2 More immigrants.

2.3 Extinction.

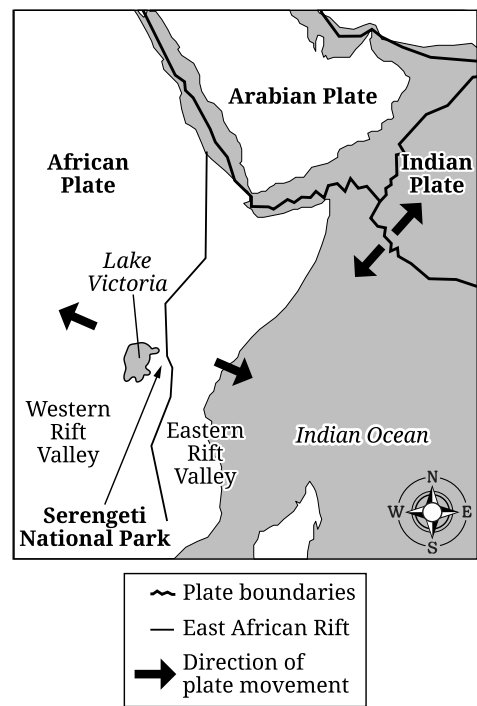
3.1 B — fewer species (less immigration).

3.2 (a) The large fragment. (b) A larger area has more habitat and larger populations (lower extinction), so it keeps more species, like a large island.

3.3 Corridors let species move between fragments, increasing immigration and gene flow and reducing extinction — effectively making the fragments act like one larger habitat.

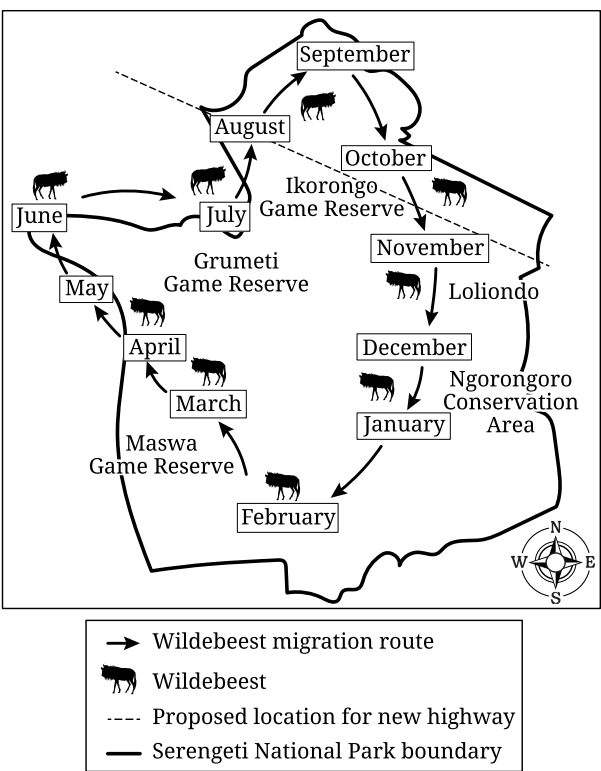
Serengeti National Park is located in Tanzania, Africa. The park is located in a valley along a tectonic plate boundary called the East African Rift. Figure 1 shows the East African Rift and other plate boundaries near the east coast of Africa.

Figure 1. Tectonic Plate Movement near East Coast of Africa



Serengeti National Park contains a variety of tropical habitats but is dominated by wideopen lands that include a variety of grass species with scattered trees and shrubs. Most grass growth occurs after the March through May rainy season. Many of the park’s herbivores, such as wildebeest and zebra, migrate through the park in an annual cycle following the growth of new grass (Figure 2).

Figure 2. Annual Migration of Wildebeest in Serengeti National Park



2. Respond to parts A, B, C, D, E, F, G, H, I, and J.

- A. Based on the information in Figure 1, **identify** the type of plate boundary that runs beneath Serengeti National Park.
- B. Based on the information provided, **identify** the dominant biome within the Serengeti.
- C. Wildebeest give birth to their young when new grasses are growing. Based on the information in Figure 2, **identify** the location in the Serengeti where wildebeest are most likely to give birth.
- D. The Serengeti has two primary types of grasses: long and short. The two grass types provide similar levels of nutrition for animals. Wildebeest primarily consume long grasses, while other herbivores such as gazelle consume the short grasses. These two similar species coexist in Serengeti National Park.

Explain why resource partitioning allows for the coexistence of the wildebeest and the gazelle in the Serengeti.

- E. The Tanzanian government plans to build a highway across the northern portion of the Serengeti, as shown in Figure 2.

Describe one way the planned highway shown in Figure 2 could negatively affect the wildebeest population in the Serengeti.

- F. **Propose** a solution to the negative effect created by the planned highway described in part E.
- G. Many organisms live in grasslands. One weed species, the spotted knapweed, was introduced at one location in North America in the 1890s and is currently found throughout the rangelands of the western United States. The spotted knapweed poses several environmental problems in North America. Farmers often use crop rotation to control populations of pests like the spotted knapweed. A more traditional method of controlling pests involves spraying pesticides.

Describe a characteristic of an invasive species, such as the spotted knapweed, that allows them to outcompete native species.

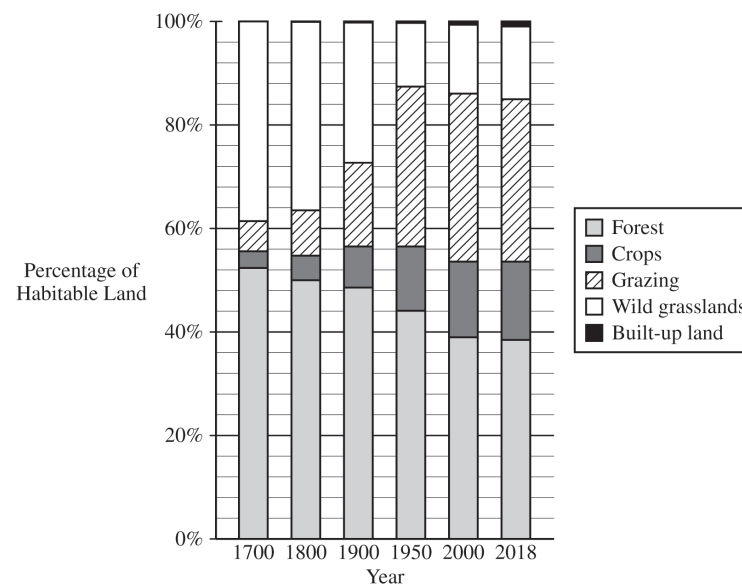
- H. **Justify** the use of crop rotation as an environmental solution by providing an additional advantage, other than controlling pest populations.

- I. **Describe** an environmental problem associated with controlling pest populations with large amounts of pesticide.

- J. **Propose** a solution to controlling pests, other than pesticides or crop rotation.

2. The following graph shows how global uses of habitable land have changed since 1700.

Land Use Changes on Earth, 1700–2018



- (a) Based on the data in the graph, **identify** the year with the highest percentage of forest.
- (b) Based on the data in the graph, **describe** the relationship between the land use changes in the wild grasslands and grazing from 1700 to 1950.
- (c) **Identify** an environmental problem associated with overgrazing by livestock.
- (d) A student hypothesized that the change in the percentage of forest from 1700 to 2018 has decreased atmospheric carbon dioxide concentrations. **Explain** whether the hypothesis is supported or refuted based on the data in the graph.

Urban environments have accounted for an increasing percentage of land use within the last few decades.

- (e) **Describe** a water-related environmental problem associated with urbanization.
- (f) **Describe** a potential response to mitigate the environmental problem identified in part (e).

Farmers who own large sections of cropland notice that bobcats, a medium-sized predatory forest cat, were present many years ago but are now virtually absent in the area. Instead, smaller mammal species now inhabit the area. Over time, the farmers have cleared nearly all of the forest on their property and converted it to farmland.

- (g) **Explain** why there are fewer bobcats present on the farmland now compared to several decades ago.

The small mammal species are considered pests by the farmers. The farmers partner with a conservation group to increase the number of bobcats in the area. As a solution, the conservation group will introduce bobcats onto the few isolated patches of the original forested habitat left in the area. They can introduce only a small number of bobcats in each patch.

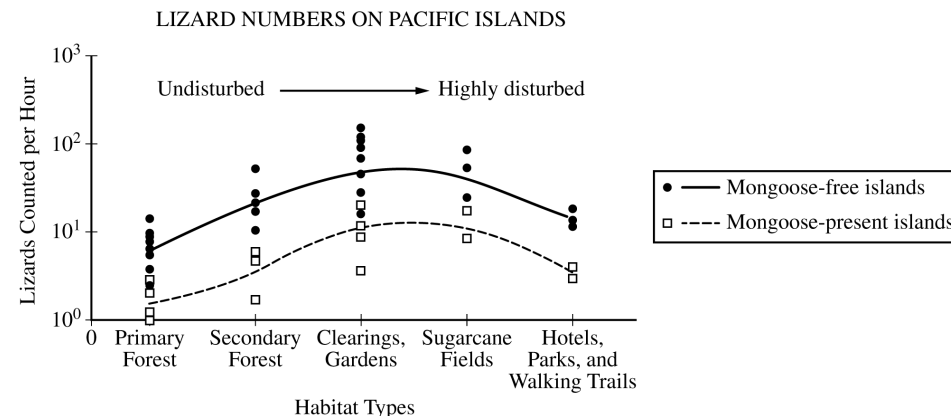
- (h) **Describe** a disadvantage of introducing only a small population of bobcats.

- (i) **Propose** a solution to improve the chances that the bobcat reintroductions will be successful in reestablishing wild populations.

- (j) **Justify** the solution proposed in part (i) by describing an additional advantage, other than reestablishing the bobcat population near the farms.

Begin your response to this question at the top of a new page in the separate Free Response booklet and fill in the appropriate circle at the top of each page to indicate the question number.

2. Biologists collected data on the abundance of lizards on several Pacific islands with and without mongoose populations. The surveys were conducted at different locations on the islands by counting the number of lizards observed per hour and included habitats with both undisturbed areas and anthropogenically disturbed areas.

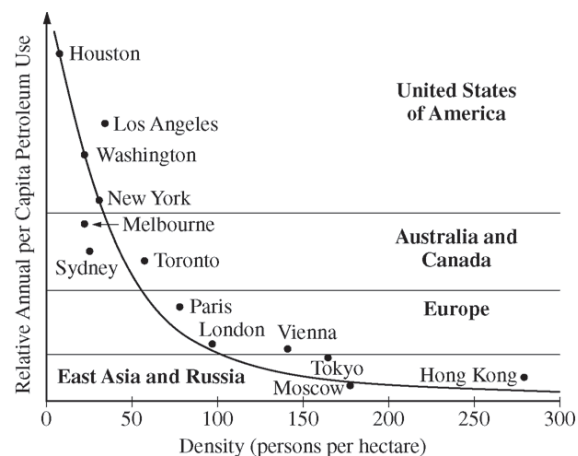


- (a) The graph shows data collected by biologists on lizard numbers on several Pacific islands.
- Based on the data in the graph, **identify** the habitat type with the greatest number of lizards.
 - Based on the data in the graph, **describe** the relationship between the lizard numbers observed on islands with and without mongoose populations.
- Globally, islands vary in size, location, and habitat.
- (b) Based on the theory of island biogeography, **describe** the characteristics of an island with the greatest species diversity.
- (c) Island ecosystems are often threatened by invasive species, such as the mongoose populations studied in the survey.
- Describe** one environmental problem caused by invasive animal species.
 - Invasive species are often pests. **Make a claim** that proposes one way to control pest species.
 - Justify** the solution proposed in (c)(ii) by providing an additional benefit of the solution.
- (d) Islands provide humans with many ecosystem services. However, humans may alter ecosystems when they obtain these services. Large-scale commercial sugarcane farming on the Pacific islands has led to significant ecological damage.
- Identify** a provisioning ecosystem service provided by primary forests.
 - Based on the data in the graph, **explain** how replacing primary forests with sugarcane fields may have affected the number of lizards counted on the mongoose-free Pacific islands.
 - The long-term use of monocultures in commercial sugarcane farming is one cause of the ecological damage. **Describe** one problem associated with monocultures.

One solution to the ecological damage of monocultures is to use a form of crop rotation using legumes.

- (e) **Describe** an advantage of crop rotation using legumes on soil fertility.

4. The term “urban sprawl” describes the expansion of cities into rural areas. This phenomenon has occurred around the world and has had economic, health, and environmental consequences.
- Describe** TWO causes of urban sprawl.
 - Discuss** TWO human health effects associated with urban sprawl.
 - The graph below shows the relationship between population density and petroleum use in selected cities. **Describe** the relationship between population density and petroleum use shown in the graph.



- Smart growth focuses on ways to encourage sustainable urban development. **Describe** TWO steps a municipality could take to encourage smart growth in order to limit urban sprawl.
- Highway systems and urban sprawl often threaten wildlife populations. **Describe** TWO methods to reduce harmful effects on wildlife populations from highways and urban sprawl.
- Urban sprawl often results in the loss of productive agricultural land near cities. **Describe** one practical way to increase food production within urban areas.

STOP

END OF EXAM

AP ENVIRONMENTAL SCIENCE • EXERCISE SHEET

2.4 Ecological Tolerance

Name: _____ Class: _____ Date: _____ Total: 9 marks

KEY WORDS optimal range 最适范围 • range of tolerance 耐受范围 • zones of stress 胁迫区
 • ecological tolerance 生态耐受性

Objective

Build the skills to answer exam questions on **ecological tolerance**.

You must be able to:

- describe a **range of tolerance** 耐受范围 and the optimal range
- read a tolerance curve
- explain how conditions limit where a species lives

1 Worked examples

Study these first. Each one shows the method for a question type used later — follow the steps and you can do the Practice and Exam-style questions yourself.

■ Range of tolerance

Every species survives only within a **range of tolerance** for each condition (temperature, pH, salinity). Within it there is an **optimal range** where the species thrives.

■ The tolerance curve

Plotting performance (or population) against a factor gives a curve: high in the **optimal** middle, lower in the **zones of stress** on either side, and zero beyond the tolerance limits.

■ Limits set distribution

A species cannot live where a factor is outside its tolerance. So temperature or salinity limits **where** a species is found.

■ A worked reading

A fish thrives at 20–25°C (optimal), survives with stress at 15–30°C, and dies outside 10–35°C (tolerance limits).

2 Practice

Now apply the methods above.

2.1 What is a range of tolerance? [1]

2.2 Where on a tolerance curve does a species thrive best? [1]

2.3 What are the regions just inside the tolerance limits called? [1]

3 Exam-style questions

3.1 A species performs best in the [1]

- **A** zone of stress
- **B** optimal range
- **C** area beyond its limits
- **D** coldest conditions

3.2 A plant tolerates soil pH from 5 to 8, with best growth at 6–7.

(a) State its optimal range. [1]

(b) Predict what happens at pH 4, and explain. [2]

3.3 Explain how a species' range of tolerance limits where it can live. [2]

Solutions

2.1 The range of a condition within which a species can survive.

2.2 The optimal range.

2.3 Zones of stress.

3.1 B — the optimal range.

3.2 (a) pH 6–7. (b) pH 4 is below its tolerance limit (5), so the plant cannot survive there.

3.3 A species can only survive where every condition is within its tolerance; where a factor is outside that range, the species is absent, so tolerance limits its geographic distribution.

ENVIRONMENTAL SCIENCE

SECTION II

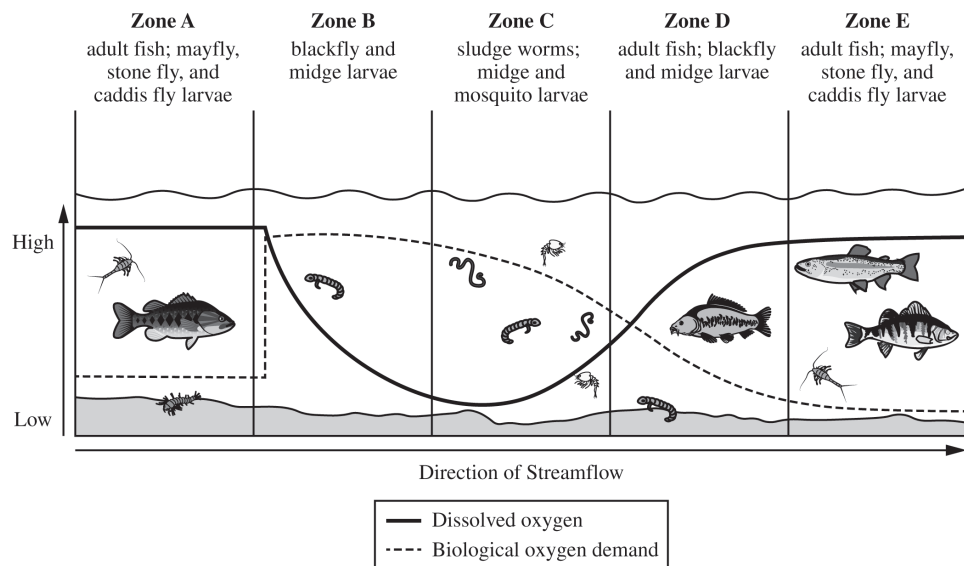
Time—1 hour and 10 minutes

3 Questions

Directions: Answer all three questions, which are weighted equally; the suggested time is about 22 minutes for answering each question. Write all your answers in the Free Response booklet. Where calculations are required, clearly show how you arrived at your answer. Where explanation or discussion is required, support your answers with relevant information and/or specific examples. You may plan your answers in this orange booklet, but no credit will be given for anything written in this booklet. **You will only earn credit for what you write in the separate Free Response booklet.**

1. Researchers are studying the stream ecosystem shown in the following diagram. They have identified five different zones based on the dissolved oxygen levels and biological oxygen demand as the water flows downstream. Biological oxygen demand is the amount of oxygen needed by bacteria and other microorganisms to break down organic material in water. Some of the most common fish and macroinvertebrate species found in each zone are listed in the diagram.

Dissolved Oxygen and Biological Oxygen Demand in a Stream Ecosystem



- (a) Based on the information in the diagram, **identify** the zone with the lowest level of dissolved oxygen..
- (b) Based on the information in the diagram, **describe** the relationship between biological oxygen demand and dissolved oxygen.
- (c) Based on the information in the diagram, **identify** the zone where there is most likely point-source water pollution discharged into the stream.

The research team is interested in investigating the relationship between dissolved oxygen levels and macroinvertebrate species richness in the stream. Researchers counted the number of macroinvertebrate species in zones A, B, and C during the summer months. The researchers selected zone A to serve as the control in the investigation.

- (d) **Identify** the dependent variable in the researchers' investigation.
- (e) **Identify** a testable hypothesis for the researchers' investigation.
- (f) **Describe** the reason the researchers selected zone A to serve as the control in the investigation.

The researchers decided to repeat their data collection during the winter months.

- (g) **Explain** how the modification to collect data in the winter months could alter the results of the investigation.

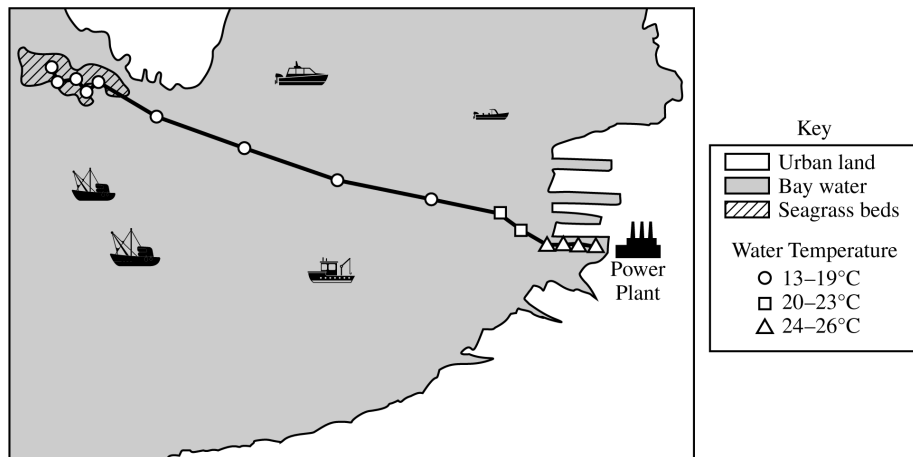
Stream ecosystems are affected by point-source organic pollution in a variety of ways.

- (h) **Describe** the effect that the introduction of raw sewage into the stream could have on the population of bacteria in the stream.
- (i) **Identify** an abiotic factor other than dissolved oxygen and organic pollution that could also influence the population size of bacteria in the stream.
- (j) **Explain** how persistent organic pollutants can affect higher trophic levels in an aquatic food web.

Begin your response to this question at the top of a new page in the separate Free Response booklet and fill in the appropriate circle at the top of each page to indicate the question number.

2. The diagram shows the movement of one adult manatee over a 12-hour period across an active shipping channel during the winter. Manatees are large, aquatic, herbivorous mammals that primarily eat seagrass. Manatees can travel several miles to graze. Manatees mature slowly, have low biotic potential, and inhabit warm coastal waters. They cannot survive in water below 20°C for extended periods of time.

Satellite Track and Water Temperature Log of the Movement of One Adult Manatee Over a 12-Hour Period



- (a) Based on the information in the diagram, **identify** the temperature range of the water through which the majority of the adult manatee's daily movement occurs.
- (b) Large groups of manatees are often observed in shallow waters near the waste water released by the electrical power plant during the winter. Based on the information in the diagram, **identify** a characteristic of the power plant waste water that would attract the manatees.
- (c) Based on the information in the diagram, **describe** a potential negative impact of the waste water released by the power plant on other aquatic species.
- (d) Seagrass beds have declined significantly over the last several years. In 2021 manatee mortality was three times higher than the previous five-year average.
- Describe** a characteristic of the manatees that increases their vulnerability to the recent decline of seagrasses.
 - Describe** the change in energy flow through the trophic levels that occurs when there is a significant loss of seagrasses.

- (e) Research has shown increased nutrient and sediment runoff can cause seagrass beds to decline.
- Propose** a solution to reduce nutrient or sediment pollution in an estuary that is surrounded by urban development.
 - Justify** the solution proposed in part (e)(i) by providing an additional advantage of reduced nutrients in an estuary, other than one related to manatees.

Urban areas have a heavy dependence on automobiles and often experience photochemical smog.

- (f) **Describe** how summertime weather conditions can increase the frequency of photochemical smog.
- (g) **Identify** one ecological problem that results from exposure to photochemical smog.

A potential solution to reduce photochemical smog in urban areas with high automobile traffic is to replace gasoline-powered cars with cars powered by hydrogen fuel cells.

- (h) **Describe** a potential disadvantage of using hydrogen fuel cells to power automobiles.

Begin your response to this question at the top of a new page in the separate Free Response booklet and fill in the appropriate circle at the top of each page to indicate the question number.

2.5 Natural Disruptions to Ecosystems

Name: _____ Class: _____ Date: _____ **Total: 11 marks**

KEY WORDS periodic 周期性 • random 随机 • episodic 偶发性 • biodiversity 生物多样性
• ecological succession 生态演替

Objective

Build the skills to answer exam questions on **natural disruptions to ecosystems**.

You must be able to:

- give examples of natural disruptions (fire, flood, volcano, drought)
- distinguish periodic, episodic, and random events
- explain both harmful and beneficial effects

1 Worked examples

Study these first. Each one shows the method for a question type used later — follow the steps and you can do the Practice and Exam-style questions yourself.

■ Types of natural disruption

- **Periodic** — regular, predictable (seasonal flooding).
- **Episodic** — occasional, irregular (a fire every few decades).
- **Random** — unpredictable (a volcanic eruption).

■ Harmful and beneficial

Disruptions can harm an ecosystem (killing organisms) but also **benefit** it: fire clears dead material and releases nutrients; floods deposit fertile sediment.

■ A worked example

A wildfire kills many plants (harm) but also clears the canopy, returns nutrients to the soil, and triggers some seeds to germinate (benefit) — so some ecosystems depend on periodic fire.

■ Recovery

Ecosystems often recover through **succession** after a disruption. High biodiversity speeds recovery.

2 Practice

Now apply the methods above.

2.1 Give two examples of natural disruptions. [2]

2.2 Classify seasonal flooding (periodic, episodic, or random). [1]

2.3 State one beneficial effect of a wildfire. [1]

3 Exam-style questions

3.1 A volcanic eruption is an example of a [1]

- **A** periodic disruption
- **B** random disruption
- **C** human disruption
- **D** gradual change

3.2 A forest experiences a wildfire.

(a) State one harmful and one beneficial effect. [2]

(b) Explain why some ecosystems depend on periodic fire. [2]

3.3 Explain how an ecosystem recovers after a natural disruption.

[2]

Solutions

2.1 Any two: fire, flood, volcanic eruption, drought, storm.

2.2 Periodic.

2.3 Any one: clears dead material, releases nutrients, triggers germination.

3.1 B — a random disruption.

3.2 (a) Harmful: kills plants/animals; beneficial: releases nutrients / clears the canopy.

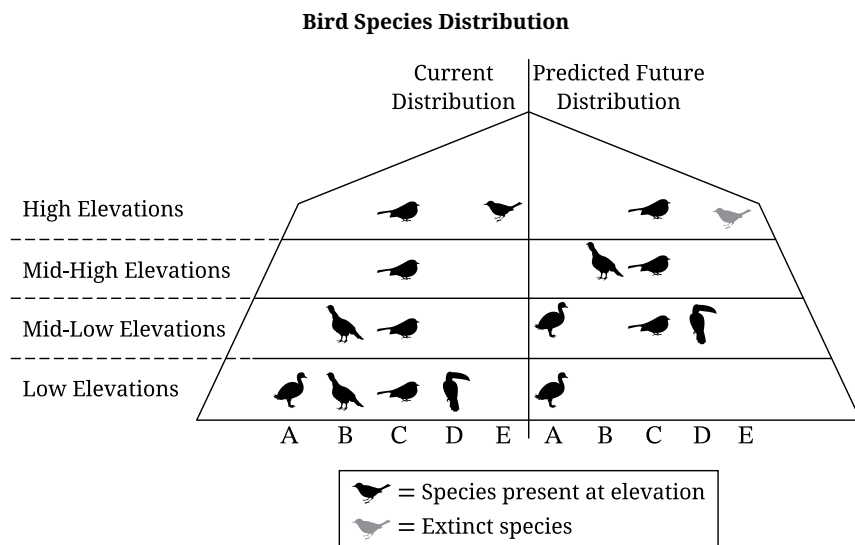
(b) Some plants need fire to release seeds or clear competitors, and periodic fire recycles nutrients, so those ecosystems are adapted to it.

3.3 Through ecological succession — pioneer species recolonize, and the community rebuilds over time; high biodiversity speeds this recovery.

The following information applies to parts A, B, C, D, and E.

Climate change can affect both terrestrial and marine organisms. Researchers studying the effect of climate change on bird distribution mapped elevation zones at which five bird species lived within a tropical mountain range. Birds are distributed in part according to climate-related adaptations. Researchers modeled where the birds would most likely live in the future based on climate change predictions.

The results of this study are shown in the following diagram. Each unique shape in the diagram represents a different bird species, labeled A through E. Current distribution is shown on the left side of the figure, and predicted future distribution is shown on the right.

**The following information applies to parts F, G, and H.**

Some organisms such as birds can move in response to environmental changes, while other organisms such as corals cannot. Researchers studying the effect of climate change on marine organisms conducted two experiments involving photosynthetic algae that have a symbiotic relationship with corals.

In Experiment 1, the researchers placed photosynthetic algal colonies living in corals in three different saltwater tanks. The temperature of Tank 1 was set to 27°C, the average temperature at which most corals live. Water circulation in each tank mimicked natural ocean currents. After 30 days, the researchers counted the number of bleached corals. The tank setups are shown in the following list.

- Tank 1: 27°C and no sediment
- Tank 2: 32°C and no sediment
- Tank 3: 37°C and no sediment

In Experiment 2, the researchers used the same photosynthetic algae living in corals but modified the conditions of the tanks as shown in the following list. Water circulation kept the sediment in the tanks suspended. After 30 days, the researchers counted the number of bleached corals.

- Tank 1: 27°C and no sediment
- Tank 2: 27°C and moderate sediment
- Tank 3: 27°C and high sediment

1. Respond to parts A, B, C, D, E, F, G, H, I, and J.**Part A**

Based on the information in the diagram, **identify** the elevation zone that has the highest species richness for the current distribution.

Part B

Describe a climate condition at high elevations that is different than it is at low elevations.

Part C

A predator at low elevations currently feeds on Species C and D. Based on the information in the diagram, **describe** what could happen to the predator species in the future in response to the predicted changes in the prey community.

Part D

Species C is considered a generalist, while Species E is considered a specialist. **Explain** why Species C and E are predicted to respond differently to climate change.

Part E

Based on the information in the diagram, **explain** why the bird community at low elevations in the future would be less likely to recover from natural disruptions than the current low-elevation bird community.

Part F

Identify the independent variable in Experiment 1.

Part G

Identify a likely scientific question for Experiment 1.

Part H

In Experiment 2 the temperature of the tanks was held constant, while the amount of sediment was varied. **Explain** how this modification could affect the results of this experiment.

Part I

Changes in climate also affect Arctic ecosystems. One impact of climate change is the loss of ice and snow in polar regions. **Describe** a positive feedback loop that results from the loss of ice and snow in polar regions.

Part J

Describe one problem that Arctic species, such as polar bears or ringed seals, face because of warming in polar regions.

Chickadees are a K-selected species of bird that eat insects and spiders. Spiders consume insects, and many insects consume plants as shown in the following food chain.

Plants → Insects → Spiders

Chickadee habitat includes forests and residential yards. Residential yards often contain nonnative plants, which do not naturally exist in an area, but were introduced by humans.

Scientists measured the average number of insects and spiders as related to the percentage of nonnative plants (Figure 1). The scientists also measured the chickadees' average population growth rate (Figure 2) to determine the impact of nonnative plants on chickadee populations.

Figure 1. Percentage of Nonnative Plants and Average Number of Individual Spiders and Insects

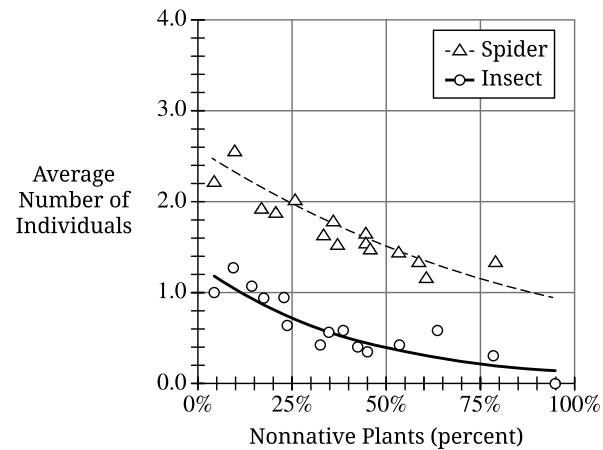
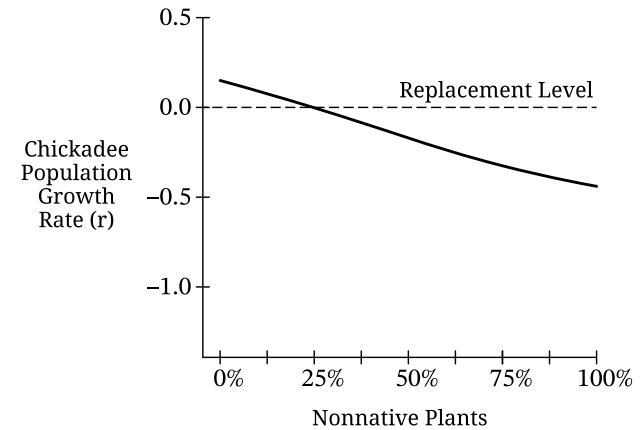


Figure 2. Chickadee Population Average Growth Rate and Percentage of Nonnative



1. Respond to parts A, B, C, D, E, F, G, and H, and all subparts.

- A. **Describe** one reproductive strategy used by a K-selected species such as the chickadee.
- B. Based on the information provided, **explain** how a decrease in spider populations could affect a lower trophic level.
- C. Based on the data in Figure 1, **identify** the number of spiders per sample at 25% nonnative plants.
- D. Based on the data in Figure 1, **describe** the trend in the number of insects per sample in relation to the percentage of nonnative plants.
- E. Scientists hypothesized that the population of chickadees would be stable or growing with fewer than 25% nonnative plants. **Describe** one way that the data in Figure 2 support this hypothesis.
- F. Insect biodiversity is important to maintain ecosystem health. A group of students was interested in learning about factors that affect ant biodiversity. They located two study sites near their school: a frequently mowed urban park and an unmowed grassland. The students used traps designed to collect ants. They loaded 10 of these traps with the same food and placed them randomly at different locations within each site. Students collected the traps after 24 hours and counted the number of different ant species in each trap to determine species richness.
- Identify** a likely scientific question for the students' investigation of ant diversity.
 - Identify** the dependent variable in the students' investigation.
- G. The data from the student investigation of ant diversity are shown in the following table. An "X" in the table indicates that the species was present at that site.

Ant Species Present in an Urban Park and Unmowed Grassland

Site	Species A	Species B	Species C	Species D	Species E	Species F
Urban park	X			X	X	
Grassland	X	X	X	X		X

- Explain** why the ant community of the unmowed grassland would be more likely to recover from a disturbance, such as a flood or fire, than the ant community in the mowed urban park would.
 - Explain** how the results of the investigation could have been altered if students had measured ant biodiversity at a paved playground rather than in the grassland.
- H. Habitat fragmentation has impacts on a variety of species. Paved roads can lead to habitat fragmentation.
- Describe** one effect that a paved road in a forest can have on animal species such as deer or bears.

There is a natural climate phenomenon that occurs in the equatorial Pacific Ocean because of periodic fluctuations in sea surface conditions and atmospheric circulation. This phenomenon happens every few years, resulting in shifts in temperature and precipitation in many parts of the world.

Figure 1 shows temperature and precipitation patterns associated with one phase of this phenomenon in the equatorial Pacific Ocean. Figure 2 shows the associated temperature and precipitation patterns that occur over North America.

Figure 1. Effects of Changes in Sea Surface Conditions in Equatorial Pacific Ocean

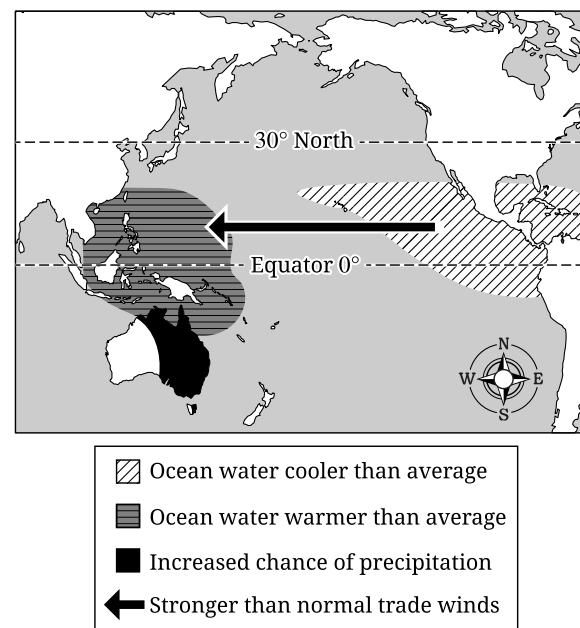
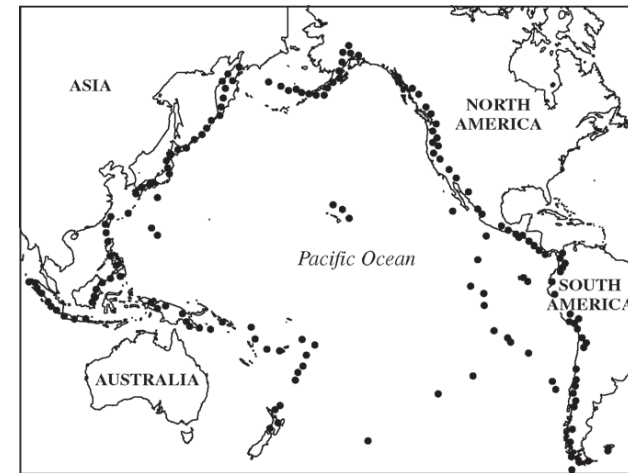
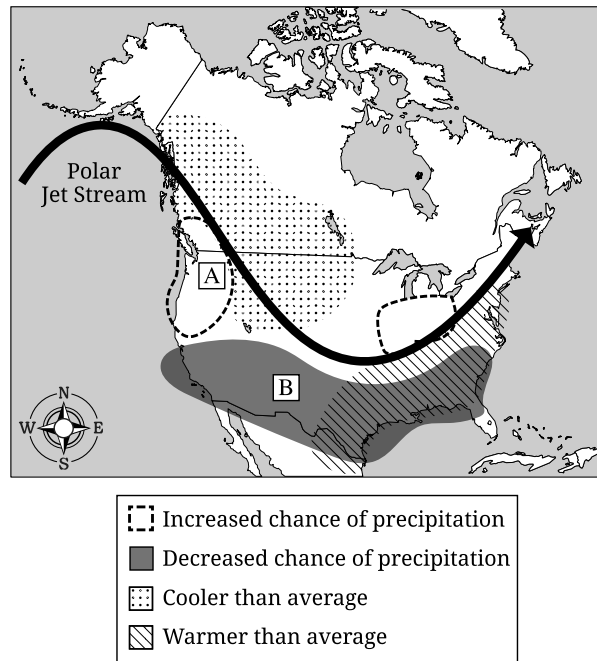


Figure 2. Polar Jet Stream and Climate Conditions in North America



3. Plate-tectonic theory states that the Earth's lithosphere is broken into very slowly moving pieces or plates. Plate movements over vast stretches of time have led to the current orientation of our continents and oceans. Individual events along plate boundaries, such as earthquakes and volcanic eruptions, pose periodic threats to human activity and ecosystems. The "Ring of Fire" is a term that describes the location of increased seismic and volcanic activity around the margins of the Pacific Ocean basin. On the map above, each dot represents a volcano or an earthquake.
- (a) Japan, Indonesia, and the Philippines are examples of volcanic island chains that have formed along subduction zones between plates in the western Pacific.
 - (i) **Describe** what happens when two tectonic plates collide along a subduction zone.
 - (ii) **Explain** how subduction leads to volcanic activity.
 - (b) Although the landscape following a volcanic eruption may appear unable to support ecological communities, over time the area can be transformed through succession.
 - (i) What is primary succession?
 - (ii) **Explain** how primary succession can lead to soil formation on a newly formed volcanic landscape.
 - (c) In addition to volcanic activity, highly destructive tsunamis are generated along Pacific Plate subduction zones.
 - (i) **Explain** how a tsunami is generated along a subduction zone.
 - (ii) **Describe** one negative ecological impact that tsunamis have on coastal environments.
 - (d) Southern California experiences periodic devastating earthquakes along the San Andreas Fault, which is a transform boundary located along the eastern edge of the Pacific Plate.
 - (i) **Describe** what happens to the tectonic plates along a transform boundary at the moment when an earthquake occurs.
 - (ii) **Describe** what happens to the tectonic plates along a transform boundary during the time between earthquakes.

2.6 Adaptations

Name: _____ Class: _____ Date: _____ **Total: 12 marks**

KEY WORDS adaptation 适应 • structural 结构 • behavioral 行为 • physiological 生理
• natural selection 自然选择

Objective

Build the skills to answer exam questions on **adaptations**.

You must be able to:

- distinguish **structural** 结构, **physiological** 生理, and **behavioral** 行为 adaptations
- explain how adaptations arise by **natural selection**
- link an adaptation to survival in an environment

1 Worked examples

Study these first. Each one shows the method for a question type used later — follow the steps and you can do the Practice and Exam-style questions yourself.

■ Types of adaptation

- **Structural** — a physical feature (thick fur, sharp claws).
- **Physiological** — an internal process (venom, water conservation).
- **Behavioral** — an action (migration, hibernation).

■ Adaptations arise by selection

Adaptations are heritable traits that improve survival/reproduction. They spread through a population by **natural selection** over generations, matching the species to its environment.

■ A worked classification

A camel's hump (fat store) is **structural**; its ability to go without water is **physiological**; a desert lizard being active at night is **behavioral**.

■ Adaptation and environment

Each adaptation suits a specific challenge — cold, drought, predators — so an organism is well matched to where it lives.

2 Practice

Now apply the methods above.

2.1 Name the three types of adaptation. [3]

2.2 Classify thick fur on an arctic fox. [1]

2.3 How do adaptations spread through a population? [1]

3 Exam-style questions

3.1 Hibernating through winter is a [1]

- **A** structural adaptation
- **B** physiological adaptation
- **C** behavioral adaptation
- **D** learned habit only

3.2 A desert plant has a thick waxy coating and stores water in its stem.

(a) Classify each of these two features. [2]

(b) Explain how these adaptations help it survive. [2]

3.3 Explain how a beneficial adaptation becomes common in a population over time. [2]

Solutions

2.1 Structural, physiological, behavioral.

2.2 Structural.

2.3 By natural selection over generations.

3.1 C — a behavioral adaptation.

3.2 (a) Waxy coating = structural; storing water = physiological (or structural stem). (b) The waxy coating reduces water loss and the stored water lets the plant survive drought, so it survives in a dry desert.

3.3 Individuals with the adaptation survive and reproduce more, passing the trait to offspring; over generations it becomes common in the population.

3. The Rocky Mountains, the headwaters for the Colorado River, have experienced a severe drought for many of the past twenty years. States and cities downstream that depend on the river water have had to find solutions to the reduced water flow.

One city located downstream from the Rocky Mountains is Las Vegas, Nevada. In Las Vegas, one solution to reduce the amount of water used for irrigation is to remove landscaping and lawns that use grasses not native to the local area and replace them with desert-tolerant landscaping.

- (a) **Identify** a typical type of plant that would be used in desert-tolerant landscaping.
- (b) **Justify** the removal of landscaping and lawns that use grasses not native to the local area by describing an additional advantage, other than reducing the amount of water needed for irrigation.

Warmer seasonal temperatures in the Rocky Mountains have led to earlier mountain snowmelt and an increased risk of forest fires as soil and vegetation dry out.

- (c) **Describe** how a prescribed burn would reduce the severity and spread of forest fires.
- (d) **Describe** a disadvantage of a prescribed burn in a forested ecosystem.

Lake Powell is a large reservoir on the Colorado River. Lake Powell is formed by a dam with a hydroelectric power plant. At full capacity or full pool, Lake Powell contains 25.16 million acre-feet (maf) of water. Currently, Lake Powell is at 36% full capacity.

- (e) **Calculate** the number of million acre-feet (maf) of water currently in Lake Powell. **Show** your work.

In 2021, after years of drought, Lake Powell held 7.9 million acre-feet (maf) of water. One million acre-feet is equivalent to 3.26×10^{11} gallons.

- (f) The watershed of the Upper Colorado River contributes an average of 9.60 maf of water to Lake Powell annually. The melted mountain snow found in the watershed contributes 50% of the average river flow into Lake Powell. In 2021, the river flow was 36% of the annual average. Assuming that all resources to that flow contributed the same proportions as in prior years, **calculate** the amount of water (in million acre-feet) that was contributed by the melted mountain snow in 2021. **Show** your work.

- (g) The average household in the United States consumes 5.0×10^4 gallons of water in a year. **Calculate** the number of households that could be supported for one year by the average flow of 9.60 maf of water into Lake Powell. **Show** your work.

Begin your response to this question at the top of a new page in the separate Free Response booklet and fill in the appropriate circle at the top of each page to indicate the question number.

STOP

END OF EXAM

ENVIRONMENTAL SCIENCE

SECTION II

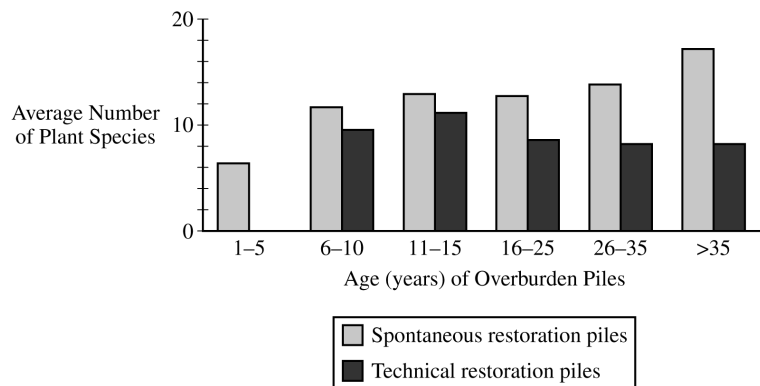
Time—1 hour and 10 minutes

3 Questions

Directions: Answer all three questions, which are weighted equally; the suggested time is about 22 minutes for answering each question. Write all your answers in the Free Response booklet. Where calculations are required, clearly show how you arrived at your answer. Where explanation or discussion is required, support your answers with relevant information and/or specific examples. You may plan your answers in this orange booklet, but no credit will be given for anything written in this booklet. **You will only earn credit for what you write in the separate Free Response booklet.**

1. Two restoration methods designed to reclaim the overburden piles removed from open pit coal mines in temperate forests of eastern Europe were studied over several years. The first method was spontaneous restoration, where the soil and rock were dumped in noncompacted, random piles and not replanted with vegetation. The second method was technical restoration, where the land was leveled by heavy machinery, organic material was added, and eight plant species were added. Technical restoration started 5 years after the piles were formed, so no bar is included in the 1–5 year range in the graph.

Number of Plant Species in Spontaneous and Technically Restored Overburden Piles over Time



- (a) Based on the data in the graph, **identify** the average number of species found in technically restored piles 16–25 years after restoration started.
- (b) Based on the data in the graph, **describe** the relationship between the average number of species and the age of the spontaneous restoration piles.

Scientists hypothesized that after 35 years, the number of animal species in the spontaneously restored piles would be higher than the number of animal species in the technically restored piles.

- (c) Using the data in the graph, **make a claim** that supports or refutes the hypothesis that the number of animal species in the spontaneously restored piles would be higher than the number of animal species in the technically restored piles.
- (d) **Describe** a characteristic of a plant species that would have been present in the spontaneous restoration piles from years 1 to 5.
- (e) **Explain** how the return of plant life would have been altered in the spontaneous piles if the mining had taken place in the tundra rather than in temperate forests.

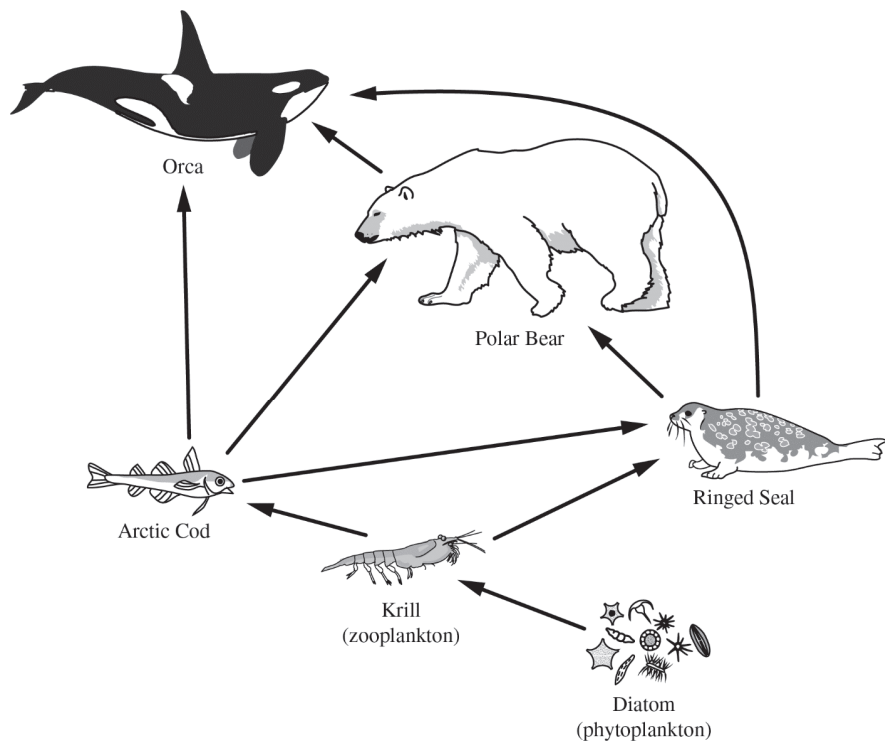
Limiting runoff on disturbed land improves soil and water quality. To model water runoff, students set up three large plastic trays and filled each tray with loam soil to 1 centimeter below the edge. Loam soil is a balance of sand, silt, and clay soil. One tray was seeded with wheatgrass and grown for 30 days, one tray was covered with small wood chips, and one tray was soil only. Five hundred milliliters of water was sprinkled evenly onto the soil surface of each tray. All three trays were placed on a slight slope, and water that ran off the surface was collected. The results are shown in the following table.

Tray	Water Collected (mL)	Water Appearance
Wheatgrass grown in soil; no small wood chips	190	Clear
Small wood chips covered soil; no wheatgrass	300	Transparent; light brown
Soil only; no wheatgrass or small wood chips	360	Cloudy; dark brown

- (f) **Identify** the scientific question for the investigation.
- (g) **Identify** a dependent variable in the experiment.
- (h) **Explain** how the results of the experiment would likely have been altered if the soil had contained a higher percentage of sand, which has the largest particle size of the components of loam.
- Runoff from mining waste can also affect water quality.
- (i) **Describe** one ecological impact that could result from the drainage from mine waste into nearby waterways.
- (j) **Describe** one strategy to reduce the drainage from mine waste into waterways downstream from mines.

Begin your response to this question at the top of a new page in the separate Free Response booklet and fill in the appropriate circle at the top of each page to indicate the question number.

3. An Arctic food web includes the following organisms.



Note: Figures not drawn to scale.

(a) Refer to the food web above to complete the following table.

	Organism from Arctic food web
(i) Identify a primary producer	
(ii) Identify a primary consumer	
(iii) Identify a secondary consumer	

(b) Other than showing which organisms are consumed by other organisms, **describe** what is indicated by the direction of the arrows in the diagram.

As the amount of sea ice has decreased, larger expanses of the Arctic Ocean are now completely free of sea ice for several weeks each summer. Ringed seals, the preferred prey of polar bears, come to holes in the sea ice to breathe.

- (c) **Describe** how the change in sea ice habitat is affecting polar bears' ability to hunt and feed.
- (d) **Explain** how melting sea ice leads to a feedback loop that increases Arctic warming.
- (e) Many species, including some whales and birds, will travel thousands of kilometers during annual migrations.
 - (i) **Provide** one reason a species may migrate a long distance.
 - (ii) The North Atlantic right whale migrates between subtropical and polar waters annually. Nearly 50 percent of right whale deaths are due to human activities. **Describe** one commercial activity, other than whaling, that may result in the death of right whales.
 - (iii) **Describe** one strategy that could reasonably be implemented to decrease right whale deaths caused by the commercial activity you described in part (ii).

2.7 Ecological Succession

Name: _____ Class: _____ Date: _____

Total: 10 marks

KEY WORDS primary 初级演替 • ecological succession 生态演替 • lichens 地衣
• pioneer species 先锋物种 • secondary succession 次级演替

Objective

Build the skills to answer exam questions on **ecological succession**.

You must be able to:

- distinguish **primary** 初级演替 and **secondary succession** 次级演替
- describe **pioneer species** 先锋物种 and the **climax community** 顶极群落
- order the stages of succession

1 Worked examples

Study these first. Each one shows the method for a question type used later — follow the steps and you can do the Practice and Exam-style questions yourself.

■ Primary vs secondary succession

- **Primary succession** — begins on **bare rock** with no soil (after a volcano or glacier retreat); very slow.
- **Secondary succession** — begins where soil **already exists** (after a fire or abandoned farm); much faster.

■ Pioneer species

The first colonizers are **pioneer species** (lichens, mosses in primary; fast-growing weeds/grasses in secondary). They begin building/enriching soil.

■ The sequence

Pioneers → grasses → shrubs → fast trees → slow trees, ending in a stable **climax community** that persists unless disturbed.

■ A worked ordering

After a forest fire (soil remains): grasses → shrubs → pine trees → oak forest (climax). This is **secondary** succession.

2 Practice

Now apply the methods above.

2.1 What is the main difference between primary and secondary succession? [1]

2.2 What are pioneer species? [1]

2.3 What is a climax community? [1]

3 Exam-style questions

3.1 Succession that begins on bare rock with no soil is [1]

- **A** primary succession
- **B** secondary succession
- **C** a climax community
- **D** eutrophication

3.2 A farm field is abandoned and slowly becomes a forest.

(a) State whether this is primary or secondary succession, with a reason. [2]

(b) Order the stages: shrubs, grasses, mature forest, weeds. [2]

3.3 Explain why secondary succession is faster than primary succession. [2]

Solutions

- 2.1 Primary starts on bare rock with no soil; secondary starts where soil already exists.
- 2.2 The first species to colonize a bare area.
- 2.3 A stable, mature community that persists until disturbed.
- 3.1 **A** — primary succession.
- 3.2 (a) Secondary — the soil already exists (the field was farmed). (b) weeds → grasses → shrubs → mature forest.
- 3.3 Secondary succession already has soil (and often seeds/roots), so plants can establish immediately, while primary succession must first form soil from bare rock, which takes a long time.

There is a natural climate phenomenon that occurs in the equatorial Pacific Ocean because of periodic fluctuations in sea surface conditions and atmospheric circulation. This phenomenon happens every few years, resulting in shifts in temperature and precipitation in many parts of the world.

Figure 1 shows temperature and precipitation patterns associated with one phase of this phenomenon in the equatorial Pacific Ocean. Figure 2 shows the associated temperature and precipitation patterns that occur over North America.

Figure 1. Effects of Changes in Sea Surface Conditions in Equatorial Pacific Ocean

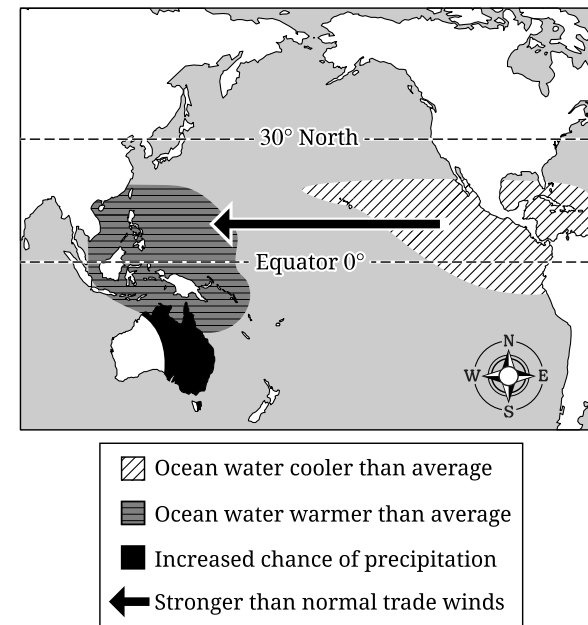
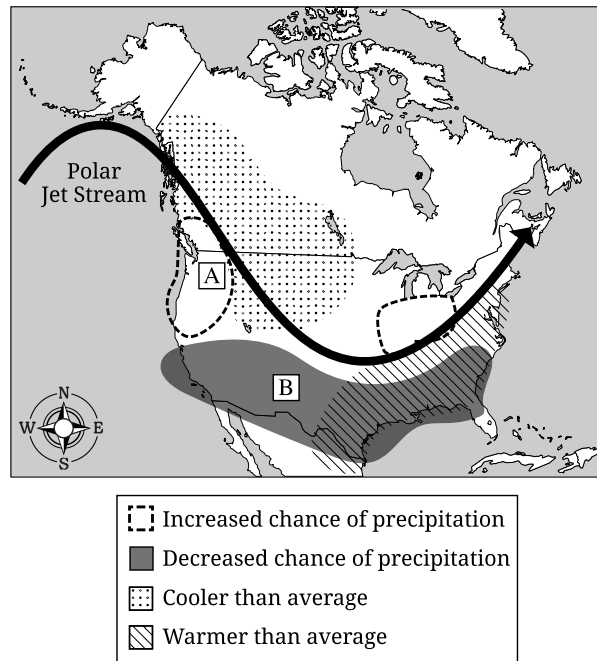


Figure 2. Polar Jet Stream and Climate Conditions in North America

2. Respond to parts A, B, C, D, E, F, G, H, I, and J.

- A. Identify** the sea surface condition for the eastern equatorial area of the Pacific Ocean illustrated in Figure 1.
- B.** Based on the information in Figure 1, **identify** the climate phenomenon associated with the sea surface conditions shown in the equatorial area of the Pacific Ocean.
- C.** Based on the information in Figure 2, **describe** a difference in climate patterns between the regions A and B.
- D.** Increases in regional precipitation can lead to increased flooding in certain locations. **Describe** one reason why there is an increased risk of flooding in urban areas during extended periods of precipitation.
- E. Propose** a realistic solution a city could implement to decrease the risk of flooding in urban areas.
- F. Justify** the solution proposed in part E by providing an additional advantage other than a reduction in the risk of flooding.
- G.** Terrestrial biomes are primarily determined by temperature and precipitation patterns. **Describe** one difference between the climate of a temperate seasonal forest and that of a savanna.
- H.** Droughts are one environmental problem that can affect the frequency and severity of forest fires. **Identify** the ecological process that occurs following a forest fire that leaves the soil intact.
- I. Describe** one way burning forests contribute to atmospheric pollution.
- J. Describe** one sustainable forestry practice that could be used to reduce the occurrence or severity of forest fires.

ENVIRONMENTAL SCIENCE

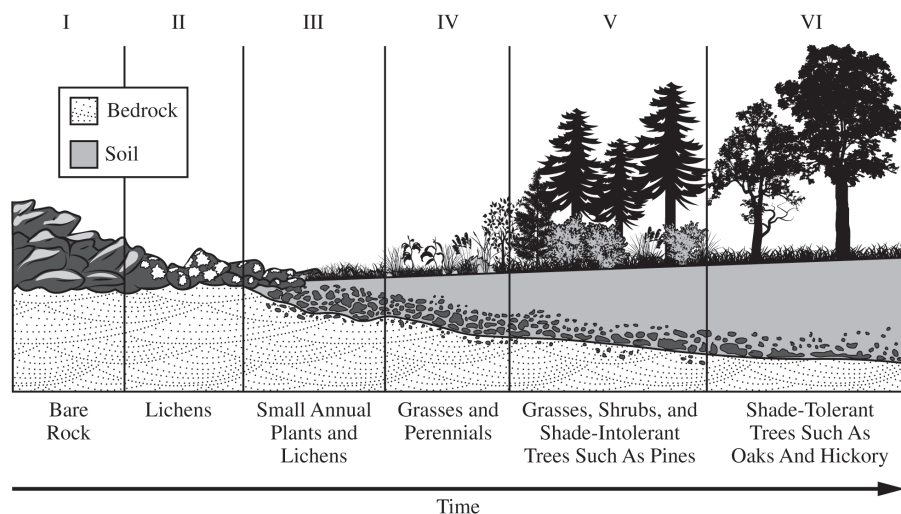
SECTION II

Time—1 hour and 10 minutes

3 Questions

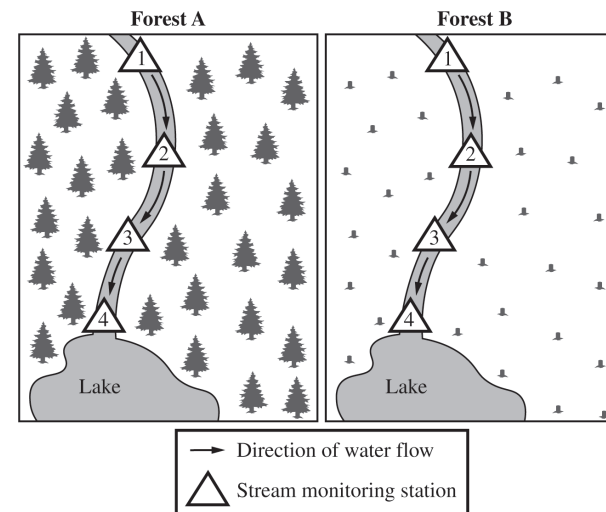
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1. The following diagram shows how an area changed over time. The dominant vegetation in each stage is labeled in the diagram. Each roman numeral represents a stage in the ecological process.



- Identify** the ecological change over time illustrated in the diagram.
- Identify** the stage in which pioneer species first appear.
- Describe** how soil forms from stage II to stage III.
- Identify** a cultural ecosystem service that may be provided by a mature forest.

Researchers are interested in investigating the effect of the removal of trees on the water quality of nearby waterways. To conduct their experiment, the researchers locate two identical forest watersheds, both with a river running through them. Forest A is an intact forest and forest B is a clear-cut forest. Four stream monitoring stations are set up in each forest study area. Each station monitors a variety of water quality indicators, including water temperature, at various locations along the river. The experimental setup is shown in the following diagrams. The arrows shown in the rivers represent the direction of water flow. The triangles in the river show the location of the stream monitoring stations.



- Identify** a testable hypothesis being investigated by the researchers.
- Identify** the independent variable in the experiment.
- Describe** the purpose of forest A in the experiment.
- Explain** why the water temperature might change because of clear-cutting trees in forest B.

After the experiment was completed, land developers constructed a golf course in the clear-cut area of forest B. To prepare the land, developers removed any remaining stumps and newly grown trees and began planting and fertilizing new grass. The researchers are interested in the effect the golf course may have on the water quality of the river. To monitor the river in forest B, the researchers repeated the experiment once the golf course had been constructed.

- Explain** why an indicator of water quality other than temperature could be altered by the golf course in forest B.
- Explain** how the aquatic organisms living in the lake illustrated in the diagram of forest B are likely to be affected by the new golf course.

Begin your response to this question at the top of a new page in the separate Free Response booklet and fill in the appropriate circle at the top of each page to indicate the question number.

ENVIRONMENTAL SCIENCE

SECTION II

Time—1 hour and 10 minutes

3 Questions

Directions: Answer all three questions, which are weighted equally; the suggested time is about 22 minutes for answering each question. Write all your answers in the Free Response booklet. Where calculations are required, clearly show how you arrived at your answer. Where explanation or discussion is required, support your answers with relevant information and/or specific examples. You may plan your answers in this orange booklet, but no credit will be given for anything written in this booklet. **You will only earn credit for what you write in the separate Free Response booklet.**

1. Researchers interested in sustainability developed three new varieties of genetically modified green beans designed to produce higher yields in arid regions. Four plots (A–D) were set up on a floodplain of a river to grow beans. Plots A, B, and C were each planted with seeds of different types of genetically modified strains of green beans. Plot D was planted with seeds of unmodified green beans. Each plot was given equal amounts of fertilizer, which contains phosphorus and nitrogen, and water and was irrigated using spray irrigation for one hour per day. Throughout the growing season, researchers measured the amount of green beans harvested within each plot. The plots with genetically modified beans had higher crop yields than the plot with unmodified beans.

- (a) **Identify** the control group in this experiment.
- (b) **Identify** the scientific question for the investigation.
- (c) Researchers repeated the experiment by modifying the length of time for the spray irrigation to 20 minutes per day. **Explain** how the results of the experiment could be altered with this modification.

Researchers also monitored the amount of sediment and fertilizer washing into the river from each plot in the original study. The soil temperature was also measured in each plot at the same depth and at the same time each day approximately 0.05 meters below the surface of the soil.

Genetically Modified Green Bean Experimental Results

Plot	Sediment Runoff (mg/L)	Phosphorus Runoff (mg/L)	Nitrogen Runoff (mg/L)	Soil Temperature (°C)
A (Type 1 GMO beans)	2.4	0.11	1.07	18.6
B (Type 2 GMO beans)	2.1	0.02	0.56	18.3
C (Type 3 GMO beans)	0.9	0.04	0.68	18.3
D (Unmodified beans)	3.5	0.15	1.24	17.6

- (d) Based on the data in the table, **identify** the plot with the lowest soil temperature.
- (e) **Describe** how sediment runoff and fertilizer runoff compare between the unmodified green beans and the genetically modified green beans.

- (f) The Type 2 GMO beans in Plot B were developed to grow more quickly than the unmodified beans in Plot D. Researchers have hypothesized that the Type 2 beans would use fertilizer more completely than the other varieties. Based on the data in the table and the experimental design, **explain** whether the researchers' hypothesis was supported or refuted.

Once the experiment was concluded, the researchers burned the plots to remove the crops that had been planted. After a few years, the researchers returned to the plots and observed a variety of plants, insects, and bird species living there.

- (g) **Describe** the ecological process that occurred on the plots after the crops were burned.

A survey indicated that one of the plots had twice the plant diversity that the other plots had. Over the next five years, the river occasionally flooded the plots, killing off many of the species that inhabited the plots.

- (h) After each flooding event, the plot with twice the plant diversity returned to its prior level of biodiversity more quickly than the other plots did. **Explain** why a community with more plant diversity will recover more quickly from the flooding.
- (i) After the last flooding event, a beetle not previously known in the area appeared in one of the plots with less plant diversity. Over a period of a few months, the new beetle population increased, whereas the existing beetle species in the plot had declining populations. **Explain** why the new beetle species could be better able to successfully populate this plot than the existing beetle species could.
- (j) **Describe** one realistic method to prevent the new beetle from spreading beyond the experimental plot.

Begin your response to this question at the top of a new page in the separate Free Response booklet and fill in the appropriate circle at the top of each page to indicate the question number.

ENVIRONMENTAL SCIENCE

SECTION II

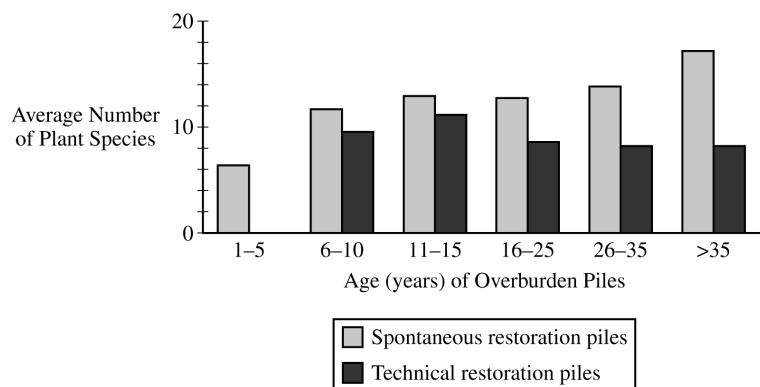
Time—1 hour and 10 minutes

3 Questions

Directions: Answer all three questions, which are weighted equally; the suggested time is about 22 minutes for answering each question. Write all your answers in the Free Response booklet. Where calculations are required, clearly show how you arrived at your answer. Where explanation or discussion is required, support your answers with relevant information and/or specific examples. You may plan your answers in this orange booklet, but no credit will be given for anything written in this booklet. **You will only earn credit for what you write in the separate Free Response booklet.**

1. Two restoration methods designed to reclaim the overburden piles removed from open pit coal mines in temperate forests of eastern Europe were studied over several years. The first method was spontaneous restoration, where the soil and rock were dumped in noncompacted, random piles and not replanted with vegetation. The second method was technical restoration, where the land was leveled by heavy machinery, organic material was added, and eight plant species were added. Technical restoration started 5 years after the piles were formed, so no bar is included in the 1–5 year range in the graph.

Number of Plant Species in Spontaneous and Technically Restored Overburden Piles over Time



- (a) Based on the data in the graph, **identify** the average number of species found in technically restored piles 16–25 years after restoration started.
- (b) Based on the data in the graph, **describe** the relationship between the average number of species and the age of the spontaneous restoration piles.

Scientists hypothesized that after 35 years, the number of animal species in the spontaneously restored piles would be higher than the number of animal species in the technically restored piles.

- (c) Using the data in the graph, **make a claim** that supports or refutes the hypothesis that the number of animal species in the spontaneously restored piles would be higher than the number of animal species in the technically restored piles.
- (d) **Describe** a characteristic of a plant species that would have been present in the spontaneous restoration piles from years 1 to 5.
- (e) **Explain** how the return of plant life would have been altered in the spontaneous piles if the mining had taken place in the tundra rather than in temperate forests.

Limiting runoff on disturbed land improves soil and water quality. To model water runoff, students set up three large plastic trays and filled each tray with loam soil to 1 centimeter below the edge. Loam soil is a balance of sand, silt, and clay soil. One tray was seeded with wheatgrass and grown for 30 days, one tray was covered with small wood chips, and one tray was soil only. Five hundred milliliters of water was sprinkled evenly onto the soil surface of each tray. All three trays were placed on a slight slope, and water that ran off the surface was collected. The results are shown in the following table.

Tray	Water Collected (mL)	Water Appearance
Wheatgrass grown in soil; no small wood chips	190	Clear
Small wood chips covered soil; no wheatgrass	300	Transparent; light brown
Soil only; no wheatgrass or small wood chips	360	Cloudy; dark brown

- (f) **Identify** the scientific question for the investigation.
- (g) **Identify** a dependent variable in the experiment.
- (h) **Explain** how the results of the experiment would likely have been altered if the soil had contained a higher percentage of sand, which has the largest particle size of the components of loam.
- Runoff from mining waste can also affect water quality.
- (i) **Describe** one ecological impact that could result from the drainage from mine waste into nearby waterways.
- (j) **Describe** one strategy to reduce the drainage from mine waste into waterways downstream from mines.

Begin your response to this question at the top of a new page in the separate Free Response booklet and fill in the appropriate circle at the top of each page to indicate the question number.

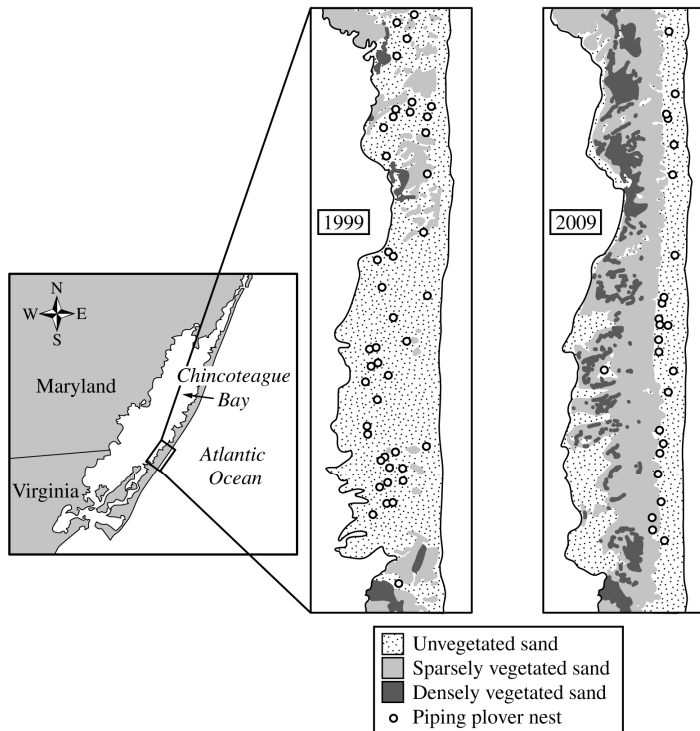
ENVIRONMENTAL SCIENCE**SECTION II****Time—1 hour and 30 minutes****4 Questions**

Directions: Answer all four questions, which are weighted equally; the suggested time is about 22 minutes for answering each question. Write all your answers on the pages following the questions in this book. Where calculations are required, clearly show how you arrived at your answer. Where explanation or discussion is required, support your answers with relevant information and/or specific examples.

1. The piping plover is a globally threatened species, with perhaps as few as 2,000 nesting pairs remaining in the Atlantic population of these migratory shorebirds. Plovers were nearly hunted to extinction in the nineteenth century.

Plovers prefer to nest and search for food on open sandy beaches between sparsely vegetated sand dunes. Washovers, where sand is washed up from the beach and buries vegetated areas during big storms, are also important to plovers because they provide moist and undisturbed habitat for plover adults and their chicks. Ecologists with the Elliott Oceanographic Institute mapped the distribution of plover nests during two seasonal surveys of nesting sites over a ten-year period on Assateague Island. This is a barrier island, a long, narrow island running parallel to the Atlantic coast of Virginia.

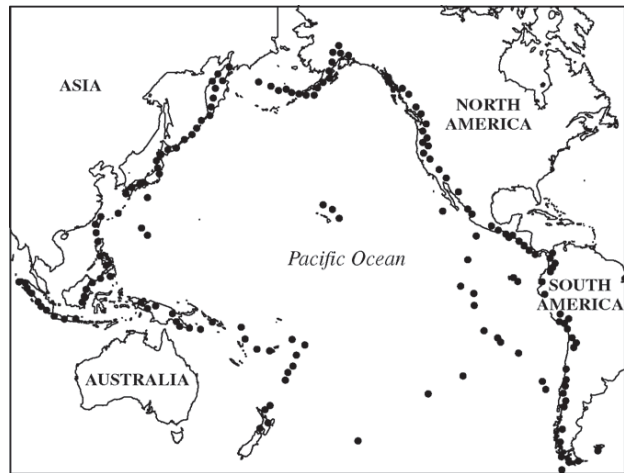
SPRING PIPING PLOVER NESTING SITES
ON ASSATEAGUE ISLAND, VIRGINIA



- (a) Use the maps provided to answer the following questions.
- Identify** the preferred nesting habitat for piping plovers.
 - Describe** the change in the number of piping plover nests on Assateague Island between 1999 and 2009.
 - Describe** one likely reason for the change in the number of piping plover nests between 1999 and 2009.
- (b) Coastal species are affected by more than just natural events.
- Special beach restrictions can help piping plovers during nesting season. **Describe** one restriction that could reasonably be implemented to help prevent the destruction of plover nests by human actions.
 - In addition to providing habitat for piping plovers, barrier islands (and closely related landforms) are important for other reasons. **Explain** one way that these features help to preserve and protect the environment in coastal regions.
 - Identify** one human action that directly threatens coastal habitats and **describe** one impact on species, other than the piping plover, that use the habitat.

Approximately 40% of the United States population resides in coastal areas, such as areas near Assateague Island, where sea level rise and shoreline erosion is occurring.

- Identify** one economic impact on coastal communities that has resulted from rising sea levels.
- Describe** TWO methods that may be used locally to protect coastal communities from rising sea levels.



3. Plate-tectonic theory states that the Earth's lithosphere is broken into very slowly moving pieces or plates. Plate movements over vast stretches of time have led to the current orientation of our continents and oceans. Individual events along plate boundaries, such as earthquakes and volcanic eruptions, pose periodic threats to human activity and ecosystems. The "Ring of Fire" is a term that describes the location of increased seismic and volcanic activity around the margins of the Pacific Ocean basin. On the map above, each dot represents a volcano or an earthquake.
- (a) Japan, Indonesia, and the Philippines are examples of volcanic island chains that have formed along subduction zones between plates in the western Pacific.
- (i) **Describe** what happens when two tectonic plates collide along a subduction zone.
 - (ii) **Explain** how subduction leads to volcanic activity.
- (b) Although the landscape following a volcanic eruption may appear unable to support ecological communities, over time the area can be transformed through succession.
- (i) What is primary succession?
 - (ii) **Explain** how primary succession can lead to soil formation on a newly formed volcanic landscape.
- (c) In addition to volcanic activity, highly destructive tsunamis are generated along Pacific Plate subduction zones.
- (i) **Explain** how a tsunami is generated along a subduction zone.
 - (ii) **Describe** one negative ecological impact that tsunamis have on coastal environments.
- (d) Southern California experiences periodic devastating earthquakes along the San Andreas Fault, which is a transform boundary located along the eastern edge of the Pacific Plate.
- (i) **Describe** what happens to the tectonic plates along a transform boundary at the moment when an earthquake occurs.
 - (ii) **Describe** what happens to the tectonic plates along a transform boundary during the time between earthquakes.