

Week 11

AP Environmental Science

Homework bundle for this week

本周作业合集

exercises.lol

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5. Land and Water Use

Starter Quiz · 课前小测

AP Environmental Science

Name: _____ Score: _____

1. The **tragedy of the commons** happens when...

- ☐ individuals overuse a shared resource, ruining it for all
- ☐ a resource is privately owned
- ☐ no one uses a resource
- ☐ a resource grows forever

2. **Clearcutting** is...

- ☐ cutting down all the trees in an area at once
- ☐ planting new trees
- ☐ watering a forest
- ☐ a type of soil

3. The **Green Revolution** was a big rise in food production driven by...

- ☐ high-yield crops, fertilisers, pesticides, and irrigation
- ☐ planting fewer crops
- ☐ stopping all farming
- ☐ moving farms to cities

4. How does heavy **tillage** (ploughing) harm soil?

- ☐ it bares the soil and speeds up erosion
- ☐ it adds new soil
- ☐ it makes rock
- ☐ it has no effect

5. **Irrigation** is...

- ☐ supplying water to crops artificially
- ☐ harvesting crops
- ☐ ploughing the soil
- ☐ spraying pesticides

6. One way to avoid the tragedy is to _____ how much each person can take (rules or limits).

7. Clearcutting destroys habitat, causing a loss of _____.

8. Growing vast fields of a single crop is called _____.

9. When over-irrigation leaves salt building up in dry soils, it is called _____.

10. Covering a whole field with water, which wastes a lot, is called _____ irrigation.

1. **individuals overuse a shared resource, ruining it for all**

The **tragedy of the commons**: each person, acting in self-interest, overuses a shared resource until it collapses.

2. **cutting down all the trees in an area at once**

Clearcutting removes every tree in an area — fast and cheap, but very damaging.

3. **high-yield crops, fertilisers, pesticides, and irrigation**

The **Green Revolution** used new **high-yield** crop varieties plus fertilisers, pesticides, and irrigation to grow far more food.

4. **it bares the soil and speeds up erosion**

Heavy **tillage** breaks up and bares the soil, letting wind and rain erode it faster.

5. **supplying water to crops artificially**

Irrigation supplies water to crops where rainfall is not enough.

6. **limit**

Rules, quotas, or shared ownership that **limit** use can protect a common resource.

7. **biodiversity**

Removing a whole forest destroys the homes of countless species, lowering **biodiversity**.

8. **monoculture**

Monoculture raises yields but reduces variety, so one pest or disease can wipe out the whole crop.

9. **salinization**

Salinization is salt building up in soil from irrigation, making it too salty for crops.

10. **flood**

Flood irrigation is cheap but wastes much water to evaporation and runoff.

5.1 The Tragedy of the Commons

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

KEY WORDS tragedy of the commons 公地悲剧 • overfishing 过度捕捞 • overgrazing 过度放牧

Objective

Build the skills to answer exam questions on the **tragedy of the commons**.

You must be able to:

- explain the **tragedy of the commons** 公地悲剧
- give examples (overfishing, grazing, pollution)
- describe solutions (regulation, privatization, quotas)

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.

■ The idea

The **tragedy of the commons** occurs when a shared resource (open to all, owned by none) is **overused** because each individual benefits from using more, while the cost of depletion is shared by everyone.

■ Why it happens

Each user gains the **full benefit** of taking more, but bears only a **small share** of the harm. So everyone takes as much as they can, and the resource collapses.

■ Examples

Overfishing shared oceans, overgrazing common pasture, polluting shared air/water — all are commons problems.

■ Solutions

- **Regulation** — laws limiting use.
- **Quotas** — caps on how much each can take.
- **Privatization** — giving ownership so the owner protects the resource.
- International agreements for global commons.

2 Practice

Now apply the methods above.

2.1 What is the tragedy of the commons? [1]

2.2 Give one example of a commons problem. [1]

2.3 State one solution. [1]

3 Exam-style questions

3.1 The tragedy of the commons happens because each user gains the full benefit but [1]

- **A** bears the full cost
- **B** shares the cost with everyone
- **C** gains no benefit
- **D** owns the resource

3.2 Fishers all take as many fish as they can from an open ocean.

(a) Explain why this leads to collapse of the fishery. [2]

(b) State one solution that could prevent it. [1]

3.3 Explain how assigning ownership (privatization) can protect a shared resource. [2]

Solutions

2.1 A shared, unowned resource is overused because individuals benefit from taking more while the cost is shared.

2.2 Any one: overfishing, overgrazing, air/water pollution.

2.3 Any one: regulation, quotas, privatization.

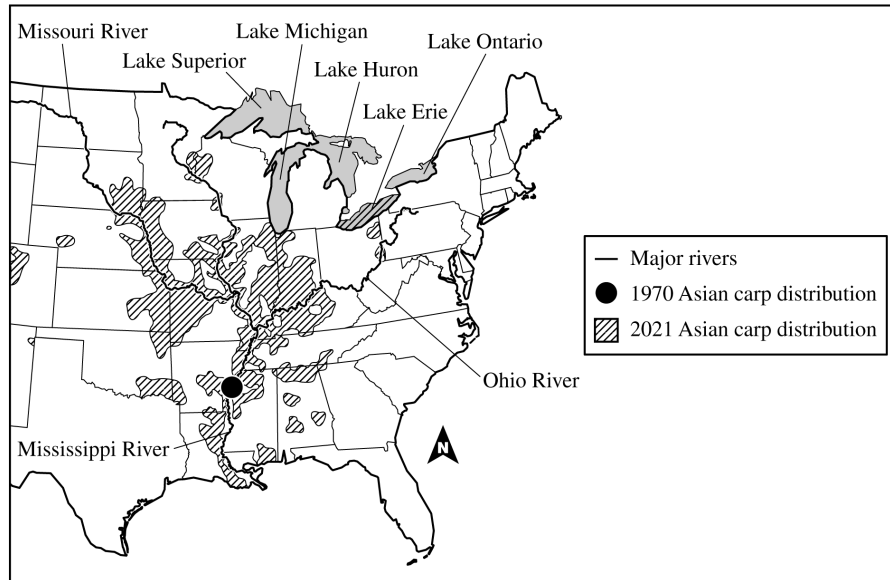
3.1 B — shares the cost with everyone.

3.2 (a) Each fisher gains fully from catching more but shares the cost of depletion, so all overfish and the stock collapses. (b) Any one: catch quotas, regulation, protected areas.

3.3 An owner bears the full cost of overuse, so they have an incentive to use the resource sustainably to preserve its long-term value.

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.

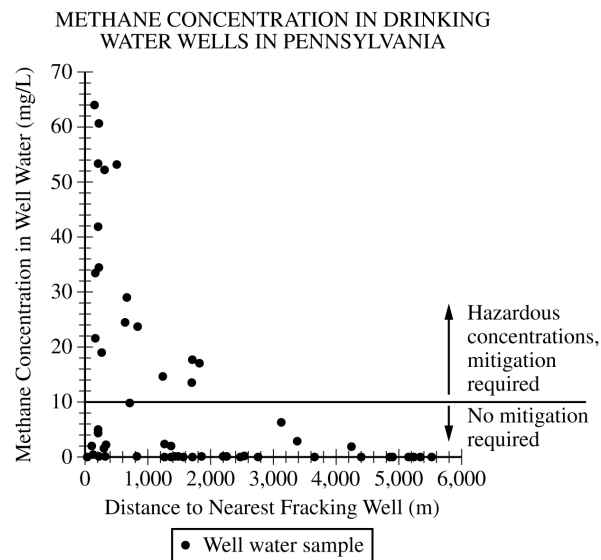
The blue pike, a fish that was endemic to the Great Lakes, was commercially fished from the late 1800s until their population crashed in 1958. In 1970, the species was declared to be extinct.

- (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. Developments in advanced hydraulic fracturing (fracking) technologies have allowed the total oil and gas production in the United States to increase rapidly.



- (a) The graph shows the methane concentration in drinking water from home wells and the distance to the nearest fracking well in Pennsylvania.
- Based on the data in the graph, **identify** the highest methane concentration found in well water in Pennsylvania.
 - Based on the data in the graph, **describe** the relationship between the concentration of methane in well water and the distance to a fracking well.
 - Based on the data in the graph, **identify** the minimum safe distance that a new water well should be located from an existing fracking well.
 - Explain** how fracking fluid is used to access oil and natural gas in sedimentary rock, such as shale, during the fracking process.
 - Identify** one negative geologic effect in an area where hydraulic fracturing (fracking) occurs.
- (b) The volume of water used for oil and gas extraction is 28 times greater than it was fifteen years ago. Much of the water used for oil and gas extraction comes from groundwater sources in arid or semiarid regions. This increased use of water for fracking may mean that less water is available for local use.
- The use of groundwater for fracking is an example of individuals using a shared resource for their own self-interest. **Identify** the environmental concept illustrated by this example of overuse of a shared resource.
 - Describe** one environmental problem that may result from increased use of groundwater for fracking in arid or semiarid regions.
 - Describe** how overuse of coastal groundwater supplies can result in water that is unsuitable for human consumption.

- (c) In addition to water quality issues caused by fossil fuel extraction, air quality can also be negatively affected by combustion of oil and natural gas.
- Make a claim** for a realistic governmental action to improve air quality by reducing consumption of oil.
 - Justify** the action proposed in part (c)(i) by stating a potential environmental advantage of that action, other than slowing global climate change.

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.

5.2 Clearcutting

Name: _____ Class: _____ Date: _____

Total: 10 marks**KEY WORDS** clearcutting 皆伐 • erosion 侵蚀 • selective cutting 择伐

Objective

Build the skills to answer exam questions on **clearcutting**.**You must be able to:**

- describe **clearcutting** 皆伐 and its impacts
- link it to erosion, habitat loss, and flooding
- compare it with selective cutting

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.

■ What clearcutting is

Clearcutting removes **all** trees from an area at once. It is cheap and efficient for timber, but has severe environmental impacts.

■ Impacts

- **Soil erosion** — no roots hold the soil; heavy rain washes it away.
- **Habitat loss** — species lose their homes.
- **Flooding and sedimentation** — more runoff (less infiltration/transpiration) raises flood risk and silts up rivers.
- **Loss of carbon storage** — fewer trees absorb CO₂.

■ Selective cutting

Selective cutting removes only some trees, leaving the forest largely intact — less erosion and habitat loss, but more costly and slower.

■ A worked comparison

A clearcut hillside erodes badly after rain; a selectively-cut one keeps most roots and soil in place.

2 Practice

Now apply the methods above.

2.1 What is clearcutting? [1]**2.2** State one environmental impact of clearcutting. [1]**2.3** How does selective cutting differ from clearcutting? [1]

3 Exam-style questions

3.1 Clearcutting increases soil erosion mainly because it removes the [1]

- **A** roots that hold soil
- **B** rocks
- **C** groundwater
- **D** air

3.2 A hillside forest is clearcut.

(a) Explain why erosion and flooding increase afterward. [3]

(b) State one advantage of clearcutting to a timber company. [1]

3.3 Explain one advantage and one disadvantage of selective cutting compared with clearcutting. [2]

Solutions

- 2.1 Removing all the trees from an area at once.
- 2.2 Any one: soil erosion, habitat loss, flooding, loss of carbon storage.
- 2.3 Selective cutting removes only some trees, leaving the forest largely intact.
- 3.1 **A** — the roots that hold soil.
- 3.2 (a) Without trees, roots no longer hold the soil and there is less transpiration and infiltration, so rain washes soil away (erosion) and runs off quickly (flooding). (b) It is cheaper/faster and yields more timber at once.
- 3.3 Advantage: less erosion and habitat loss (forest stays intact); disadvantage: it is more expensive and slower.

Name: _____

AP Environmental Science: 2024 Set 2

ENVIRONMENTAL SCIENCE

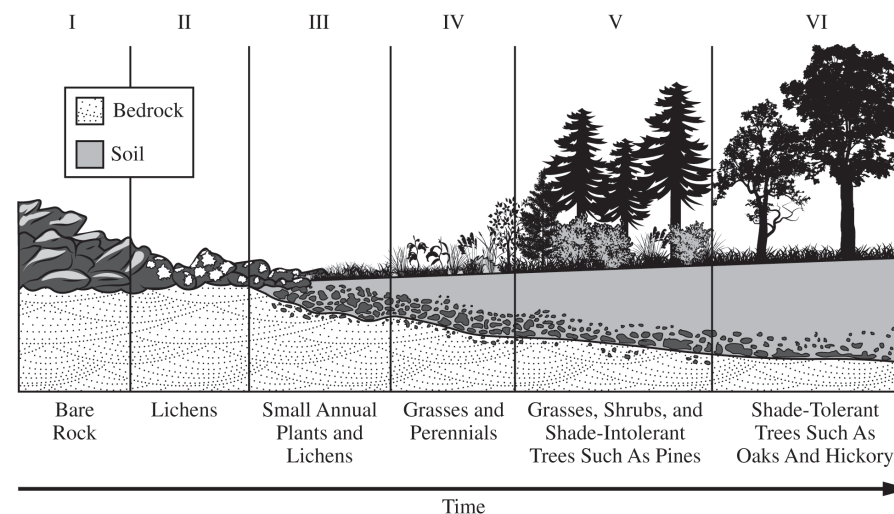
SECTION II

Time—1 hour and 10 minutes

3 Questions

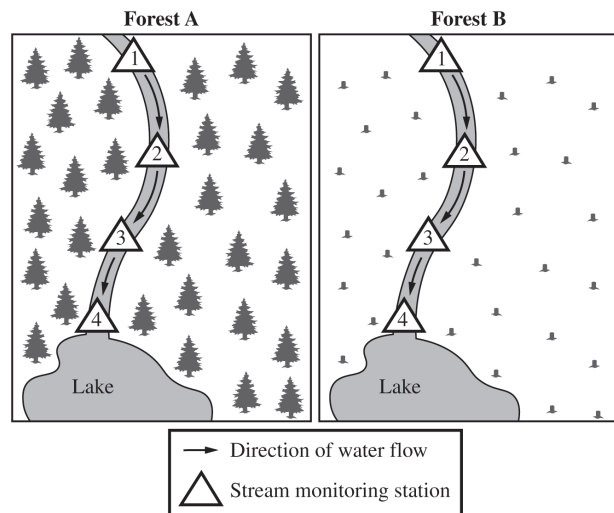
Directions: Answer all three questions, which are weighted equally; the suggested time is about 22 minutes for answering each question. Write all your answers in the Free Response booklet. Where calculations are required, clearly show how you arrived at your answer. Where explanation or discussion is 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.



- (a) **Identify** the ecological change over time illustrated in the diagram.
- (b) **Identify** the stage in which pioneer species first appear.
- (c) **Describe** how soil forms from stage II to stage III.
- (d) **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.



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

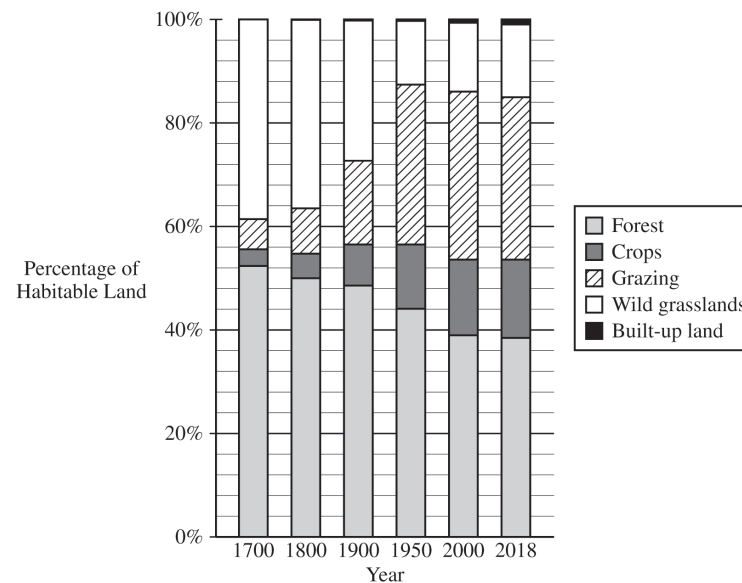
After the experiment was completed, land developers constructed a golf course in the clear-cut area of forest B. To prepare the land, developers removed any remaining stumps and newly grown trees and began planting and fertilizing new grass. The researchers are interested in the effect the golf course 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.

- (i) **Explain** why an indicator of water quality other than temperature could be altered by the golf course in forest B.
- (j) **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.

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.

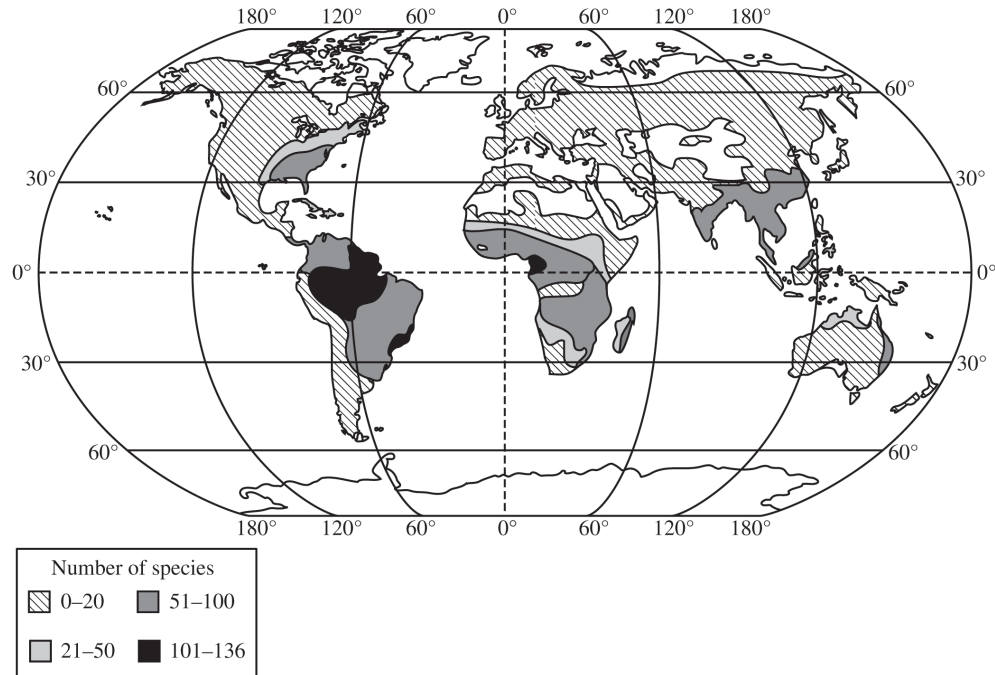
(g) **Calculate** the percentage of each of the 1,000 lots that would need to be set aside in order to support the goal of 275 male wood thrush territories. **Show** your work.

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.

- (i) **Identify** the latitudinal range with the greatest amphibian species richness.
 - (ii) **Identify** what biome this range most likely represents.
 - (iii) **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.
- (i) **Explain** how the species richness of an ecosystem influences its response to environmental stressors.
 - (ii) **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.

- (i) **Identify** one specific piece of legislation that has been designed to protect species threatened by extinction.
 - (ii) **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.
- (i) **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.
 - (ii) **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.

3. Approximately 350 coal-fired power plants in the United States are older than the 30-year anticipated life-span for a coal generator. One problem with these aging power plants is that many lack the necessary modern air pollution controls. Additionally, there are concerns about rising fuel costs, so many utility companies are planning to retire coal-fired plants and build new natural-gas power plants.

- (a) **Describe** why coal is considered a nonrenewable energy source.
- (b) **Describe** one potential environmental advantage of replacing a coal-fired power plant with a natural-gas power plant.
- (c) **Describe** one economic advantage of using natural gas, rather than coal, in producing electricity.
- (d) When natural gas is used to heat homes, it can produce carbon monoxide gas, which can lead to carbon monoxide poisoning in humans. **Propose** a solution to reduce the incidence of carbon monoxide poisoning in humans.

Particulate matter is another common pollutant in emissions from vehicles, coal-fired power plants, and various other sources. One size of particulates, $PM_{2.5}$, presents a particular risk to human health.

ATMOSPHERIC CONCENTRATION OF PARTICULATE MATTER IN 1990 AND 2016

Year	Average Annual Atmospheric Concentration of $PM_{2.5}$ ($\mu g/m^3$)
1990	85
2016	188

- (e) **Calculate** the percent change in the average annual $PM_{2.5}$ concentration in the air from 1990 to 2016. **Show** your work.
- (f) Trees can remove $PM_{2.5}$ from the atmosphere when particulates settle on the leaves and are subsequently washed onto soil by rain. The average annual removal of $PM_{2.5}$ is 2.3 kilograms per hectare. **Calculate** the decrease in $PM_{2.5}$ removal in kilograms if logging reduced a forested area from 50,000 hectares to 43,000 hectares. **Show** your work.
- (g) Research has shown that hospital admissions for cardiovascular problems increase 1% with every 10% increase in $PM_{2.5}$ concentration. A city experienced a 23% increase in $PM_{2.5}$ concentration and had 7,390 hospital admissions for cardiovascular issues over a one-year period. **Calculate** the anticipated increase in the number of hospital admissions for cardiovascular issues during the next year if the $PM_{2.5}$ concentration continues to rise at an identical rate. **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

AP Environmental Science: 2017

3. Haiti shares a border with the Dominican Republic on the Caribbean island of Hispaniola.
- (a) The border between the two countries can be seen using satellite images because of the severe deforestation in Haiti.
- (i) **Provide** one reason why deforestation commonly occurs in a less developed country such as Haiti.
- (ii) **Describe** one realistic strategy to reduce deforestation in a less developed country.
- (b) Deforestation can affect water quality. **Identify** one change that can occur in the water quality of streams within a watershed that has been deforested. **Explain** how deforestation can lead to this change.
- (c) **Identify** TWO environmental benefits, other than those related to water quality, of maintaining forest ecosystems.

The table below contains demographic data for Haiti in 1995 and 2015.

DEMOGRAPHIC DATA FOR HAITI

Measure	1995	2015
Fertility rate (number of children per woman)	5.2	2.7
Life expectancy (years)	55	64
Infant mortality (deaths per 1,000)	85	48

- (d) **Identify** and **discuss** one factor in a less developed country that could contribute significantly to a change in life expectancy, similar to what occurred in Haiti from 1995 to 2015.
- (e) **Identify** and **discuss** one economic or cultural factor in a less developed country that could contribute significantly to a change in the fertility rate, similar to what occurred in Haiti from 1995 to 2015.

5.3 The Green Revolution

Name: _____ Class: _____ Date: _____

Total: 11 marks

KEY WORDS monoculture 单一栽培 • green revolution 绿色革命 • irrigation 灌溉
• synthetic fertilizers 化肥 • pesticides 农药

Objective

Build the skills to answer exam questions on the **Green Revolution**.

You must be able to:

- describe the **Green Revolution** 绿色革命 and its methods
- state its benefits and costs
- link it to fertilizer, irrigation, and monoculture

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.

■ What it was

The **Green Revolution** greatly increased crop yields using **high-yield seeds**, **synthetic fertilizers**, **pesticides**, **irrigation**, and **mechanization**.

■ Benefits

It **fed billions** and reduced famine by producing much more food per area.

■ Costs

- **Soil degradation** and erosion from intensive farming.
- **Water pollution** from fertilizer/pesticide runoff.
- **High energy and water use**.
- Loss of crop diversity through **monoculture** (growing one crop).

■ Monoculture risk

Monoculture raises efficiency but makes crops vulnerable — a single pest or disease can destroy the whole field, and it depletes specific soil nutrients.

2 Practice

Now apply the methods above.

2.1 Name two methods of the Green Revolution. [2]

2.2 State one benefit of the Green Revolution. [1]

2.3 What is monoculture? [1]

3 Exam-style questions

3.1 A drawback of monoculture is that a single pest or disease can [1]

- **A** improve the harvest
- **B** destroy the entire crop
- **C** increase diversity
- **D** enrich the soil

3.2 A country adopts Green Revolution farming.

(a) State one benefit and one environmental cost. [2]

(b) Explain why fertilizer use can harm nearby waterways. [2]

3.3 Explain why monoculture increases the risk of crop failure. [2]

Solutions

2.1 Any two: high-yield seeds, synthetic fertilizers, pesticides, irrigation, mechanization.

2.2 It greatly increased food production / reduced famine.

2.3 Growing a single crop over a large area.

3.1 B — destroy the entire crop.

3.2 (a) Benefit: much more food; cost: any one of soil degradation, water pollution, high water/energy use, loss of diversity. (b) Excess fertilizer runs off into water, adding nutrients that cause algal blooms and eutrophication.

3.3 With genetically similar plants over a large area, one pest or disease that can attack it can spread and wipe out the whole crop.

5.4 Impacts of Agricultural Practices

Name: _____ Class: _____ Date: _____

Total: 9 marks

KEY WORDS eutrophication 富营养化 • tilling 耕作 • erosion 侵蚀 • methane 甲烷

Objective

Build the skills to answer exam questions on **impacts of agricultural practices**.

You must be able to:

- describe impacts of **tilling** 耕作, fertilizer, and confined animal feeding
- link practices to erosion, runoff, and pollution
- suggest mitigation

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.

■ Tilling

Tilling (plowing) loosens soil for planting but **exposes** it to wind and water, increasing **erosion** and releasing stored carbon.

■ Fertilizer and runoff

Fertilizers boost yields but excess washes off as **runoff**, adding nutrients to water and causing **eutrophication**.

■ Confined animal feeding (CAFOs)

Concentrated livestock operations produce huge amounts of **manure/waste**, which can pollute water with nutrients and pathogens, and release methane.

■ Mitigation

- **No-till** or reduced tilling to cut erosion.
- **Buffer strips** and precise fertilizer use to cut runoff.
- Proper **manure management**.

2 Practice

Now apply the methods above.

2.1 How does tilling increase erosion? [1]

2.2 What water problem does fertilizer runoff cause? [1]

2.3 State one way to reduce fertilizer runoff. [1]

3 Exam-style questions

3.1 Excess fertilizer washing into a lake most directly causes [1]

- **A** erosion
- **B** eutrophication
- **C** drought
- **D** deforestation

3.2 A farm tills its soil and applies heavy fertilizer near a river.

(a) Explain two impacts on the environment. [2]

(b) Suggest one practice to reduce these impacts. [1]

3.3 Explain why concentrated animal feeding operations (CAFOs) are a water-pollution concern. [2]

Solutions

2.1 It exposes and loosens the soil, so wind and water remove it more easily.

2.2 Eutrophication (nutrient pollution / algal blooms).

2.3 Any one: buffer strips, precise/reduced fertilizer, no-till.

3.1 B — eutrophication.

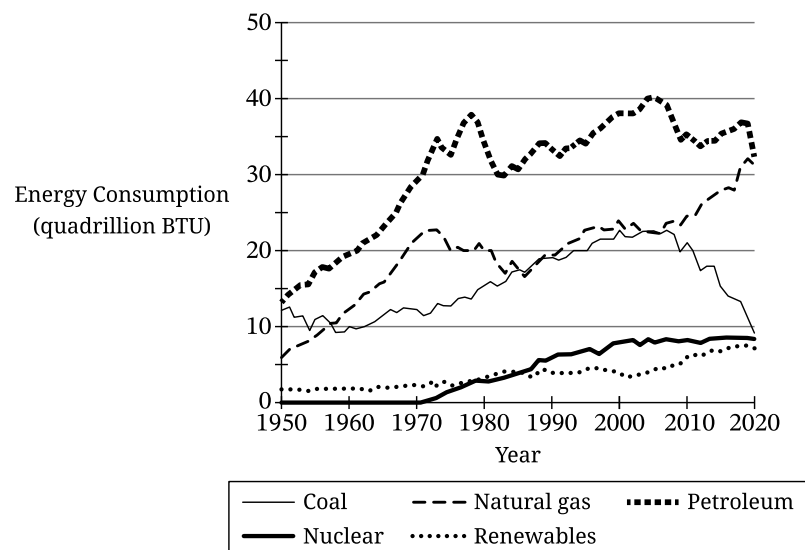
3.2 (a) Any two: tilling causes soil erosion; fertilizer runoff causes eutrophication; loss of soil carbon. (b) Any one: no-till, buffer strips, reduced fertilizer.

3.3 They concentrate large amounts of animal waste in one place; if it runs off it adds nutrients and pathogens to water, causing eutrophication and disease risk.

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

The following graph shows the number of quadrillion British thermal units (BTUs) that were consumed in the United States using five different energy sources from 1950 to 2020.

Energy Consumption by Source in the United States, 1950–2020



The following information applies to parts H and I.

Researchers studied an aquatic ecosystem near an area of land that had been converted to agricultural use. They reported an increase in nutrients, such as nitrates and phosphates, in the water.

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

Part A

Identify one renewable energy source that is used to generate electricity.

Part B

Based on the data in the graph, **identify** the energy source that had the highest consumption in 2010.

Part C

Based on the data in the graph, **describe** the pattern in the energy consumption from coal in the United States from 1960 to 2020.

Part D

Based on the data in the graph and your knowledge of energy consumption, **explain** one likely reason why the use of coal for energy changed between 2010 and 2020.

Part E

Explain how fossil fuels are used to generate electricity.

Part F

In addition to fossil fuels, nuclear power can be used to generate electricity. **Identify** one negative impact associated with nuclear energy.

Part G

Fossil fuel combustion leads to ocean warming. **Describe** one environmental problem other than coral bleaching that is associated with warming oceans.

Part H

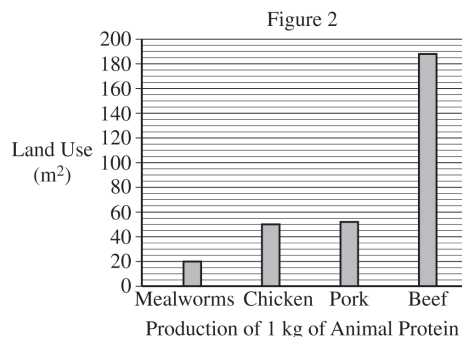
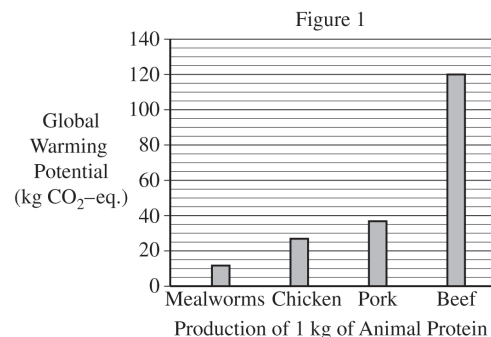
Explain how an increase in nutrients, such as nitrates and phosphates, can negatively affect an aquatic ecosystem.

Part I

- Propose** a realistic solution that would reduce nutrient pollution of waterways, while still allowing cultivation of crops.
- Justify** the solution proposed in part I (i) by explaining one potential advantage other than reducing nutrient runoff.

2. As the human population continues to grow, the demand for animal protein is expected to double by 2050. Animal protein can be obtained from conventional livestock and other sources. The production of all animal protein has environmental costs, as shown in the following graphs. In Figure 1, global warming potential (GWP) is measured in kilograms of carbon dioxide equivalent (kg CO₂-eq). Carbon dioxide equivalent is a measure of the warming effect of a gas relative to that of carbon dioxide. In Figure 2, land use is measured in meters squared (m²).

Global Warming Potential and Land Use from Animal Protein Production



- (a) Based on the data in the graphs, **identify** the amount of land required to produce 1 kilogram of chicken protein.

Mealworms, the larvae of the darkling beetle, consume grains and decaying plant material. Darkling beetles are an *r*-selected species, and the entire mealworm can be consumed by humans for protein.

- (b) Based on the information provided, **identify** the type of survivorship curve exhibited by the darkling beetle.

- (c) **Explain** why the reproductive strategy of the darkling beetle is an advantage for using mealworms as an alternative protein source for the rapidly growing human population.

An individual's diet choices affect greenhouse gas emissions and land use.

- (d) Based on the data in the graphs, **explain** whether producing 1 kilogram of chicken protein or 1 kilogram of pork protein would cause less environmental damage.

Cattle emit methane from fermentation in their digestive systems. The other animals do not emit methane.

- (e) Based on the data in the graphs, **explain** why the production of 1 kilogram of beef protein has a different impact on global warming than the production of 1 kilogram of protein from any of the other animals studied would have.

Agricultural practices can have negative impacts on rivers and streams.

- (f) **Describe** how water quality can be altered by cattle grazing that occurs near a stream or river.
- (g) **Propose** a solution to reduce the negative impacts on waterways that result from cattle grazing, while still allowing cattle to graze.
- (h) Crop production can cause soil erosion. **Describe** a sustainable agricultural practice used to reduce soil erosion.
- (i) **Justify** the use of the sustainable practice described in part (h) by describing an additional advantage, other than the reduction of soil erosion.
- (j) Crop production around the world is affected by climate change. **Describe** how crop production could be negatively affected by climate change.

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

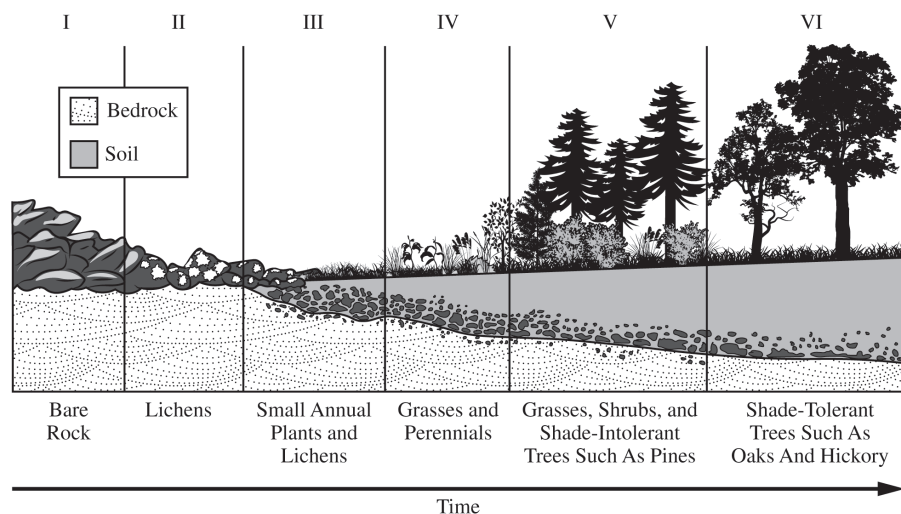
SECTION II

Time—1 hour and 10 minutes

3 Questions

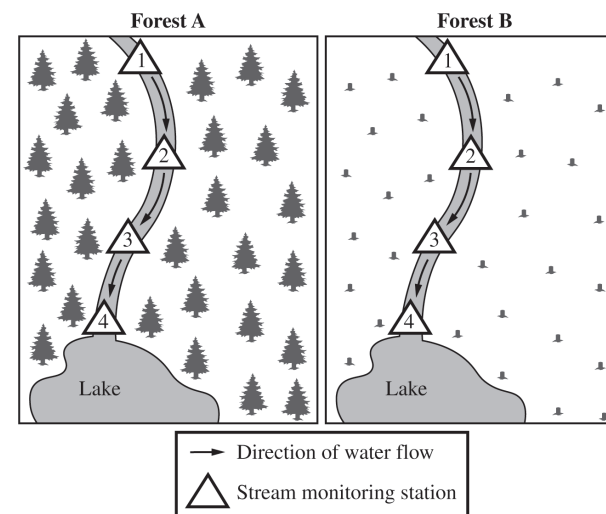
Directions: Answer all three questions, which are weighted equally; the suggested time is about 22 minutes for answering each question. Write all your answers in the Free Response booklet. Where calculations are required, clearly show how you arrived at your answer. Where explanation or discussion is 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. 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.

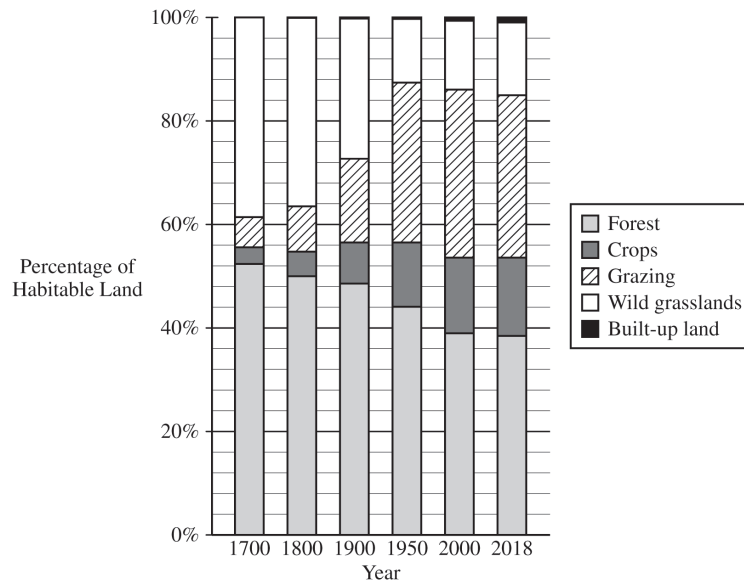
After the experiment was completed, land developers constructed a golf course in the clear-cut area of forest B. To prepare the land, developers removed any remaining stumps and newly grown trees and began planting and fertilizing new grass. The researchers are interested in the effect the golf course 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.

ENVIRONMENTAL SCIENCE

SECTION II

Time—1 hour and 10 minutes

3 Questions

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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. Human activities generate large amounts of solid waste, including organic waste. The decomposition of organic waste in landfills can result in the release of methane into the atmosphere.

(a) **Describe** one environmental problem associated with the release of methane into the atmosphere.

There are biological and physical factors that can affect the decomposition of the solid waste in a landfill and the release of methane in the atmosphere.

(b) **Describe** one factor that could affect the decomposition of the solid waste in a landfill.

(c) **Propose** a solution to decrease the amount of methane released from landfills into the atmosphere.

(d) **Justify** the solution proposed in part (c) by describing an additional advantage, other than decreasing the amount of methane released from landfills.

Another anthropogenic activity that releases methane is raising beef cattle. In 2021, 31.2 million beef cattle were raised in the United States.

(e) The average cow releases 150 liters of methane per day. **Calculate** the amount of methane that was released by all beef cattle raised in the United States in 2021. **Show** your work.

Another environmental concern with raising beef cattle for food is that it is not as efficient as growing crops for food.

(f) A typical beef cow needs 11.8 kilograms of food per day, and each hectare of cattle pasture produces 26.2 kilograms of grasses. **Calculate** the number of hectares of pasture that would be needed to support all beef cattle raised in the United States for one day. **Show** your work.

(g) The average American consumes 2,250 kilocalories of food per day. Beef cattle can produce 2.7 million kilocalories per hectare of land. Corn can produce 30.4 million kilocalories per hectare of land. **Calculate** how many more American people could be fed if 150 hectares of land was used to grow corn instead of raising beef cattle. **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

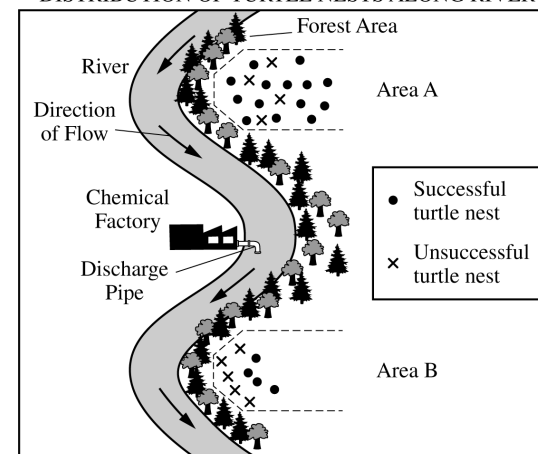
Time—1 hour and 10 minutes

3 Questions

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1. Common snapping turtles, *Chelydra serpentina*, are primarily aquatic, but they lay their eggs on land. Researchers are interested in understanding the impact of pollution on turtle nesting sites. The researchers examined nesting sites at two agricultural areas along the floodplain of a river upstream and downstream from a chemical factory that is a known source of aqueous mercury pollution. Turtle eggs, soil, and vegetation samples taken from areas around turtle nests downstream from the chemical factory showed high levels of mercury in a previous study. Mercury was not detected in samples taken upstream from the chemical factory.

DISTRIBUTION OF TURTLE NESTS ALONG RIVER



(a) The map shows locations of both successful and unsuccessful turtle nests.

- Identify** the area with the greatest nest success rate, based on the information in the diagram.
- Identify** the dependent variable in the study.
- Based on the information provided, **identify** a likely scientific question for the study.
- Describe** why researchers measured mercury levels in locations upstream from the factory.
- There are plans to remove trees and other vegetation along the river bank. **Explain** how this modification could affect the location and number of successful turtle nests in Area B.

(b) Mercury can affect organisms and ecosystems in many ways.

- Describe** how a persistent pollutant, such as mercury, can negatively affect an organism.
- Describe** how a persistent pollutant, such as mercury, can negatively affect an ecosystem.
- Researchers measured methylmercury in a location downstream from the factory. **Explain** how methylmercury could be present in the stream.
- Researchers claimed that the soil nearest to the river has higher levels of mercury than the field has, and those elevated levels have affected the nesting success for turtles. **Explain** how the pattern shown in the diagram supports or refutes this claim.

(c) The turtle study was conducted in an agricultural area. **Describe** how a specific agricultural practice changes the soil in an area.

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

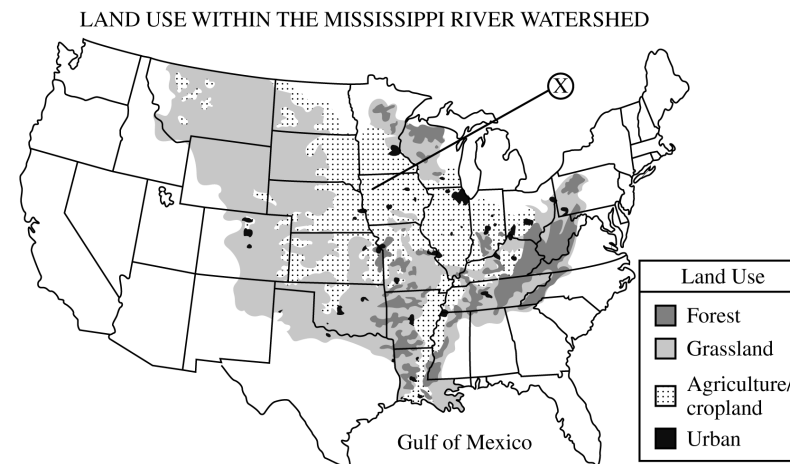
SECTION II

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- The dead zone in the Gulf of Mexico occurs every summer when winter snow melts and spring rain flows into the Mississippi River. Recent studies have shown that both the total area covered by algae and the depth of the algal mass in the dead zone are increasing.



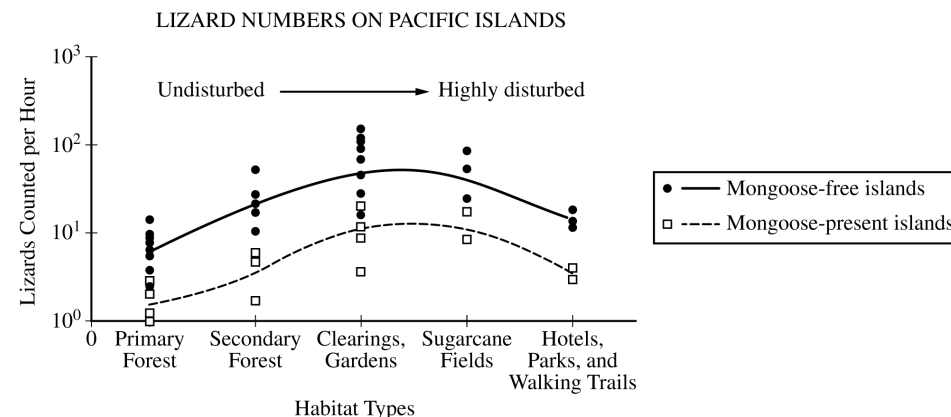
(a) Various land use practices can have different effects on the waters that surround a dead zone.

- Identify** the land use that covers the least amount of area in the Mississippi River watershed, based on the diagram.
- Describe** one way that the land use practice at location X in the diagram could contribute to the dead zone in the Gulf of Mexico.
- Describe** one way that urban areas in the Mississippi River watershed could contribute to the dead zone in the Gulf of Mexico.

- (b) The dead zone in the Gulf of Mexico has both economic and environmental effects for coastal communities.
- Describe** how a dead zone affects marine organisms living in the Gulf of Mexico.
 - Describe** one economic effect on communities along the Gulf of Mexico that can result from the presence of the dead zone.
 - Describe** one factor that causes the area of the dead zone in the Gulf of Mexico to increase in the summer months.
- (c) Researchers want to examine the effect of riparian vegetation buffers on water quality in streams in agricultural areas. Researchers will measure the water nutrient concentrations over the course of one year. The study sites are located 100 meters downstream from areas either with or without riparian vegetation buffers.
- Identify** a testable hypothesis for the study.
 - Describe** a control that the researchers could use in the study.
 - Identify** one water quality test, other than measuring nitrates or phosphates, that the researchers could use to evaluate how riparian vegetation buffers affect water quality.
 - During the investigation, researchers discovered that some of the land next to one of the streams with a riparian vegetation buffer is going to be converted from cornfields into a large-scale concentrated animal feeding operation. **Explain** one way that this change in land use could alter the results of the study.

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.

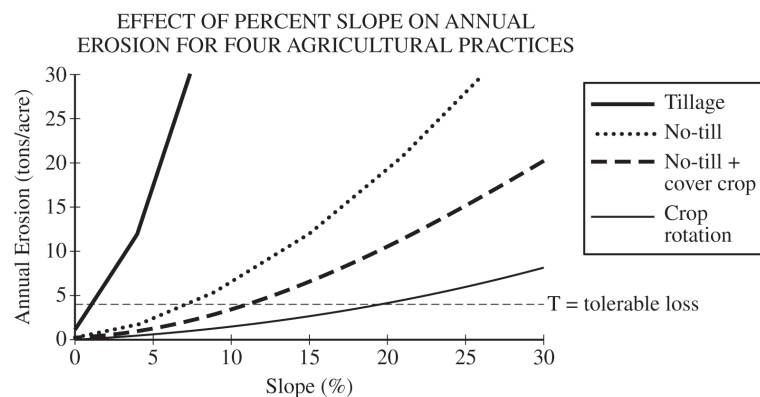
ENVIRONMENTAL SCIENCE

SECTION II

Time—1 hour and 10 minutes

3 Questions

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1. Soil erosion is one of the most serious soil-degrading processes. Each year tons of soil erode from cropland, pastures, forests, and other places. The amount of erosion varies dramatically among various land-use types. The figure above shows the effects of different agricultural practices and slopes on annual erosion rates.

(a) Refer to the graph above for the following.

- (i) **Identify** the scientific question that resulted in the data presented in the graph.
- (ii) **Identify** the agricultural practice that could be used on a 15% slope without leading to a higher than tolerable loss of soil.
- (iii) **Describe** the effect of adding a cover crop compared to using the no-till method.
- (iv) **Identify** one natural mechanism of soil erosion.

- (b) Sediment from erosion can enter streams and affect water quality. One way sediment can enter a stream is from nearby road construction. Two methods to reduce sediment run-off in streams are to either put down straw bales or plant grass. The hypothesis to be tested is that straw bales reduce more sediment run-off than planted grass does. To test the hypothesis, two plots near a road under construction are measured. On one plot (A), straw bales are used to cover the soil, while a second plot (B) is planted with grass. The sediment discharge from each plot is measured after rainfall.

- (i) **Identify** the dependent variable stated in the hypothesis.
- (ii) **Describe** one way to add a control to improve the design of the study.
- (iii) **Identify** one variable that was not discussed that could affect the results of the study.

Sediments reaching streams affect water clarity, which is tested by determining turbidity. Turbidity can be determined by measuring the depth at which a submerged object can no longer be seen from the surface.

Sample Group	Turbidity
Straw bale plots (plot A)	12 cm
Planted grass plots (plot B)	28 cm

- (iv) Based on the data in the table above, **make a claim** about the stated hypothesis.
- (c) Several fish species lay their eggs in the gravel in the streams under investigation in the study.
- (i) **Describe** the type of survivorship curve expected for these fish species.
- (ii) **Explain** why the input of sediment to a stream can negatively affect reproduction of fish that lay their eggs in the gravel of the streambed.

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.

4. Soil is a complex mixture of living organisms and organic material, along with minerals and other abiotic components. Soils help sustain life and support ecosystem functions.

- (a) **Describe** how TWO climate factors affect the rate of soil formation.
- (b) As soils form, distinct layers known as horizons develop over time. One of these is the A horizon.
- (i) **Identify** one specific biotic component of the A horizon.
- (ii) **Identify** one abiotic component of the A horizon.

Resources such as soil and water can be degraded by human activities.

- (c) Nitrate levels exceeding the United States Environmental Protection Agency's primary drinking water standard have been found in the groundwater of areas with intensive agriculture.
- (i) **Identify** one agricultural practice that can lead to elevated nitrate levels in groundwater.
- (ii) **Describe** how the practice you identified in (c)(i) leads to elevated nitrate levels in groundwater.
- (d) Acid deposition has affected soil quality in many parts of the northeastern United States.
- (i) **Explain** one way acid deposition onto soil can affect plant health.
- (ii) **Describe** one method for remediating soil affected by acid deposition.
- (e) Climate change is causing far-reaching ecosystem changes, including soil degradation in many of the world's biomes. **Describe** TWO ways that climate change can degrade soil.

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 article below and answer the questions that follow.

The Floridian Daily

May 21, 2013

The small community located on the edge of the magnificent wetlands of Florida's Everglades was the site of a press conference today where Governor Gayle Moss announced that the restoration of the Everglades is successfully underway. She noted that the Everglades ecosystem has suffered threats to its water quality, water quantity, and habitats in recent decades. Moss noted that intensive urban and agricultural development in adjacent areas has diverted substantial amounts of freshwater resources and impaired water quality. Governor Moss then emphasized that the preservation and enhancement of the Everglades, key goals of the restoration program, are absolutely essential for the continued environmental and economic health of the state. She closed the press conference by saying, "The Everglades is a gem not only for Florida but for the entire world. Each of us has the responsibility to do our part to preserve this magnificent resource."

- (a) **Describe** how TWO human activities, other than those that result in anthropogenic climate change, have resulted in a decrease in the amount of freshwater flowing into the Everglades ecosystem.
- (b) In addition to water quantity problems, the Everglades is faced with a variety of water quality issues. For example, phosphorus concentrations in the Everglades have increased since the 1960s.
- (i) **Describe** how one specific human activity contributes to increased phosphorus levels in the Everglades.
- (ii) **Explain** one way in which an increase in phosphorus levels can adversely affect the Everglades ecosystem.
- (iii) **Describe** one step that could be taken to reduce phosphorus inputs from the activity you identified in part (i).
- (c) Climate change could have a variety of impacts on water quantity, water quality, and habitat. For EACH of these three factors, **identify and describe** one specific example of an impact on the Everglades likely to result from climate change.
- (d) The article states that Governor Moss believes that the "preservation and enhancement of the Everglades, key goals of the restoration program, are absolutely essential for the continued environmental and economic health of the state."
- (i) **Describe** one way that restoring water quantity and water quality in the Everglades is expected to improve the structure and function of the ecosystem.
- (ii) **Describe** one way that restoring the Everglades is expected to provide economic benefits to Florida.

5.5 Irrigation Methods

Name: _____ Class: _____ Date: _____

Total: 10 marks**KEY WORDS** drip 滴灌 • salinization 盐碱化 • waterlogging 涝渍 • irrigation 灌溉

Objective

Build the skills to answer exam questions on **irrigation methods**.**You must be able to:**

- compare **flood/furrow**, **spray**, and **drip** 滴灌 irrigation for efficiency
- explain **waterlogging** 涝渍 and **salinization** 盐碱化
- link method to water loss

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.

■ Irrigation methods

- **Flood/furrow** — floods the field; cheap but wasteful (much evaporation and runoff).
- **Spray (sprinkler)** — sprays water; moderate efficiency, some evaporation loss.
- **Drip** — delivers water slowly to roots; **most efficient**, least evaporation, but costly to install.

■ Waterlogging

Over-watering can saturate soil (**waterlogging**), starving roots of oxygen.

■ Salinization

As irrigation water evaporates, it leaves **salts** behind. Over time salts build up in the soil (**salinization**), reducing fertility — a major problem in dry regions.

■ A worked comparison

Drip irrigation delivers water straight to the roots with little evaporation, so it uses far less water than flooding a field.

2 Practice

Now apply the methods above.

2.1 Which irrigation method is the most water-efficient? [1]**2.2** What is salinization? [1]**2.3** What causes waterlogging? [1]

3 Exam-style questions

3.1 The most water-efficient irrigation method is [1]

- **A** flood irrigation
- **B** furrow irrigation
- **C** drip irrigation
- **D** spray irrigation

3.2 A dry-region farm uses flood irrigation for years.

(a) Explain how this leads to salinization. [2]

(b) Suggest a more efficient method and why. [2]

3.3 Explain why waterlogging harms crops. [2]

Solutions

2.1 Drip irrigation.

2.2 Build-up of salts in the soil as irrigation water evaporates.

2.3 Over-watering that saturates the soil.

3.1 C — drip irrigation.

3.2 (a) The water evaporates and leaves dissolved salts in the soil; repeated over years, salts build up and reduce fertility. (b) Drip irrigation — it delivers water to the roots with little evaporation, so less salt is left behind and less water is used.

3.3 Waterlogged soil has no air spaces, so roots cannot get oxygen and the plant suffocates/dies.

Name:

AP Environmental Science: 2023 Set 1

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.



AP ENVIRONMENTAL SCIENCE • EXERCISE SHEET

5.6 Pest Control Methods

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

KEY WORDS pesticides 农药 • pesticide resistance 抗药性
• integrated pest management 综合虫害管理 • crop rotation 轮作

Objective

Build the skills to answer exam questions on **pest control methods**.

You must be able to:

- describe chemical **pesticides** 农药 and their problems
- explain **pesticide resistance** 抗药性 and the “pesticide treadmill”
- describe biological control

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.

■ Chemical pesticides

Pesticides kill pests and raise yields, but they also **harm non-target species** (bees, birds), **pollute water**, and can **bioaccumulate** in food chains.

■ Pesticide resistance

Using a pesticide **selects** for the few resistant pests, which survive and reproduce. Over time the pest population becomes **resistant**, so the pesticide stops working.

■ The pesticide treadmill

As resistance grows, farmers apply **more** or **stronger** pesticides for the same effect — the “**pesticide treadmill**” — raising costs and pollution.

■ Biological control

Biological control uses a pest's natural **predators** or parasites instead of chemicals — targeted and less polluting, but must be managed to avoid introducing a new problem species.

2 Practice

Now apply the methods above.

2.1 State one problem caused by chemical pesticides. [1]

2.2 How does pesticide resistance develop? [1]

2.3 What is biological pest control? [1]

3 Exam-style questions

3.1 Repeated pesticide use leads to resistance because it [1]

- **A** kills all pests equally
- **B** selects for pests that survive
- **C** creates new genes
- **D** helps predators

3.2 A farmer sprays the same pesticide every year and finds it works less well over time.

(a) Explain why, using natural selection. [2]

(b) State one alternative to chemical pesticides. [1]

3.3 Explain one advantage and one risk of biological pest control. [2]

Solutions

2.1 Any one: harms non-target species, pollutes water, bioaccumulates, causes resistance.

2.2 The pesticide kills susceptible pests, and the surviving resistant ones reproduce, so resistance spreads.

2.3 Using a pest's natural predators or parasites to control it.

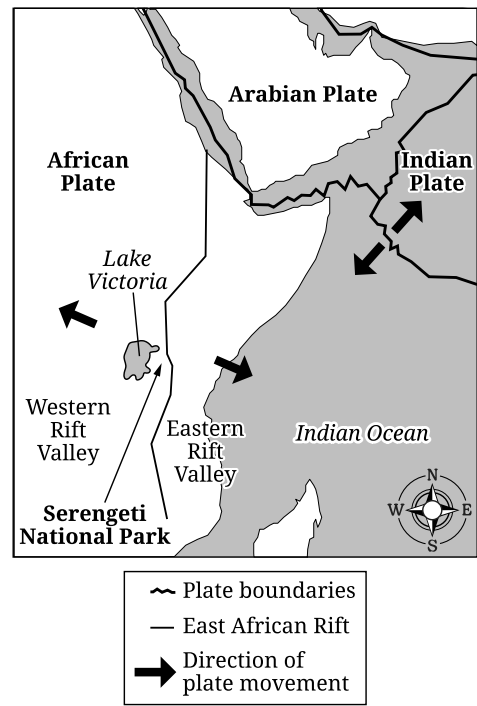
3.1 B — selects for pests that survive.

3.2 (a) A few pests already carry a resistance allele; the pesticide kills the rest, so the resistant survivors reproduce and resistance spreads. (b) Any one: biological control, integrated pest management, crop rotation.

3.3 Advantage: targeted and less polluting (no chemicals); risk: the introduced predator could become an invasive pest itself.

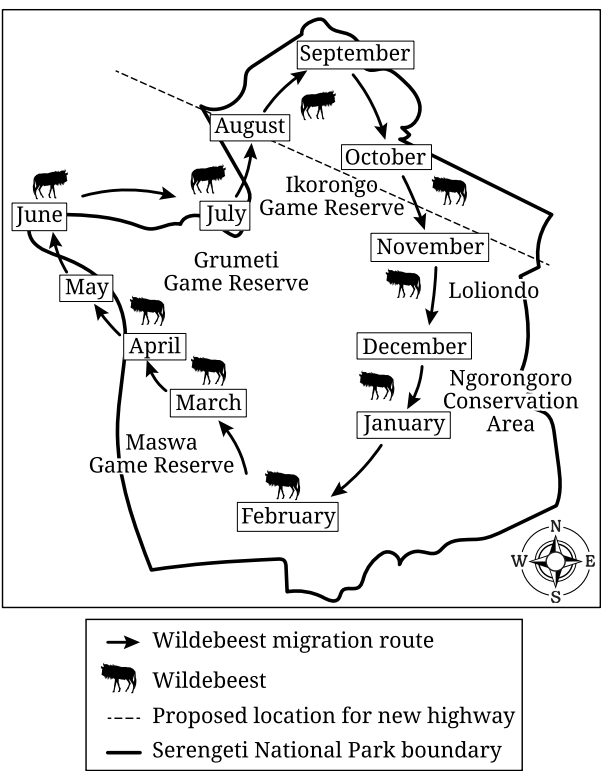
Serengeti National Park is located in Tanzania, Africa. The park is located in a valley along a tectonic plate boundary called the East African Rift. Figure 1 shows the East African Rift and other plate boundaries near the east coast of Africa.

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.

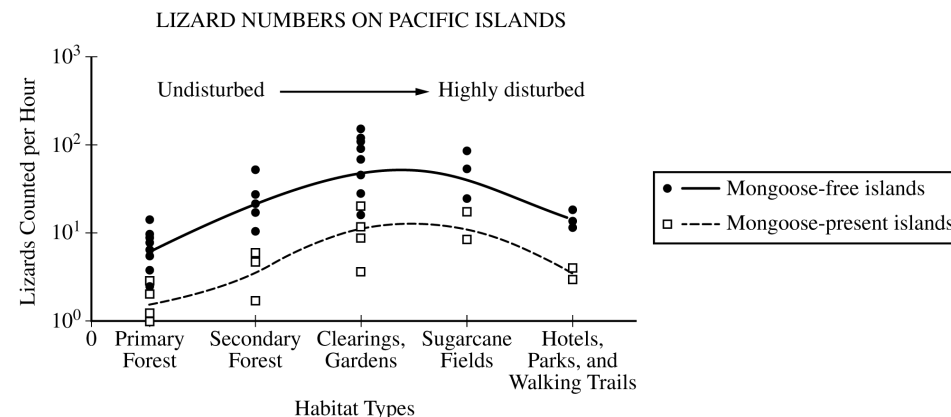
Describe one way the planned highway shown in Figure 2 could negatively affect the wildebeest population in the Serengeti.

- 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. 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.

2. Pesticides have been utilized for many years to increase food production and control pest populations. Pesticide use can be both beneficial and harmful to humans and other organisms.

- (a) Pesticide use has advantages, disadvantages, and unintended consequences on human health. **Describe** one benefit to human health that can result from the use of pesticides.
- (b) **Identify** one way chemical pesticides can enter the human body.

Cotton farmers in the southern United States used a chemical pesticide to control an insect cotton-crop pest over a 40-year period. To study the effectiveness of the pesticide as an insect pest-control strategy, traps were placed in treated cotton fields and the number of pests captured were compared to application rates for the pesticide. The results of the study are shown in the table below.

Year	Grams of Pesticide Applied per Hectare	Number of Crop Insect Pests Captured
1960	0	700
1975	500	2
1980	500	3
1985	500	8
1990	550	14
1995	600	83
2000	700	150
2005	800	405
2010	900	727
2015	1,000	1,100

- (c) Use the data in the table to answer the following questions.
- (i) **Identify** the year when the pesticide was most effective at reducing the size of the pest population.
- (ii) **Describe** the change in the number of crop insect pests in the cotton fields over time.
- (iii) **Explain** how the change in the cotton-crop pesticide effectiveness between the initial application in 1975 and the latest application in 2015 illustrates genetic resistance in pests, based on the data in the table.
- (d) **Describe** TWO effects of pesticide use, other than death, on nontarget wildlife.

- (e) There are many problems associated with the repeated application of chemical pesticides to reduce pest populations.
- (i) Crop rotation is often used to reduce pesticide use. **Describe** the process of crop rotation.
- (ii) **Propose** one reasonable method, other than crop rotation, of reducing the use of pesticides in agricultural practices while still maintaining a high crop yield.
- (iii) **Justify** how the method proposed in (e)(ii) would provide a benefit to humans.

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.

5.7 Meat Production Methods

Name: _____ Class: _____ Date: _____

Total: 10 marks

KEY WORDS methane 甲烷

Objective

Build the skills to answer exam questions on **meat production methods**.

You must be able to:

- compare **feedlots (CAFOs)** and **free-range** methods
- explain the high resource cost of meat
- link meat to greenhouse gases and land/water use

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.

■ Two methods

- **Feedlots (CAFOs)** — animals densely confined, fed grain; high output but concentrated **waste** and antibiotic use.
- **Free-range/grazing** — animals roam and graze; lower waste concentration but needs more land.

■ Meat is resource-intensive

Producing meat needs far more **land, water, and grain** than plant food, because energy is lost moving up the trophic level (the 10% rule) — feeding grain to animals is inefficient.

■ Greenhouse gases

Livestock (especially cattle) release **methane**, a potent greenhouse gas; manure and feed production add more emissions.

■ A worked comparison

A kilogram of beef needs far more water and grain than a kilogram of grain eaten directly, because most of the feed's energy is lost as the animal lives.

2 Practice

Now apply the methods above.

2.1 What is a feedlot (CAFO)? [1]

2.2 Why does meat require more resources than plant food? [1]

2.3 Which greenhouse gas do cattle release? [1]

3 Exam-style questions

3.1 Producing meat is less efficient than eating plants directly because of [1]

- **A** the 10% rule (energy lost between trophic levels)
- **B** photosynthesis
- **C** the water cycle
- **D** plate tectonics

3.2 A region shifts from grain farming to beef feedlots.

(a) State two environmental impacts. [2]

(b) Explain why more grain is needed to produce the same food energy as meat. [2]

3.3 Explain one advantage and one disadvantage of free-range meat production versus feedlots. [2]

Solutions

2.1 A concentrated animal feeding operation where animals are densely confined and fed grain.

2.2 Energy is lost moving up a trophic level, so feeding grain to animals is inefficient.

2.3 Methane.

3.1 A — the 10% rule.

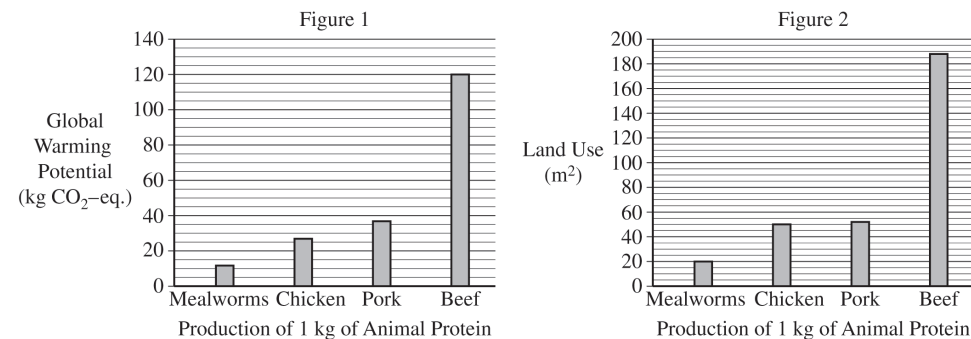
3.2 (a) Any two: concentrated waste/water pollution, methane emissions, high land/water/grain use. (b) Only ~10% of the grain's energy becomes animal tissue, so much more grain is needed to yield the same food energy as meat.

3.3 Advantage of free-range: waste is spread out (less concentrated pollution) and better animal welfare; disadvantage: it needs much more land per animal.

2. As the human population continues to grow, the demand for animal protein is expected to double by 2050.

Animal protein can be obtained from conventional livestock and other sources. The production of all animal protein has environmental costs, as shown in the following graphs. In Figure 1, global warming potential (GWP) is measured in kilograms of carbon dioxide equivalent (kg CO₂-eq). Carbon dioxide equivalent is a measure of the warming effect of a gas relative to that of carbon dioxide. In Figure 2, land use is measured in meters squared (m²).

Global Warming Potential and Land Use from Animal Protein Production



(a) Based on the data in the graphs, **identify** the amount of land required to produce 1 kilogram of chicken protein.

Mealworms, the larvae of the darkling beetle, consume grains and decaying plant material. Darkling beetles are an *r*-selected species, and the entire mealworm can be consumed by humans for protein.

(b) Based on the information provided, **identify** the type of survivorship curve exhibited by the darkling beetle.

(c) **Explain** why the reproductive strategy of the darkling beetle is an advantage for using mealworms as an alternative protein source for the rapidly growing human population.

An individual's diet choices affect greenhouse gas emissions and land use.

(d) Based on the data in the graphs, **explain** whether producing 1 kilogram of chicken protein or 1 kilogram of pork protein would cause less environmental damage.

Cattle emit methane from fermentation in their digestive systems. The other animals do not emit methane.

(e) Based on the data in the graphs, **explain** why the production of 1 kilogram of beef protein has a different impact on global warming than the production of 1 kilogram of protein from any of the other animals studied would have.

Agricultural practices can have negative impacts on rivers and streams.

(f) **Describe** how water quality can be altered by cattle grazing that occurs near a stream or river.

(g) **Propose** a solution to reduce the negative impacts on waterways that result from cattle grazing, while still allowing cattle to graze.

(h) Crop production can cause soil erosion. **Describe** a sustainable agricultural practice used to reduce soil erosion.

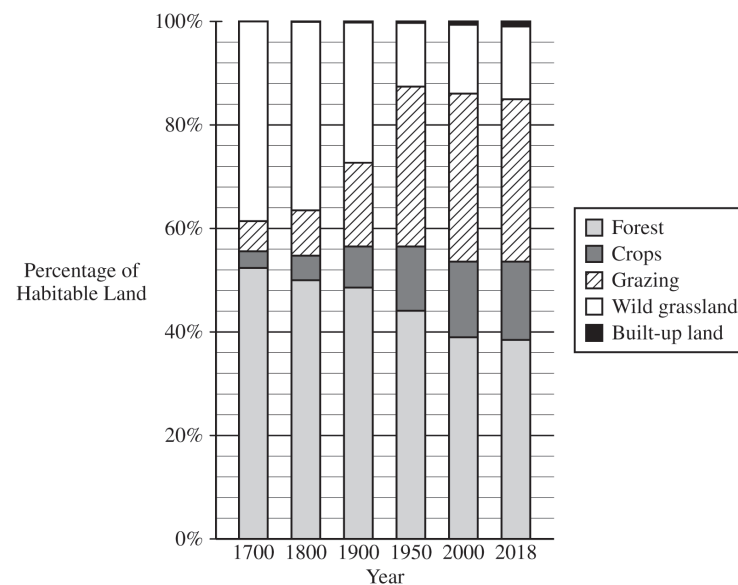
(i) **Justify** the use of the sustainable practice described in part (h) by describing an additional advantage, other than the reduction of soil erosion.

(j) Crop production around the world is affected by climate change. **Describe** how crop production could be negatively affected by climate change.

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.

3. Human activities generate large amounts of solid waste, including organic waste. The decomposition of organic waste in landfills can result in the release of methane into the atmosphere.

(a) **Describe** one environmental problem associated with the release of methane into the atmosphere.

There are biological and physical factors that can affect the decomposition of the solid waste in a landfill and the release of methane in the atmosphere.

(b) **Describe** one factor that could affect the decomposition of the solid waste in a landfill.

(c) **Propose** a solution to decrease the amount of methane released from landfills into the atmosphere.

(d) **Justify** the solution proposed in part (c) by describing an additional advantage, other than decreasing the amount of methane released from landfills.

Another anthropogenic activity that releases methane is raising beef cattle. In 2021, 31.2 million beef cattle were raised in the United States.

(e) The average cow releases 150 liters of methane per day. **Calculate** the amount of methane that was released by all beef cattle raised in the United States in 2021. **Show** your work.

Another environmental concern with raising beef cattle for food is that it is not as efficient as growing crops for food.

(f) A typical beef cow needs 11.8 kilograms of food per day, and each hectare of cattle pasture produces 26.2 kilograms of grasses. **Calculate** the number of hectares of pasture that would be needed to support all beef cattle raised in the United States for one day. **Show** your work.

(g) The average American consumes 2,250 kilocalories of food per day. Beef cattle can produce 2.7 million kilocalories per hectare of land. Corn can produce 30.4 million kilocalories per hectare of land. **Calculate** how many more American people could be fed if 150 hectares of land was used to grow corn instead of raising beef cattle. **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

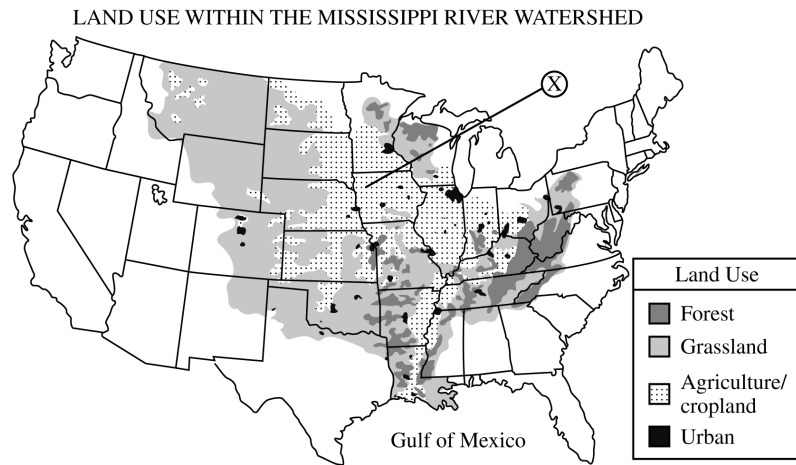
SECTION II

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 dead zone in the Gulf of Mexico occurs every summer when winter snow melts and spring rain flows into the Mississippi River. Recent studies have shown that both the total area covered by algae and the depth of the algal mass in the dead zone are increasing.



- (a) Various land use practices can have different effects on the waters that surround a dead zone.

- Identify** the land use that covers the least amount of area in the Mississippi River watershed, based on the diagram.
- Describe** one way that the land use practice at location X in the diagram could contribute to the dead zone in the Gulf of Mexico.
- Describe** one way that urban areas in the Mississippi River watershed could contribute to the dead zone in the Gulf of Mexico.

- (b) The dead zone in the Gulf of Mexico has both economic and environmental effects for coastal communities.

- Describe** how a dead zone affects marine organisms living in the Gulf of Mexico.
- Describe** one economic effect on communities along the Gulf of Mexico that can result from the presence of the dead zone.
- Describe** one factor that causes the area of the dead zone in the Gulf of Mexico to increase in the summer months.

- (c) Researchers want to examine the effect of riparian vegetation buffers on water quality in streams in agricultural areas. Researchers will measure the water nutrient concentrations over the course of one year. The study sites are located 100 meters downstream from areas either with or without riparian vegetation buffers.

- Identify** a testable hypothesis for the study.
- Describe** a control that the researchers could use in the study.
- Identify** one water quality test, other than measuring nitrates or phosphates, that the researchers could use to evaluate how riparian vegetation buffers affect water quality.
- During the investigation, researchers discovered that some of the land next to one of the streams with a riparian vegetation buffer is going to be converted from cornfields into a large-scale concentrated animal feeding operation. **Explain** one way that this change in land use could alter the results of the study.

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.

5.8 Impacts of Overfishing

Name: _____ Class: _____ Date: _____

Total: 9 marks

KEY WORDS overfishing 过度捕捞 • bycatch 兼捕

Objective

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

You must be able to:

- explain how **overfishing** 过度捕捞 collapses fish stocks
- describe **bycatch** 兼捕 and destructive methods
- suggest management (quotas, protected areas)

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.

■ How overfishing works

Fish are a **common resource**; catching them faster than they **reproduce** collapses the stock. Once a population falls too low, it may not recover.

■ Destructive methods

- **Bycatch** — non-target species (dolphins, turtles) caught and killed in nets.
- **Bottom trawling** — dragging nets over the seafloor destroys habitat.

■ Consequences

Collapsed fisheries harm the marine food web and the people who depend on fishing for food and income.

■ Management solutions

- **Catch quotas/limits** on how much can be taken.
- **Marine protected areas** where fishing is banned so stocks recover.
- **Selective gear** to reduce bycatch, and seasonal closures.

2 Practice

Now apply the methods above.

2.1 Why does overfishing collapse a fish stock? [1]

2.2 What is bycatch? [1]

2.3 State one method to manage a fishery sustainably. [1]

3 Exam-style questions

3.1 A marine protected area helps fish stocks by [1]

- **A** allowing unlimited fishing
- **B** banning fishing so populations recover
- **C** removing all fish
- **D** adding pollutants

3.2 A commercial fishery catches fish faster than they reproduce.

(a) Predict what happens to the fish population. [1]

(b) Explain two ways this could be prevented. [2]

3.3 Explain why bottom trawling is especially damaging to marine ecosystems. [2]

Solutions

2.1 Fish are caught faster than they can reproduce, so the population shrinks and may not recover.

2.2 Non-target species caught (and often killed) while fishing.

2.3 Any one: catch quotas, marine protected areas, selective gear, seasonal closures.

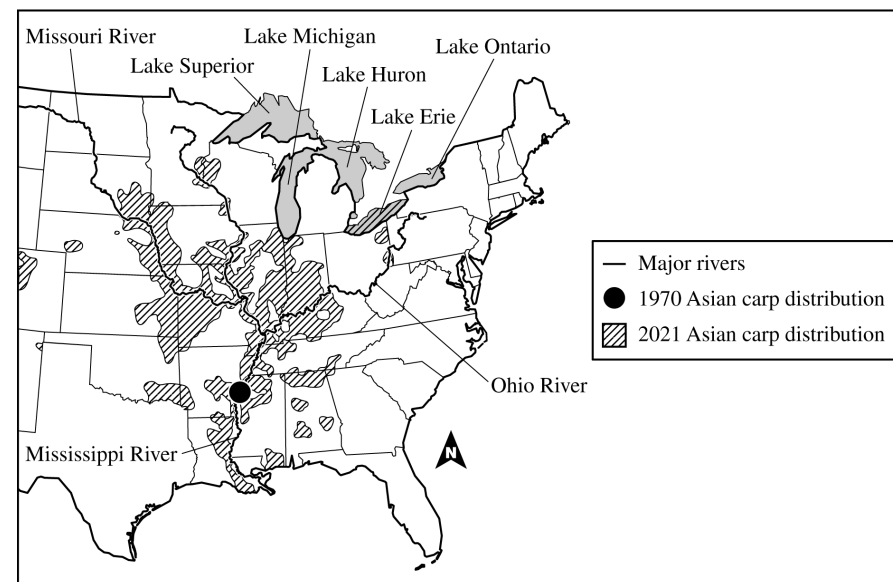
3.1 B — banning fishing so populations recover.

3.2 (a) It declines and may collapse. (b) Any two: catch quotas, marine protected areas, selective gear, seasonal closures.

3.3 Dragging nets over the seafloor destroys the habitat and organisms living there, not just the target fish, damaging the whole ecosystem.

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.



5.9 Impacts of Mining

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

KEY WORDS surface 露天开采 • mining 采矿 • subsurface 地下开采
• acid mine drainage 酸性矿山废水

Objective

Build the skills to answer exam questions on **impacts of mining**.

You must be able to:

- compare **surface** 露天开采 and **subsurface** 地下开采 mining
- describe impacts (habitat loss, **acid mine drainage** 酸性矿山废水, tailings)
- suggest reclamation

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.

■ Two mining types

- **Surface mining** (open-pit, strip, mountaintop removal) — removes overlying rock/soil; cheap but destroys large areas of habitat.
- **Subsurface mining** — tunnels underground; less surface damage but more dangerous for workers.

■ Impacts

- **Habitat destruction** and soil removal.
- **Acid mine drainage** — water reacting with exposed sulfide rock becomes acidic and toxic, polluting streams.
- **Tailings** — leftover waste that can leach toxic metals.

■ Reclamation

Reclamation restores mined land — replacing soil, replanting vegetation, and treating polluted water — to recover some ecosystem function.

■ A worked link

Rain washing through exposed sulfide-rich rock produces acid mine drainage that lowers stream pH and kills aquatic life downstream.

2 Practice

Now apply the methods above.

2.1 State one difference between surface and subsurface mining. [1]

2.2 What is acid mine drainage? [1]

2.3 What is reclamation? [1]

3 Exam-style questions

3.1 Acid mine drainage harms streams by [1]

- **A** raising their pH
- **B** lowering their pH and adding toxic metals
- **C** adding oxygen
- **D** cooling the water

3.2 A company strip-mines a forested hillside.

(a) State two environmental impacts. [2]

(b) Suggest one way to restore the land afterward. [1]

3.3 Explain how acid mine drainage forms and why it harms aquatic life. [2]

Solutions

2.1 Surface mining removes overlying rock/soil (more habitat damage); subsurface mining tunnels underground (less surface damage).

2.2 Acidic, metal-laden water from mines that pollutes streams.

2.3 Restoring mined land (soil, vegetation, water treatment).

3.1 B — lowering their pH and adding toxic metals.

3.2 (a) Any two: habitat destruction, soil loss, acid mine drainage, tailings pollution. (b) Reclamation — replace soil and replant vegetation.

3.3 Water reacts with exposed sulfide minerals to form acid; this acidic, metal-rich water lowers stream pH, which is toxic to fish and other aquatic organisms.

The local government of a newly built town has contracted with an electrical company to provide energy to the town. The company generates electricity primarily through the burning of coal and has built a new power plant for the town. A nearby deposit of coal was discovered close to the surface. To access the coal, the company decides to remove the overburden and vegetation over the deposit.

3. Respond to parts A, B, C, D, E, F, and G.

A. **Identify** a type of surface mining the company could use to access the coal.

B. **Describe** an environmental problem associated with surface mining.

C. The town is located downwind of the new coal-burning power plant.

Describe an environmental problem the town could experience as a result of the electricity generation at the coal-burning power plant.

D. The local government is concerned about the environmental consequences of using coal to generate electricity for the town.

Propose a realistic solution the local government could enact that would reduce the negative environmental consequences of using coal to generate electricity.

E. Burning one pound of coal produces an average of 0.88 kilowatt-hours (kWh) of electricity. An average household in the United States uses 1.064×10^4 kWh of electricity each year.

Calculate how many pounds of coal would need to be burned to generate enough electricity to power a town with 11,000 houses for a year. **Show** your work.

F. Researchers are concerned about the impact of noise pollution on songbirds in a forest near the power plant. Since the power plant was installed, bird species richness has declined from 7.5 species per hectare to 6.0 species per hectare.

Calculate the percent change in bird species per hectare since the power plant was installed. **Show** your work.

G. The town has been growing since it was built and had a growth rate of 5.38% in 2022, with a population of 26,250.

Assuming that the growth rate remains constant, **calculate** the year in which the population will reach 52,500. **Show** your work.

STOP
END OF EXAM



3. Crude oil is extracted, transported, and refined for various uses by humans.

(a) **Describe** one environmental impact on marine ecosystems associated with extraction or transportation of crude oil.

(b) **Identify** an atmospheric pollutant released during the combustion of refined oil products.

(c) **Propose** a solution an individual can use to reduce their reliance on refined oil products for transportation.

(d) **Justify** the solution proposed in part (c) by providing a benefit to human health.

Other natural resources, such as gold and silver, are also extracted. These resources can be used to make components for the electronics humans use. One metric ton of gold ore contains 5.0 grams of gold.

(e) A deposit is estimated to contain 260 million metric tons of gold ore. **Calculate** the number of grams of gold that could be extracted from the deposit. **Show** your work.

(f) Assuming the price of gold is \$62.56 per gram, **calculate** the value of the gold that could be recovered from 1,000 metric tons of gold ore in the deposit. **Show** your work.

(g) A typical cell phone contains 0.034 grams of gold. **Calculate** how many metric tons of gold ore would need to be mined to extract enough gold to manufacture 100,000 cell phones. **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

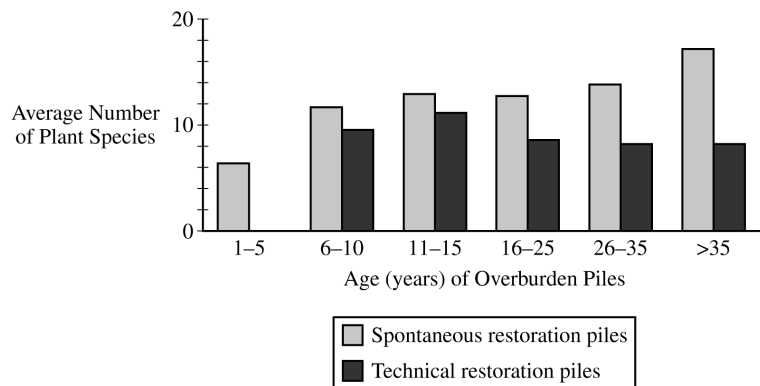
Time—1 hour and 10 minutes

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.

2. Iron ores are rocks from which metallic iron can be extracted for steel production. This process involves several steps. Iron ore is first mined and then turned into pig iron in a blast furnace, and some rock waste such as silicon dioxide is separated out. In the final step, the pig iron is refined into steel using a process that includes reacting the molten pig iron with oxygen to remove impurities.

(a) Use the data below to respond to the following. For each calculation, show all your work.

Global Iron and Steel Data
1.6 billion tons of iron ore are used yearly to make pig iron.
1.2 billion tons of pig iron are produced each year.
Iron ore reserves are estimated to be 800 billion tons.
95% of iron ore that is mined is used in steel production.

- (i) **Calculate** the weight (in tons) of rock waste produced globally each year when iron ore is converted to pig iron.
- (ii) **Calculate** the weight (in tons) of pig iron that could be produced if all of the estimated global iron ore reserves were used for pig iron production.
- (iii) **Calculate** the weight (in tons) of the current global iron ore reserves that would be used to make steel if the current trends continue.

Both iron ore and coal are mined for use in the manufacture of steel. It is estimated that for every ton of steel recycled, 1.25 fewer tons of iron ore and 0.7 fewer tons of coal must be mined. About 80 million tons of steel are recycled each year in North America.

(b) **Calculate** the weight (in tons) of coal that is conserved each year in North America by recycling steel.

Before the year 1900, most mining companies abandoned surface and subsurface coal mine sites once the resource was depleted.

- (c) **Describe** TWO environmental problems that are associated with abandoned coal mine sites.
- (d) **Describe** one method that can be used to mitigate one of the problems you identified in part (c).
- (e) **Discuss** one reason why surface coal mining is generally less expensive than subsurface mining.

5.10 Impacts of Urbanization

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

KEY WORDS urbanization 城市化 • urban sprawl 城市扩张 • urban heat island 城市热岛
• impervious surfaces 不透水面 • green roofs 绿色屋顶

Objective

Build the skills to answer exam questions on **impacts of urbanization**.

You must be able to:

- describe **urban sprawl** 城市扩张 and **impervious surfaces** 不透水面
- link paving to runoff, flooding, and the **urban heat island** 城市热岛
- suggest smart-growth solutions

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.

■ Urbanization impacts

As cities grow (**urban sprawl**), natural land is replaced with **impervious surfaces** (roads, roofs) that water cannot soak into.

■ Runoff and flooding

Impervious surfaces increase **runoff** and reduce **infiltration**, causing more **flooding** and carrying pollutants (oil, litter) into waterways.

■ Urban heat island

Cities are warmer than surrounding areas (the **urban heat island effect**) because dark surfaces absorb heat and there is little vegetation to cool the air.

■ Smart growth

Solutions include **mixed-use**, **dense development**, public transit, green roofs, and preserving green space — reducing sprawl and its impacts.

2 Practice

Now apply the methods above.

2.1 What is an impervious surface? [1]

2.2 How does paving affect runoff and infiltration? [1]

2.3 What is the urban heat island effect? [1]

3 Exam-style questions

3.1 Cities are often warmer than surrounding rural areas because of the [1]

- **A** rain shadow effect
- **B** urban heat island effect
- **C** Coriolis effect
- **D** greenhouse effect only

3.2 A city expands, paving over fields.

(a) Explain how this increases flooding. [2]

(b) Suggest one smart-growth solution. [1]

3.3 Explain why the urban heat island effect occurs. [2]

Solutions

2.1 A surface (road, roof) that water cannot soak into.

2.2 It increases runoff and reduces infiltration.

2.3 Cities being warmer than surrounding rural areas.

3.1 B — the urban heat island effect.

3.2 (a) Paving stops water soaking in, so more runs off quickly over the hard surfaces, overwhelming drainage and causing floods. (b) Any one: green roofs, permeable pavement, preserving green space, denser development.

3.3 Dark paved surfaces and buildings absorb and re-radiate heat, and there is little vegetation to cool the air by shade and transpiration, so cities stay hotter.

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

Ocelots are small wildcats that were previously found in 25 counties in Texas where shrubland is prevalent. As a result of land use changes, only 74 ocelots remain in 4 counties in Texas today. Rodents such as pocket mice are the main source of food for ocelots, but ocelots also prey on other small animals such as snakes and lizards.

3. Respond to parts A, B, C, D, E, and F, and all subparts.

Part A

Identify one environmental consequence that could result from having a smaller population of ocelots.

Part B

Calculate the percent change in the number of Texas counties where ocelots have been found historically as compared to today. **Show** your work.

Part C

Researchers expect the ocelot population to grow at a constant rate of 2.8% per year. **Calculate** the number of years it will take for the ocelot population to double based on a constant rate of growth. **Show** your work.

Part D

Pocket mice eat plants in the shrubland, while snakes are carnivores. **Explain** why the amount of primary production energy available to ocelots would change if ocelots ate only carnivores such as snakes and not pocket mice.

Part E

Ocelots need 720 grams of food per day. Pocket mice weigh an average of 43 grams each. If the ocelot diet consists of 46% pocket mice by weight, **calculate** how many pocket mice an ocelot would need to consume in one day, assuming each mouse weighs the average amount. **Show** your work.

Part F

As urbanization has increased in southern Texas, motor vehicle collisions have become the main cause of death in ocelots, which poses an added threat to the remaining ocelots.

- i. **Propose** a realistic solution to reduce the number of ocelots killed by vehicles.
- ii. **Justify** the solution proposed in part F (i) by explaining an additional advantage, other than reducing the number of ocelots killed by vehicles.

STOP
END OF EXAM

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

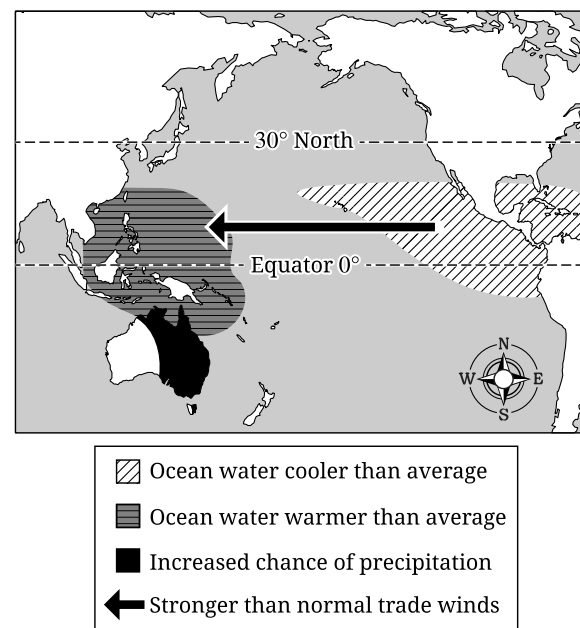
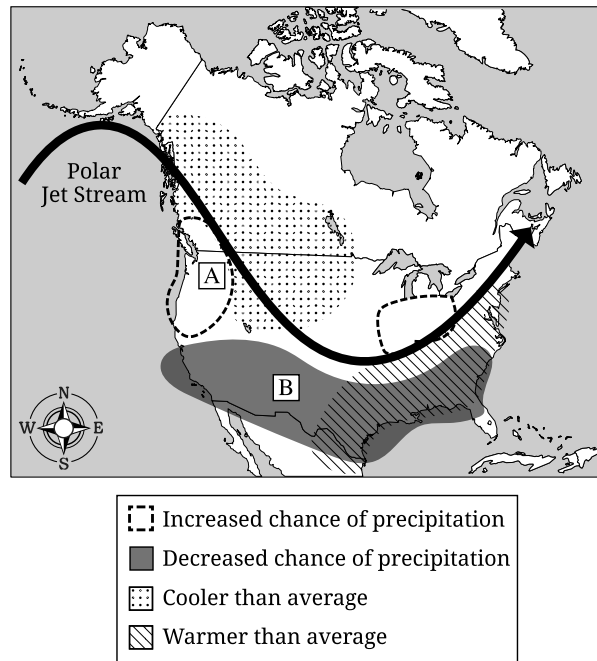


Figure 2. Polar Jet Stream and Climate Conditions in North America

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.

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.

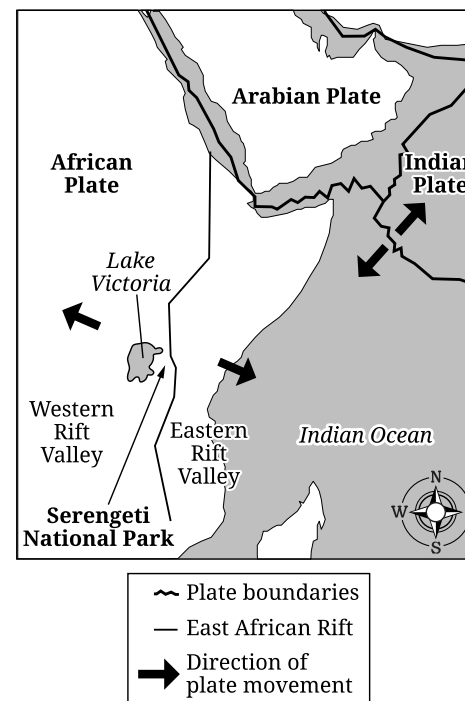
Sea Level Rise and Number of Wading Bird Species at Four Coastal Locations

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.

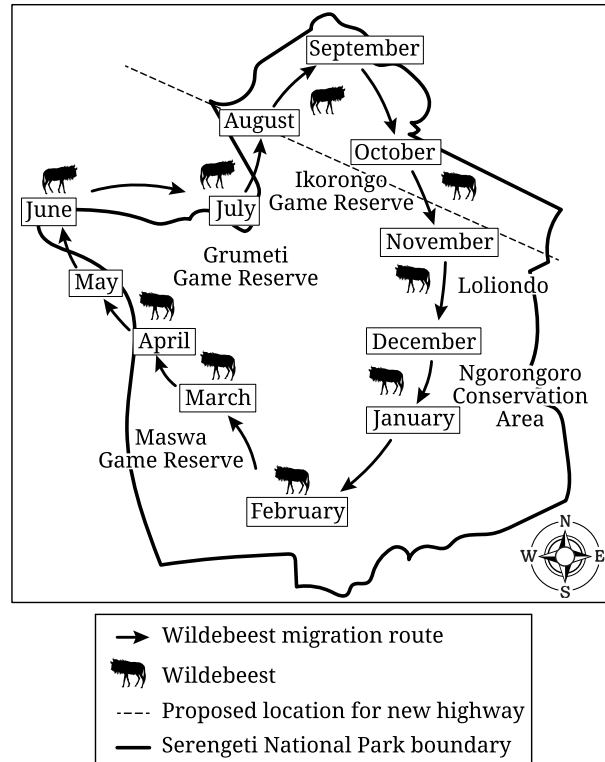
Serengeti National Park is located in Tanzania, Africa. The park is located in a valley along a tectonic plate boundary called the East African Rift. Figure 1 shows the East African Rift and other plate boundaries near the east coast of Africa.

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



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.

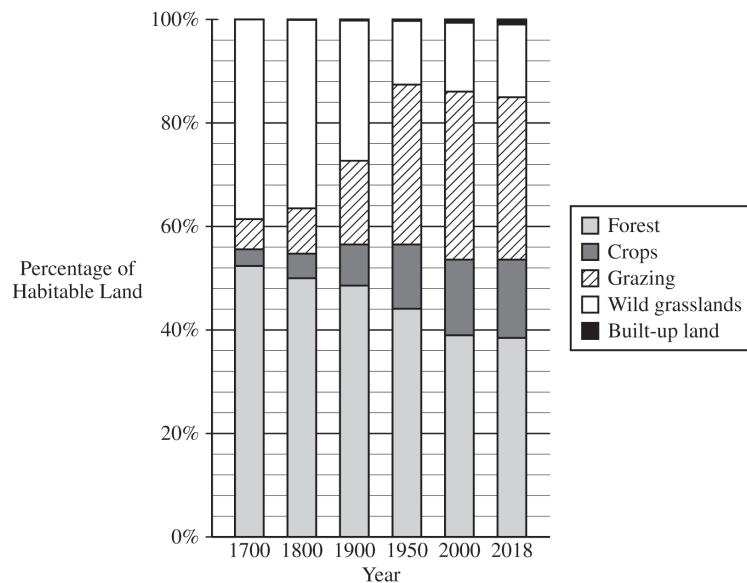
- F. Propose** a solution to the negative effect created by the planned highway described in part E.
- G.** Many organisms live in grasslands. One weed species, the spotted knapweed, was introduced at one location in North America in the 1890s and is currently found throughout the rangelands of the western 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.

3. Increasing global urbanization causes associated problems such as the formation of urban heat islands.

- (a) **Describe** how urbanization leads to the formation of urban heat islands.
- (b) Urban heat islands have been linked to a variety of environmental problems.
- Propose** a reasonable solution that could help lower the temperature increases caused by urban heat islands.
 - Justify** the solution proposed in part (b)(i) by providing one additional benefit other than reducing temperatures in urban heat islands.
- (c) Urban areas are increasingly using solar energy to generate electricity for residences and businesses.
- As a result of improved technology, the efficiency of solar panels has changed over time. In 1992 a solar cell had a maximum efficiency of 15.9%. In 2017 a solar cell prototype capable of 44.5% efficiency was produced. **Calculate** the percent change in efficiency from the 1992 cell to the 2017 cell. **Show** your work.
 - The average home in the United States uses 12,900 kWh of electricity per year. The local power company is raising the cost of purchasing electricity from \$0.11 per kWh to \$0.13 per kWh. Assuming a home uses the average kWh of electricity in one year, **calculate** the change in electricity cost for one year for the homeowner. **Show** your work.
 - The roof of a typical house in the United States receives a total of four hours of sunlight per day that can be converted by solar panels into electricity. A house has 30 solar panels on its roof, and each panel generates a maximum output of 300 watts. **Calculate** how many kWh can be produced by the system at maximum output in one calendar year. **Show** your work.
- (d) **Explain** why the Northern Hemisphere receives more solar energy from the Sun between June and August than the Southern Hemisphere receives between June and August.

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

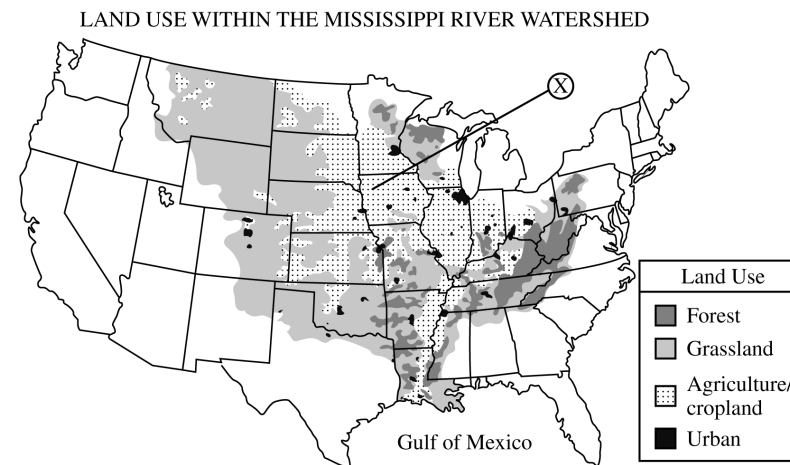
SECTION II

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 dead zone in the Gulf of Mexico occurs every summer when winter snow melts and spring rain flows into the Mississippi River. Recent studies have shown that both the total area covered by algae and the depth of the algal mass in the dead zone are increasing.



- (a) Various land use practices can have different effects on the waters that surround a dead zone.
- Identify** the land use that covers the least amount of area in the Mississippi River watershed, based on the diagram.
 - Describe** one way that the land use practice at location X in the diagram could contribute to the dead zone in the Gulf of Mexico.
 - Describe** one way that urban areas in the Mississippi River watershed could contribute to the dead zone in the Gulf of Mexico.

- (b) The dead zone in the Gulf of Mexico has both economic and environmental effects for coastal communities.
- (i) **Describe** how a dead zone affects marine organisms living in the Gulf of Mexico.
 - (ii) **Describe** one economic effect on communities along the Gulf of Mexico that can result from the presence of the dead zone.
 - (iii) **Describe** one factor that causes the area of the dead zone in the Gulf of Mexico to increase in the summer months.
- (c) Researchers want to examine the effect of riparian vegetation buffers on water quality in streams in agricultural areas. Researchers will measure the water nutrient concentrations over the course of one year. The study sites are located 100 meters downstream from areas either with or without riparian vegetation buffers.
- (i) **Identify** a testable hypothesis for the study.
 - (ii) **Describe** a control that the researchers could use in the study.
 - (iii) **Identify** one water quality test, other than measuring nitrates or phosphates, that the researchers could use to evaluate how riparian vegetation buffers affect water quality.
 - (iv) During the investigation, researchers discovered that some of the land next to one of the streams with a riparian vegetation buffer is going to be converted from cornfields into a large-scale concentrated animal feeding operation. **Explain** one way that this change in land use could alter the results of the study.

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.

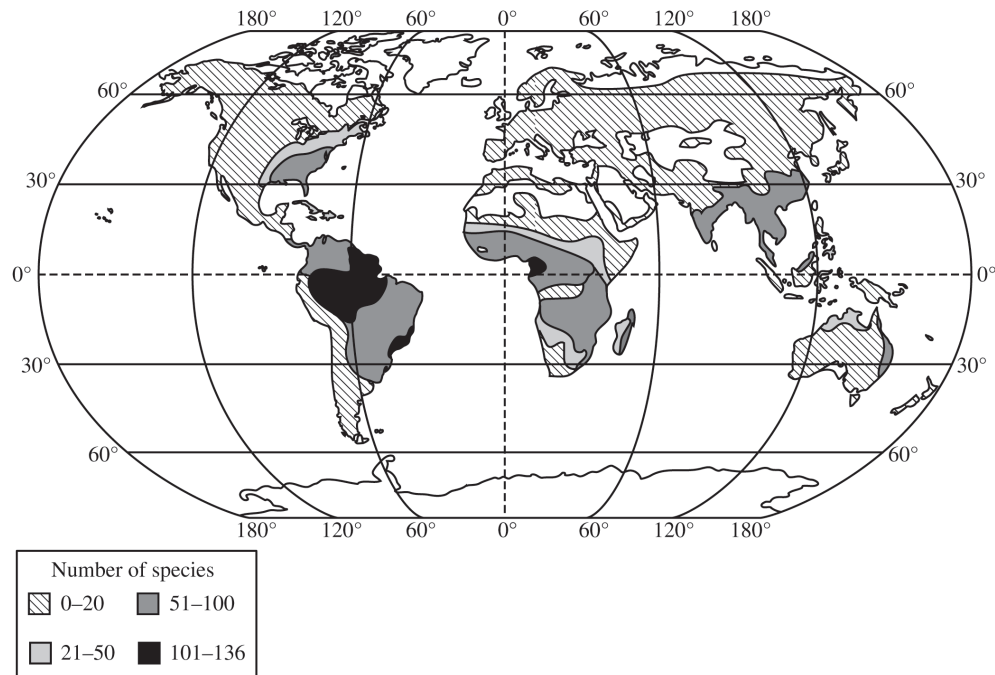
- (b) **Identify** the symbiotic relationship between the wood thrush and the cowbird.
- (c) **Describe** one ecological advantage of leaving areas of undeveloped forest in the development plan as compared to clear-cutting the property.
- (d) **Propose** a solution that will minimize the effect of development 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.

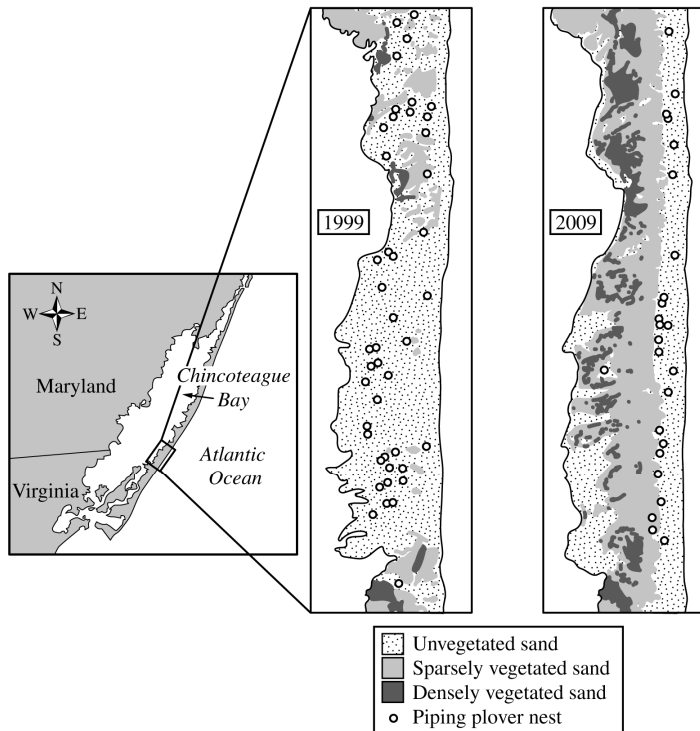
ENVIRONMENTAL SCIENCE**SECTION II****Time—1 hour and 30 minutes****4 Questions**

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.

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 article below and answer the questions that follow.

The Floridian Daily

May 21, 2013

The small community located on the edge of the magnificent wetlands of Florida's Everglades was the site of a press conference today where Governor Gayle Moss announced that the restoration of the Everglades is successfully underway. She noted that the Everglades ecosystem has suffered threats to its water quality, water quantity, and habitats in recent decades. Moss noted that intensive urban and agricultural development in adjacent areas has diverted substantial amounts of

freshwater resources and impaired water quality. Governor Moss then emphasized that the preservation and enhancement of the Everglades, key goals of the restoration program, are absolutely essential for the continued environmental and economic health of the state. She closed the press conference by saying, "The Everglades is a gem not only for Florida but for the entire world. Each of us has the responsibility to do our part to preserve this magnificent resource."

- (a) **Describe** how TWO human activities, other than those that result in anthropogenic climate change, have resulted in a decrease in the amount of freshwater flowing into the Everglades ecosystem.
- (b) In addition to water quantity problems, the Everglades is faced with a variety of water quality issues. For example, phosphorus concentrations in the Everglades have increased since the 1960s.
- Describe** how one specific human activity contributes to increased phosphorus levels in the Everglades.
 - Explain** one way in which an increase in phosphorus levels can adversely affect the Everglades ecosystem.
 - Describe** one step that could be taken to reduce phosphorus inputs from the activity you identified in part (i).
- (c) Climate change could have a variety of impacts on water quantity, water quality, and habitat. For EACH of these three factors, **identify and describe** one specific example of an impact on the Everglades likely to result from climate change.
- (d) The article states that Governor Moss believes that the "preservation and enhancement of the Everglades, key goals of the restoration program, are absolutely essential for the continued environmental and economic health of the state."
- Describe** one way that restoring water quantity and water quality in the Everglades is expected to improve the structure and function of the ecosystem.
 - Describe** one way that restoring the Everglades is expected to provide economic benefits to Florida.

2. Like many communities, Fremont has a combined sewer system that collects both sewage and storm water. When storm water runs into storm drains that connect to the city's sanitary sewer system, the storm water and sewage flow together to the Fremont Wastewater Treatment Plant (FWTP). During a major storm event, however, the combined volume of storm water and sewage may exceed the plant's capacity, and the overflow bypasses the FWTP. The untreated overflow is discharged into Fremont Creek along with the treated waste.

Recently parts of Fremont received 5 cm of rain in 60 minutes. The storm caused widespread flooding in the northeast section of town. Especially hard hit was the Shoppes at Fremont shopping center.

Use the data from the table below to answer the questions that follow. Show all calculations.

Fremont Water Data
The shopping center's parking lot is 200 meters long and 100 meters wide.
Fremont has an area of 10 km ² .
Impervious surfaces cover 20 percent of Fremont's area.
The FWTP typically treats 5,000 m ³ of domestic sewage per day.
The FWTP has the capacity to treat 10,000 m ³ of combined sewage and storm water per day.

- (a) **Identify** TWO specific pollutants in storm-water runoff that degrade the quality of surface water.
- (b) **Calculate** the volume of water (in m³) that runs off the Shoppes at Fremont parking lot after a 5 cm rainfall event. Assume that all the water that falls on the parking lot runs off.
- (c) **Calculate** the volume of storm-water runoff (in m³) generated in all of Fremont by the 5 cm rainfall event. Assume that only the impervious surfaces generate runoff.
- (d) Assume that all the runoff that you calculated in part (c) is captured by the storm sewers in one day. **Calculate** the volume of untreated water (in m³) that bypasses the plant as a result of the storm. (Note that the plant still receives 5,000 m³ of domestic sewage per day.)
- (e) **Describe** TWO ways that the volume of storm-water runoff can be reduced.
- (f) **Describe** one environmental problem (other than pollution from runoff and from untreated sewage) that results from having extensive paved areas.

5.11 Ecological Footprints

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

KEY WORDS ecological footprint 生态足迹

Objective

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

You must be able to:

- define an **ecological footprint** 生态足迹
- explain what raises or lowers it
- compare footprints between countries

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.

■ The ecological footprint

An **ecological footprint** is the area of land and water needed to supply a person’s (or population’s) resources and absorb their waste.

■ What raises it

A larger footprint comes from **high consumption**: more meat, energy, driving, and goods. Wealthy, developed countries tend to have **large** footprints per person.

■ What lowers it

Using less energy, eating lower on the food chain, recycling, and using renewable energy **lower** the footprint.

■ Overshoot

If humanity’s total footprint exceeds Earth’s **biocapacity** (what it can regenerate), we are in **overshoot** — using resources faster than they renew.

2 Practice

Now apply the methods above.

2.1 Define an ecological footprint. [1]

2.2 State one factor that increases a person’s footprint. [1]

2.3 State one way to lower your footprint. [1]

3 Exam-style questions

3.1 A person with a large ecological footprint most likely has [1]

- **A** low resource consumption
- **B** high resource consumption
- **C** no impact
- **D** a plant-based diet only

3.2 Two countries: one wealthy and high-consuming, one lower-income.

(a) Which likely has the larger per-person footprint? [1]

(b) Explain why. [2]

3.3 Explain what it means for humanity to be in ecological “overshoot”. [2]

Solutions

2.1 The area of land and water needed to supply a person's resources and absorb their waste.

2.2 Any one: high energy use, meat-heavy diet, driving, buying many goods.

2.3 Any one: use less energy, eat lower on the food chain, recycle, use renewables.

3.1 B — high resource consumption.

3.2 (a) The wealthy, high-consuming country. (b) Its people consume more energy, food, and goods and produce more waste, requiring more land and water per person.

3.3 Overshoot means humanity's total footprint exceeds Earth's biocapacity, so resources are being used faster than the planet can regenerate them.

Name:

AP Environmental Science: 2018

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.

5.12 Introduction to Sustainability

Name: _____ Class: _____ Date: _____ **Total: 10 marks**

KEY WORDS renewable 可再生 • sustainable yield 可持续产量 • nonrenewable 不可再生
• sustainability 可持续性

Objective

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

You must be able to:

- define **sustainability** 可持续性
- distinguish **renewable** 可再生 and **nonrenewable** 不可再生 resources
- explain **sustainable yield** 可持续产量

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.

■ Sustainability

Sustainability means meeting present needs **without** reducing the ability of future generations to meet theirs — living within the planet's limits.

■ Renewable vs nonrenewable

- **Renewable** — replenished naturally on a human timescale (sunlight, wind, trees if replanted).
- **Nonrenewable** — finite, formed over millions of years (fossil fuels, minerals).

■ Sustainable yield

The **sustainable yield** is the amount that can be harvested **without** depleting the resource — e.g. catching only as many fish as are replaced by reproduction.

■ A worked idea

Harvesting trees no faster than they regrow keeps the forest productive indefinitely — a sustainable yield.

2 Practice

Now apply the methods above.

2.1 Define sustainability. [1]

2.2 Classify each: (a) coal, (b) wind. [2]

2.3 What is a sustainable yield? [1]

3 Exam-style questions

3.1 A nonrenewable resource is one that [1]

- **A** is replenished quickly
- **B** takes millions of years to form
- **C** never runs out
- **D** is only sunlight

3.2 A forest is harvested for timber.

(a) Explain what “sustainable yield” means for this forest. [2]

(b) State what happens if harvest exceeds the sustainable yield. [1]

3.3 Explain why fossil fuels are considered nonrenewable even though they form naturally. [2]

Solutions

2.1 Meeting present needs without reducing future generations' ability to meet theirs.

2.2 (a) nonrenewable; (b) renewable.

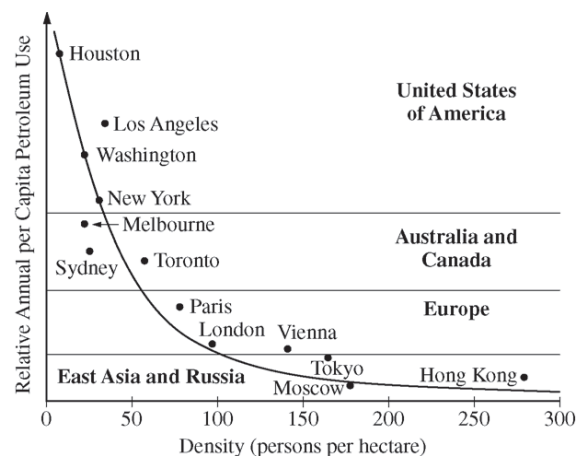
2.3 The amount that can be harvested without depleting the resource.

3.1 B — takes millions of years to form.

3.2 (a) Harvesting trees no faster than they regrow, so the forest stays productive indefinitely. (b) The forest is depleted (declines/degraded).

3.3 They form over millions of years — far slower than we use them — so on a human timescale they cannot be replenished and are effectively finite.

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

5.13 Methods to Reduce Urban Runoff

Name: _____ Class: _____ Date: _____ Total: 10 marks

KEY WORDS permeable pavement 透水路面 • green roofs 绿色屋顶 • rain gardens 雨水花园
 • impervious surfaces 不透水面

Objective

Build the skills to answer exam questions on **methods to reduce urban runoff**.

You must be able to:

- describe green infrastructure (**permeable pavement** 透水路面, **rain gardens** 雨水花园, green roofs)
- explain how each reduces runoff and pollution
- link solutions to the problem of impervious surfaces

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.

■ The problem

Cities' **impervious surfaces** cause heavy runoff that floods and carries pollutants to waterways. Solutions let water **soak in** instead.

■ Green infrastructure

- Permeable pavement** — lets water pass through into the ground.
- Rain gardens** — planted depressions that collect and absorb runoff.
- Green roofs** — vegetation on roofs that absorbs rain and cools buildings.
- Retention/detention ponds** — hold runoff and release it slowly.

■ How they help

They increase **infiltration**, reduce peak runoff (less flooding), and filter pollutants before water reaches rivers.

■ A worked link

A rain garden collects roof runoff, letting it soak into the soil where plants and soil filter out pollutants — reducing both flooding and water pollution.

2 Practice

Now apply the methods above.

2.1 How does permeable pavement reduce runoff? [1]

2.2 What is a rain garden? [1]

2.3 State one benefit of a green roof. [1]

3 Exam-style questions

3.1 Permeable pavement reduces flooding by allowing water to [1]

- **A** run off faster
- **B** soak into the ground
- **C** evaporate instantly
- **D** freeze

3.2 A city installs rain gardens and permeable pavement.

(a) Explain how these reduce runoff and pollution. [3]

(b) State the underlying problem they address. [1]

3.3 Explain how green roofs reduce both runoff and the urban heat island effect. [2]

Solutions

2.1 It lets water pass through into the ground instead of running off.

2.2 A planted depression that collects and absorbs runoff.

2.3 Any one: absorbs rain (less runoff), cools the building, reduces heat island.

3.1 B — soak into the ground.

3.2 (a) They increase infiltration so less water runs off (less flooding), and soil/plants filter pollutants before the water reaches rivers. (b) Impervious surfaces causing runoff.

3.3 The vegetation absorbs rainwater (reducing runoff) and cools the air through shade and transpiration, lowering the urban heat island effect.

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

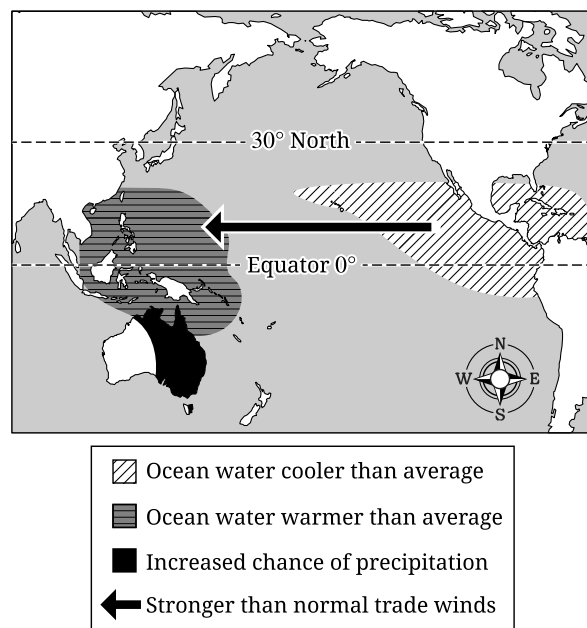
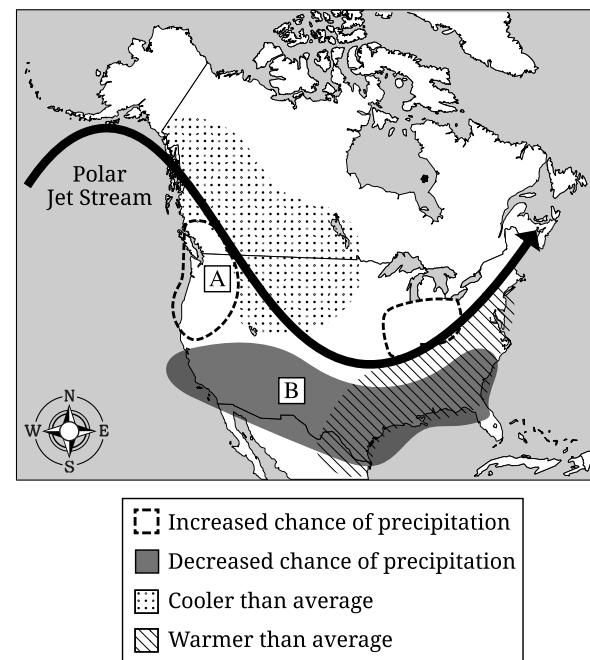


Figure 2. Polar Jet Stream and Climate Conditions in North America



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

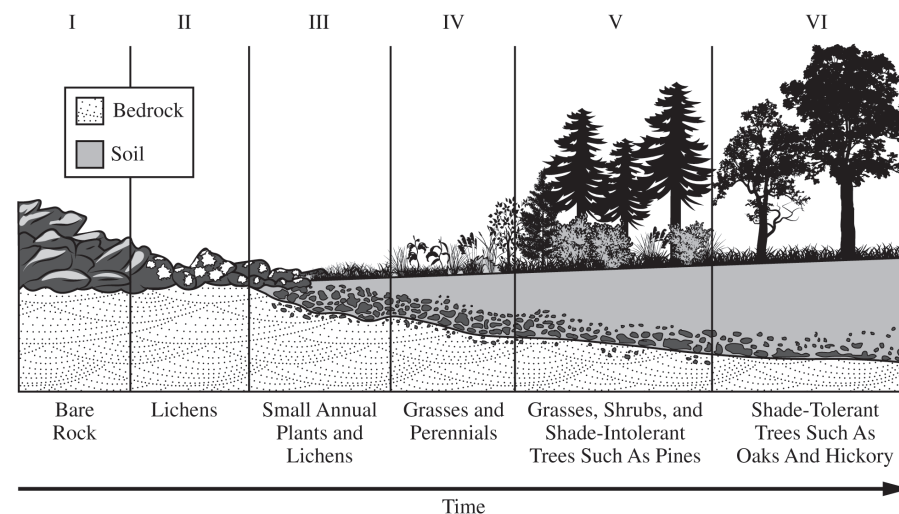
SECTION II

Time—1 hour and 10 minutes

3 Questions

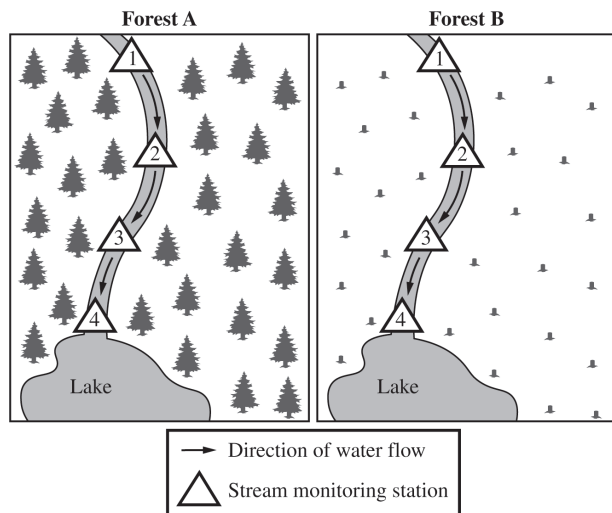
Directions: Answer all three questions, which are weighted equally; the suggested time is about 22 minutes for answering each question. Write all your answers in the Free Response booklet. Where calculations are required, clearly show how you arrived at your answer. Where explanation or discussion is 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.



- (a) **Identify** the ecological change over time illustrated in the diagram.
- (b) **Identify** the stage in which pioneer species first appear.
- (c) **Describe** how soil forms from stage II to stage III.
- (d) **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.



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

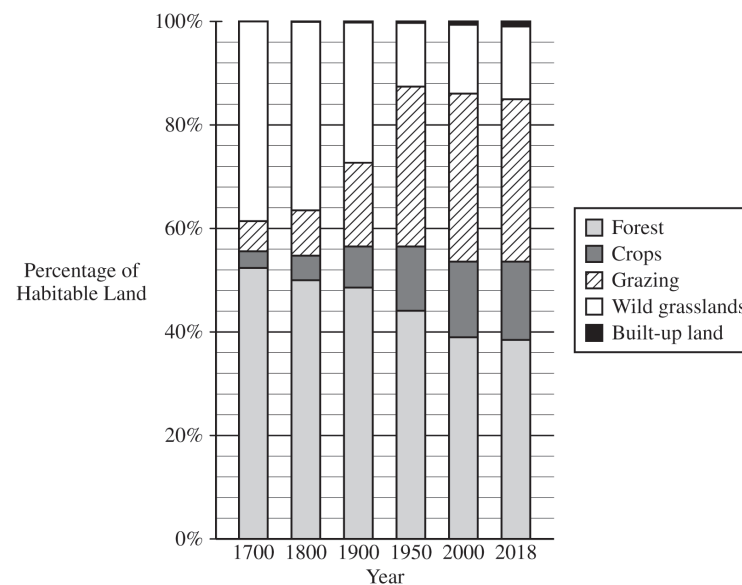
After the experiment was completed, land developers constructed a golf course in the clear-cut area of forest B. To prepare the land, developers removed any remaining stumps and newly grown trees and began planting and fertilizing new grass. The researchers are interested in the effect the golf course 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.

- (i) **Explain** why an indicator of water quality other than temperature could be altered by the golf course in forest B.
- (j) **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.

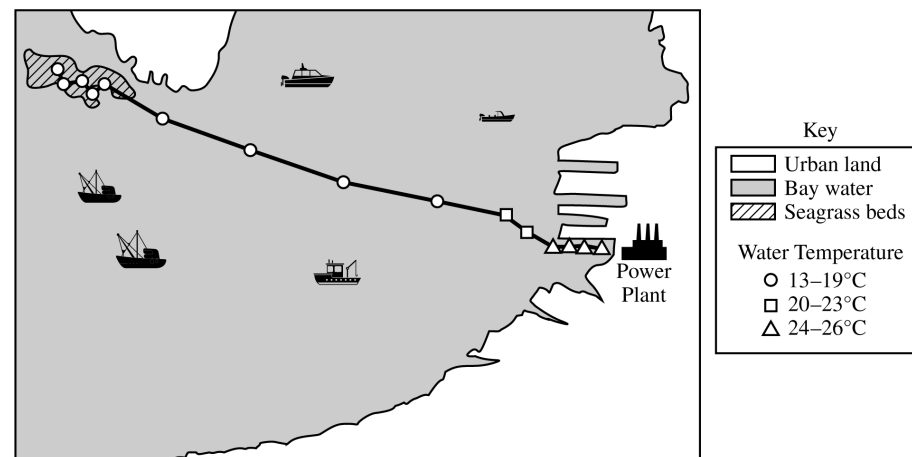
- (i) **Propose** a solution to improve the chances that the bobcat reintroductions will be successful in reestablishing wild populations.

- (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. 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.

(i) **Propose** a solution to reduce nutrient or sediment pollution in an estuary that is surrounded by urban development.

(ii) **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.

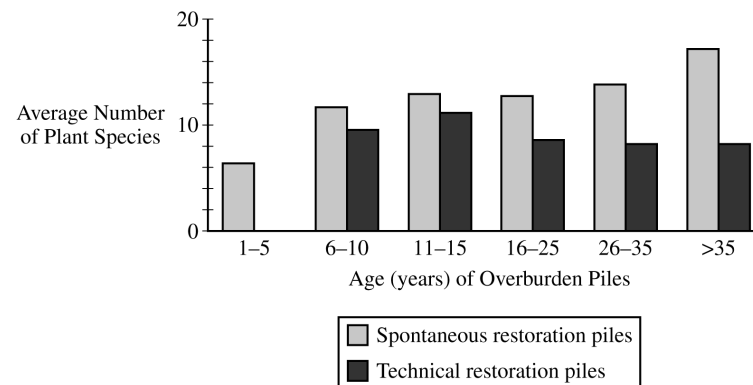
Begin your response to this question at the top of a new page in the separate Free Response booklet and fill in the appropriate circle at the top of each page to indicate the question number.

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.

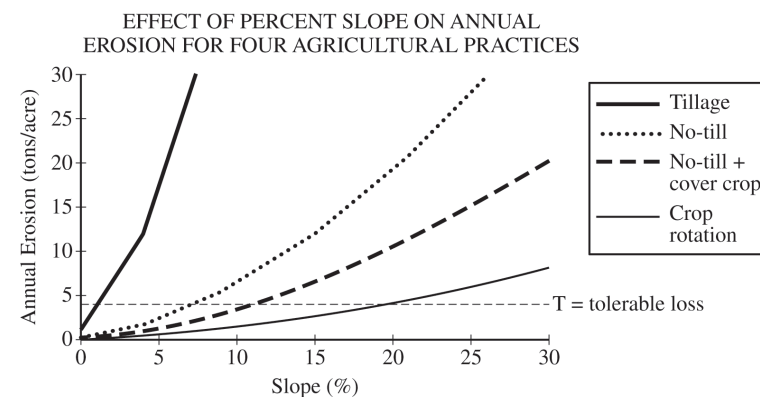
ENVIRONMENTAL SCIENCE

SECTION II

Time—1 hour and 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. Soil erosion is one of the most serious soil-degrading processes. Each year tons of soil erode from cropland, pastures, forests, and other places. The amount of erosion varies dramatically among various land-use types. The figure above shows the effects of different agricultural practices and slopes on annual erosion rates.
- (a) Refer to the graph above for the following.
- (i) **Identify** the scientific question that resulted in the data presented in the graph.
- (ii) **Identify** the agricultural practice that could be used on a 15% slope without leading to a higher than tolerable loss of soil.
- (iii) **Describe** the effect of adding a cover crop compared to using the no-till method.
- (iv) **Identify** one natural mechanism of soil erosion.

(b) Sediment from erosion can enter streams and affect water quality. One way sediment can enter a stream is from nearby road construction. Two methods to reduce sediment run-off in streams are to either put down straw bales or plant grass. The hypothesis to be tested is that straw bales reduce more sediment run-off than planted grass does. To test the hypothesis, two plots near a road under construction are measured. On one plot (A), straw bales are used to cover the soil, while a second plot (B) is planted with grass. The sediment discharge from each plot is measured after rainfall.

- (i) **Identify** the dependent variable stated in the hypothesis.
- (ii) **Describe** one way to add a control to improve the design of the study.
- (iii) **Identify** one variable that was not discussed that could affect the results of the study.

Sediments reaching streams affect water clarity, which is tested by determining turbidity. Turbidity can be determined by measuring the depth at which a submerged object can no longer be seen from the surface.

Sample Group	Turbidity
Straw bale plots (plot A)	12 cm
Planted grass plots (plot B)	28 cm

- (iv) Based on the data in the table above, **make a claim** about the stated hypothesis.
- (c) Several fish species lay their eggs in the gravel in the streams under investigation in the study.
- (i) **Describe** the type of survivorship curve expected for these fish species.
- (ii) **Explain** why the input of sediment to a stream can negatively affect reproduction of fish that lay their eggs in the gravel of the streambed.

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. 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 article below and answer the questions that follow.

The Floridian Daily

May 21, 2013

The small community located on the edge of the magnificent wetlands of Florida's Everglades was the site of a press conference today where Governor Gayle Moss announced that the restoration of the Everglades is successfully underway. She noted that the Everglades ecosystem has suffered threats to its water quality, water quantity, and habitats in recent decades. Moss noted that intensive urban and agricultural development in adjacent areas has diverted substantial amounts of freshwater resources and impaired water quality. Governor Moss then emphasized that the preservation and enhancement of the Everglades, key goals of the restoration program, are absolutely essential for the continued environmental and economic health of the state. She closed the press conference by saying, "The Everglades is a gem not only for Florida but for the entire world. Each of us has the responsibility to do our part to preserve this magnificent resource."

- (a) **Describe** how TWO human activities, other than those that result in anthropogenic climate change, have resulted in a decrease in the amount of freshwater flowing into the Everglades ecosystem.
- (b) In addition to water quantity problems, the Everglades is faced with a variety of water quality issues. For example, phosphorus concentrations in the Everglades have increased since the 1960s.
- (i) **Describe** how one specific human activity contributes to increased phosphorus levels in the Everglades.
 - (ii) **Explain** one way in which an increase in phosphorus levels can adversely affect the Everglades ecosystem.
 - (iii) **Describe** one step that could be taken to reduce phosphorus inputs from the activity you identified in part (i).
- (c) Climate change could have a variety of impacts on water quantity, water quality, and habitat. For EACH of these three factors, **identify and describe** one specific example of an impact on the Everglades likely to result from climate change.
- (d) The article states that Governor Moss believes that the "preservation and enhancement of the Everglades, key goals of the restoration program, are absolutely essential for the continued environmental and economic health of the state."
- (i) **Describe** one way that restoring water quantity and water quality in the Everglades is expected to improve the structure and function of the ecosystem.
 - (ii) **Describe** one way that restoring the Everglades is expected to provide economic benefits to Florida.

2. Like many communities, Fremont has a combined sewer system that collects both sewage and storm water. When storm water runs into storm drains that connect to the city's sanitary sewer system, the storm water and sewage flow together to the Fremont Wastewater Treatment Plant (FWTP). During a major storm event, however, the combined volume of storm water and sewage may exceed the plant's capacity, and the overflow bypasses the FWTP. The untreated overflow is discharged into Fremont Creek along with the treated waste.

Recently parts of Fremont received 5 cm of rain in 60 minutes. The storm caused widespread flooding in the northeast section of town. Especially hard hit was the Shoppes at Fremont shopping center.

Use the data from the table below to answer the questions that follow. Show all calculations.

Fremont Water Data
The shopping center's parking lot is 200 meters long and 100 meters wide.
Fremont has an area of 10 km ² .
Impervious surfaces cover 20 percent of Fremont's area.
The FWTP typically treats 5,000 m ³ of domestic sewage per day.
The FWTP has the capacity to treat 10,000 m ³ of combined sewage and storm water per day.

- (a) **Identify** TWO specific pollutants in storm-water runoff that degrade the quality of surface water.
- (b) **Calculate** the volume of water (in m³) that runs off the Shoppes at Fremont parking lot after a 5 cm rainfall event. Assume that all the water that falls on the parking lot runs off.
- (c) **Calculate** the volume of storm-water runoff (in m³) generated in all of Fremont by the 5 cm rainfall event. Assume that only the impervious surfaces generate runoff.
- (d) Assume that all the runoff that you calculated in part (c) is captured by the storm sewers in one day. **Calculate** the volume of untreated water (in m³) that bypasses the plant as a result of the storm. (Note that the plant still receives 5,000 m³ of domestic sewage per day.)
- (e) **Describe** TWO ways that the volume of storm-water runoff can be reduced.
- (f) **Describe** one environmental problem (other than pollution from runoff and from untreated sewage) that results from having extensive paved areas.

5.14 Integrated Pest Management

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

KEY WORDS crop rotation 轮作 • integrated pest management 综合虫害治理 • pesticides 农药
• pesticide resistance 抗药性

Objective

Build the skills to answer exam questions on **integrated pest management (IPM)**.

You must be able to:

- describe **integrated pest management** 综合虫害治理
- combine biological, mechanical, and limited chemical control
- explain why IPM reduces pesticide problems

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.

■ What IPM is

Integrated pest management (IPM) combines several methods to control pests with **minimal pesticide** use, keeping pests below a damaging level rather than eliminating them.

■ The tools

- **Biological** — natural predators.
- **Mechanical/physical** — traps, barriers, hand-removal.
- **Cultural** — crop rotation, resistant varieties.
- **Chemical** — pesticides only as a **last resort**, sparingly.

■ Why it works better

Using less chemical reduces **resistance**, protects non-target species, and lowers pollution — avoiding the pesticide treadmill.

■ A worked example

A farmer rotates crops, releases ladybugs to eat aphids, and only sprays a small amount if pests still exceed a threshold — that is IPM.

2 Practice

Now apply the methods above.

2.1 What is the goal of IPM regarding pesticide use? [1]

2.2 Name two non-chemical IPM methods. [2]

2.3 When are chemicals used in IPM? [1]

3 Exam-style questions

3.1 In IPM, chemical pesticides are used [1]

- **A** first and heavily
- **B** as a last resort, sparingly
- **C** never
- **D** to eliminate every pest

3.2 A farm switches from routine spraying to IPM.

(a) Describe two methods the farm might use. [2]

(b) Explain why IPM reduces pesticide resistance. [2]

3.3 Explain why IPM aims to keep pests below a threshold rather than eliminate them.^[2]

Solutions

2.1 To minimize pesticide use (use chemicals only as a last resort).

2.2 Any two: biological control, traps/barriers, crop rotation, resistant varieties.

2.3 Only as a last resort, sparingly, when pests exceed a threshold.

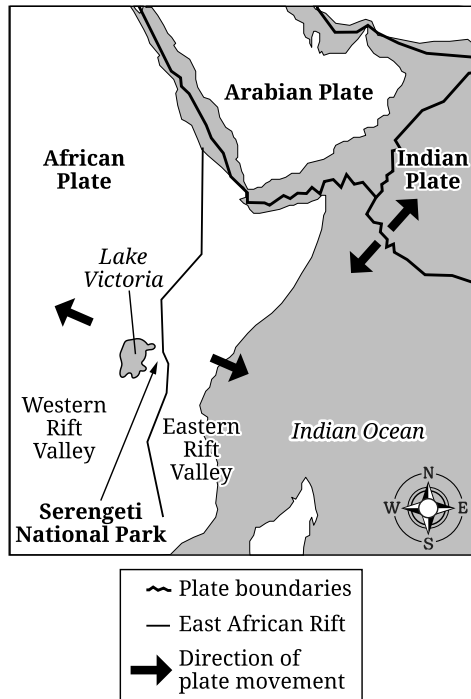
3.1 B — as a last resort, sparingly.

3.2 (a) Any two: release natural predators, use traps/barriers, rotate crops, plant resistant varieties. (b) Less pesticide use means less selection pressure on pests, so resistance develops more slowly.

3.3 Eliminating pests entirely is costly and drives resistance; keeping them below a damaging threshold protects the crop while using far fewer chemicals.

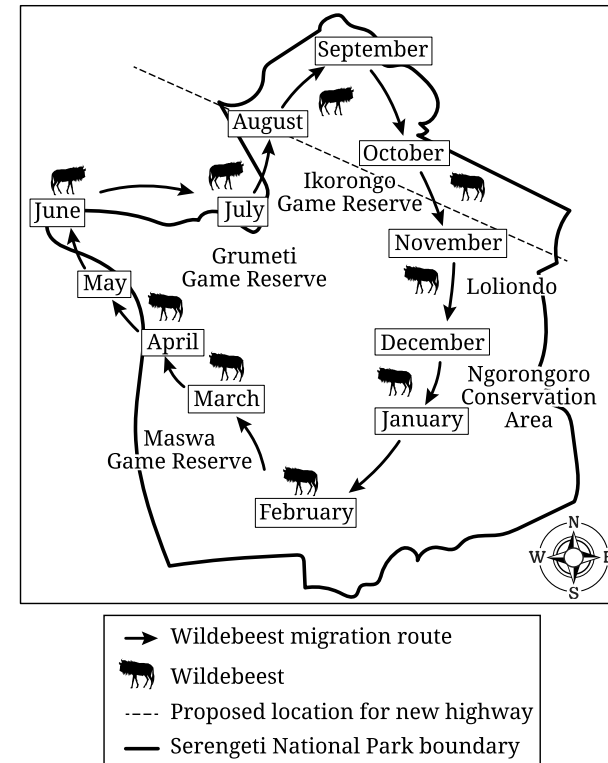
Serengeti National Park is located in Tanzania, Africa. The park is located in a valley along a tectonic plate boundary called the East African Rift. Figure 1 shows the East African Rift and other plate boundaries near the east coast of Africa.

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.

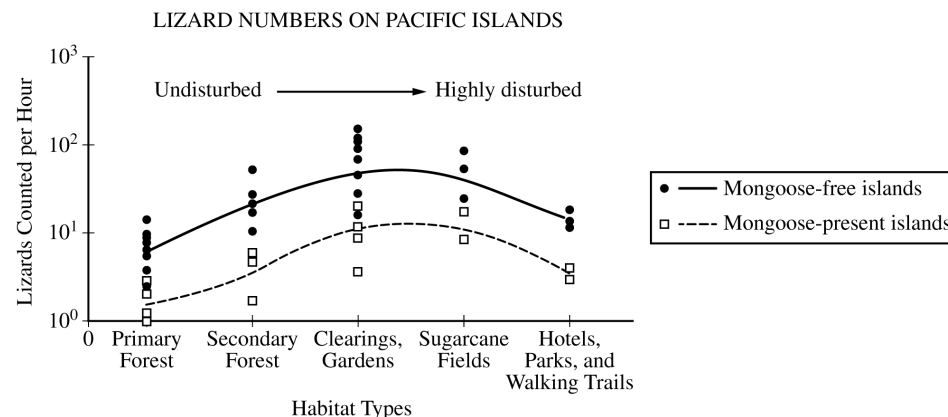
Describe one way the planned highway shown in Figure 2 could negatively affect the wildebeest population in the Serengeti.

- 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. 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.

2. Pesticides have been utilized for many years to increase food production and control pest populations. Pesticide use can be both beneficial and harmful to humans and other organisms.

- (a) Pesticide use has advantages, disadvantages, and unintended consequences on human health. **Describe** one benefit to human health that can result from the use of pesticides.
- (b) **Identify** one way chemical pesticides can enter the human body.

Cotton farmers in the southern United States used a chemical pesticide to control an insect cotton-crop pest over a 40-year period. To study the effectiveness of the pesticide as an insect pest-control strategy, traps were placed in treated cotton fields and the number of pests captured were compared to application rates for the pesticide. The results of the study are shown in the table below.

Year	Grams of Pesticide Applied per Hectare	Number of Crop Insect Pests Captured
1960	0	700
1975	500	2
1980	500	3
1985	500	8
1990	550	14
1995	600	83
2000	700	150
2005	800	405
2010	900	727
2015	1,000	1,100

- (c) Use the data in the table to answer the following questions.
- (i) **Identify** the year when the pesticide was most effective at reducing the size of the pest population.
- (ii) **Describe** the change in the number of crop insect pests in the cotton fields over time.
- (iii) **Explain** how the change in the cotton-crop pesticide effectiveness between the initial application in 1975 and the latest application in 2015 illustrates genetic resistance in pests, based on the data in the table.
- (d) **Describe** TWO effects of pesticide use, other than death, on nontarget wildlife.

- (e) There are many problems associated with the repeated application of chemical pesticides to reduce pest populations.
- (i) Crop rotation is often used to reduce pesticide use. **Describe** the process of crop rotation.
- (ii) **Propose** one reasonable method, other than crop rotation, of reducing the use of pesticides in agricultural practices while still maintaining a high crop yield.
- (iii) **Justify** how the method proposed in (e)(ii) would provide a benefit to humans.

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.

5.15 Sustainable Agriculture

Name: _____ Class: _____ Date: _____

Total: 9 marks

KEY WORDS crop rotation 轮作 • cover crops 覆盖作物 • no-till 免耕
• contour plowing 等高耕作 • terracing 梯田

Objective

Build the skills to answer exam questions on **sustainable agriculture**.

You must be able to:

- describe **crop rotation** 轮作, **cover crops** 覆盖作物, **no-till** 免耕, and **contour plowing** 等高耕作
- explain how each conserves soil and nutrients
- link practices to reduced erosion and inputs

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.

■ Sustainable practices

- Crop rotation** — changing crops each season; restores nutrients (especially with legumes) and breaks pest cycles.
- Cover crops** — plants grown to protect and enrich soil between harvests.
- No-till** — planting without plowing; keeps roots holding the soil.
- Contour plowing / terracing** — plowing across slopes to slow runoff and erosion.

■ How they conserve soil

They keep soil **covered** and **held by roots**, reducing erosion, and they **restore nutrients** naturally, cutting the need for fertilizer.

■ A worked link

Planting a legume cover crop over winter fixes nitrogen and protects the soil from erosion, so less fertilizer is needed the next season.

2 Practice

Now apply the methods above.

2.1 How does crop rotation restore soil nutrients? [1]

2.2 How does no-till farming reduce erosion? [1]

2.3 What is contour plowing for? [1]

3 Exam-style questions

3.1 Planting a legume in a rotation helps because it [1]

- A** removes nitrogen
- B** adds (fixes) nitrogen to the soil
- C** increases erosion
- D** needs no water

3.2 A farmer adopts cover crops and no-till.

(a) Explain how each reduces soil erosion. [2]

(b) State one other benefit of cover crops. [1]

3.3 Explain how contour plowing on a slope reduces erosion. [2]

Solutions

2.1 Rotating crops (especially legumes) replenishes nutrients like nitrogen.

2.2 It avoids plowing, so roots keep holding the soil in place.

2.3 To slow runoff and reduce erosion on slopes.

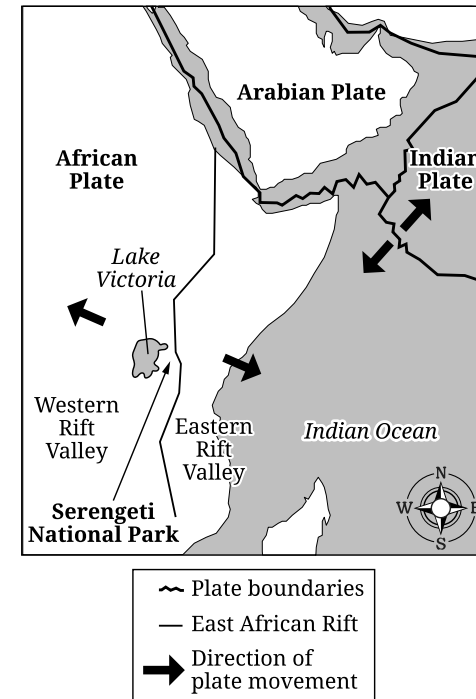
3.1 B — adds (fixes) nitrogen to the soil.

3.2 (a) Cover crops keep the soil covered and held by roots; no-till avoids exposing loose soil, so both reduce erosion. (b) Cover crops add organic matter/nutrients and suppress weeds.

3.3 Plowing across (along) the slope creates ridges that slow water flowing downhill, giving it time to soak in rather than washing soil away.

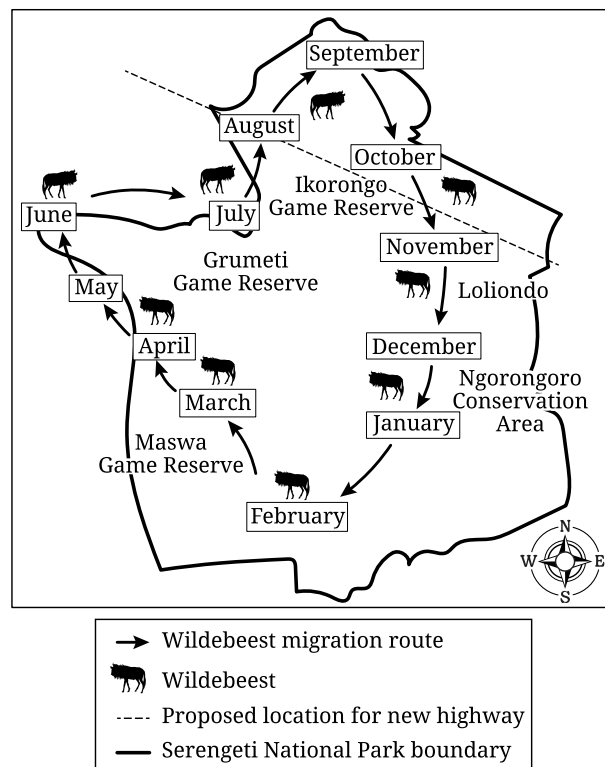
Serengeti National Park is located in Tanzania, Africa. The park is located in a valley along a tectonic plate boundary called the East African Rift. Figure 1 shows the East African Rift and other plate boundaries near the east coast of Africa.

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.

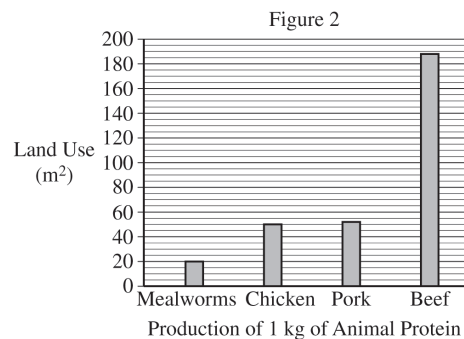
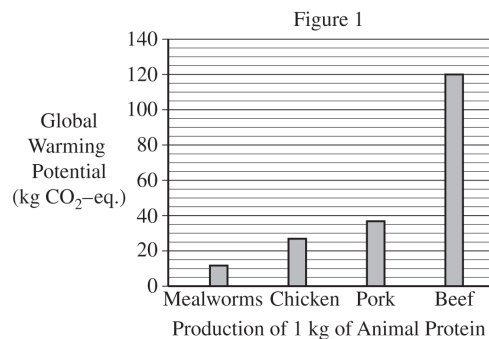
- F. Propose** a solution to the negative effect created by the planned highway described in part E.
- G.** Many organisms live in grasslands. One weed species, the spotted knapweed, was introduced at one location in North America in the 1890s and is currently found throughout the rangelands of the western 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. As the human population continues to grow, the demand for animal protein is expected to double by 2050. Animal protein can be obtained from conventional livestock and other sources. The production of all animal protein has environmental costs, as shown in the following graphs. In Figure 1, global warming potential (GWP) is measured in kilograms of carbon dioxide equivalent (kg CO₂-eq). Carbon dioxide equivalent is a measure of the warming effect of a gas relative to that of carbon dioxide. In Figure 2, land use is measured in meters squared (m²).

Global Warming Potential and Land Use from Animal Protein Production



- (a) Based on the data in the graphs, **identify** the amount of land required to produce 1 kilogram of chicken protein.

Mealworms, the larvae of the darkling beetle, consume grains and decaying plant material. Darkling beetles are an *r*-selected species, and the entire mealworm can be consumed by humans for protein.

- (b) Based on the information provided, **identify** the type of survivorship curve exhibited by the darkling beetle.

- (c) **Explain** why the reproductive strategy of the darkling beetle is an advantage for using mealworms as an alternative protein source for the rapidly growing human population.

An individual's diet choices affect greenhouse gas emissions and land use.

- (d) Based on the data in the graphs, **explain** whether producing 1 kilogram of chicken protein or 1 kilogram of pork protein would cause less environmental damage.

Cattle emit methane from fermentation in their digestive systems. The other animals do not emit methane.

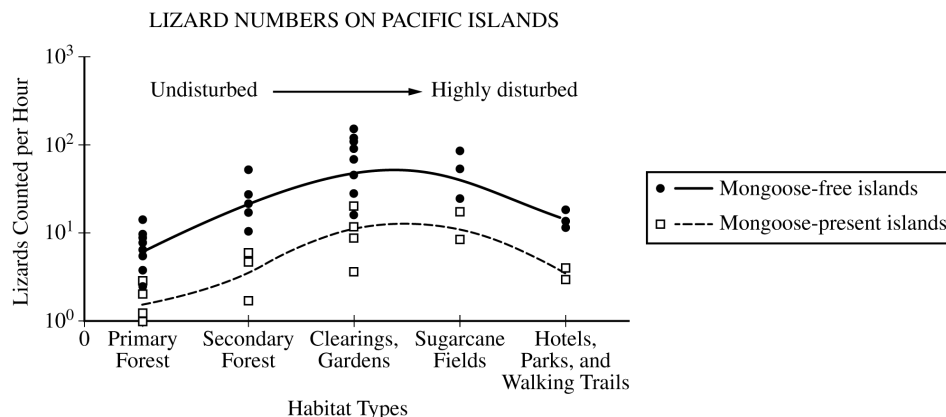
- (e) Based on the data in the graphs, **explain** why the production of 1 kilogram of beef protein has a different impact on global warming than the production of 1 kilogram of protein from any of the other animals studied would have.

Agricultural practices can have negative impacts on rivers and streams.

- (f) **Describe** how water quality can be altered by cattle grazing that occurs near a stream or river.
- (g) **Propose** a solution to reduce the negative impacts on waterways that result from cattle grazing, while still allowing cattle to graze.
- (h) Crop production can cause soil erosion. **Describe** a sustainable agricultural practice used to reduce soil erosion.
- (i) **Justify** the use of the sustainable practice described in part (h) by describing an additional advantage, other than the reduction of soil erosion.
- (j) Crop production around the world is affected by climate change. **Describe** how crop production could be negatively affected by climate change.

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.

2. Pesticides have been utilized for many years to increase food production and control pest populations. Pesticide use can be both beneficial and harmful to humans and other organisms.

- Pesticide use has advantages, disadvantages, and unintended consequences on human health. **Describe** one benefit to human health that can result from the use of pesticides.
- Identify** one way chemical pesticides can enter the human body.

Cotton farmers in the southern United States used a chemical pesticide to control an insect cotton-crop pest over a 40-year period. To study the effectiveness of the pesticide as an insect pest-control strategy, traps were placed in treated cotton fields and the number of pests captured were compared to application rates for the pesticide. The results of the study are shown in the table below.

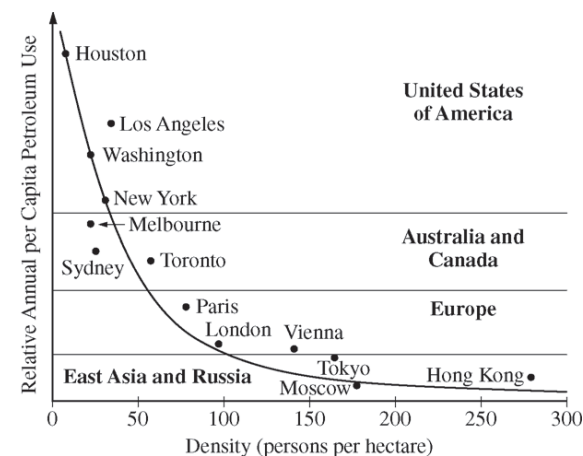
Year	Grams of Pesticide Applied per Hectare	Number of Crop Insect Pests Captured
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1985	500	8
1990	550	14
1995	600	83
2000	700	150
2005	800	405
2010	900	727
2015	1,000	1,100

- (c) Use the data in the table to answer the following questions.
- Identify** the year when the pesticide was most effective at reducing the size of the pest population.
 - Describe** the change in the number of crop insect pests in the cotton fields over time.
 - Explain** how the change in the cotton-crop pesticide effectiveness between the initial application in 1975 and the latest application in 2015 illustrates genetic resistance in pests, based on the data in the table.
- (d) **Describe** TWO effects of pesticide use, other than death, on nontarget wildlife.

- (e) There are many problems associated with the repeated application of chemical pesticides to reduce pest populations.
- (i) Crop rotation is often used to reduce pesticide use. **Describe** the process of crop rotation.
- (ii) **Propose** one reasonable method, other than crop rotation, of reducing the use of pesticides in agricultural practices while still maintaining a high crop yield.
- (iii) **Justify** how the method proposed in (e)(ii) would provide a benefit to humans.

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.

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.
- (a) **Describe** TWO causes of urban sprawl.
- (b) **Discuss** TWO human health effects associated with urban sprawl.
- (c) 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.



- (d) 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.
- (e) Highway systems and urban sprawl often threaten wildlife populations. **Describe** TWO methods to reduce harmful effects on wildlife populations from highways and urban sprawl.
- (f) 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

5.16 Aquaculture

Name: _____ Class: _____ Date: _____

Total: 10 marks**KEY WORDS** aquaculture 水产养殖 • overfishing 过度捕捞 • eutrophication 富营养化

Objective

Build the skills to answer exam questions on **aquaculture**.**You must be able to:**

- describe **aquaculture** 水产养殖 and its benefits
- explain its environmental impacts (waste, disease, escapees)
- weigh it against wild-caught fishing

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.

■ What aquaculture is

Aquaculture is farming aquatic organisms (fish, shrimp, shellfish). It can take pressure off **wild** stocks and provide protein efficiently.

■ Benefits

- Relieves **overfishing** of wild populations.
- High yield of protein in a small area.

■ Impacts

- **Waste and excess feed** pollute nearby water (nutrients → eutrophication).
- **Disease and parasites** spread in crowded pens and can infect wild fish.
- **Escapees** can become invasive or interbreed with wild fish.
- Coastal habitat (mangroves) may be cleared for ponds.

■ A worked judgement

A shrimp farm built by clearing mangroves relieves wild fishing pressure but destroys valuable coastal habitat and pollutes local water — a trade-off.

2 Practice

Now apply the methods above.

2.1 What is aquaculture? [1]**2.2** State one benefit of aquaculture. [1]**2.3** State one environmental impact of aquaculture. [1]

3 Exam-style questions

3.1 One environmental problem with fish farming is [1]

- **A** it eliminates all pollution
- **B** waste and disease can affect nearby waters
- **C** it increases wild fish stocks directly
- **D** it uses no feed

3.2 A coastal region builds fish farms.

(a) Explain one benefit and one drawback. [2]

(b) Explain how escaped farmed fish could harm wild populations. [2]

3.3 Explain why crowding in fish pens increases disease risk. [2]

Solutions

2.1 Farming aquatic organisms (fish, shellfish).

2.2 Any one: relieves overfishing, high protein yield.

2.3 Any one: waste pollution, disease spread, escapees, habitat loss.

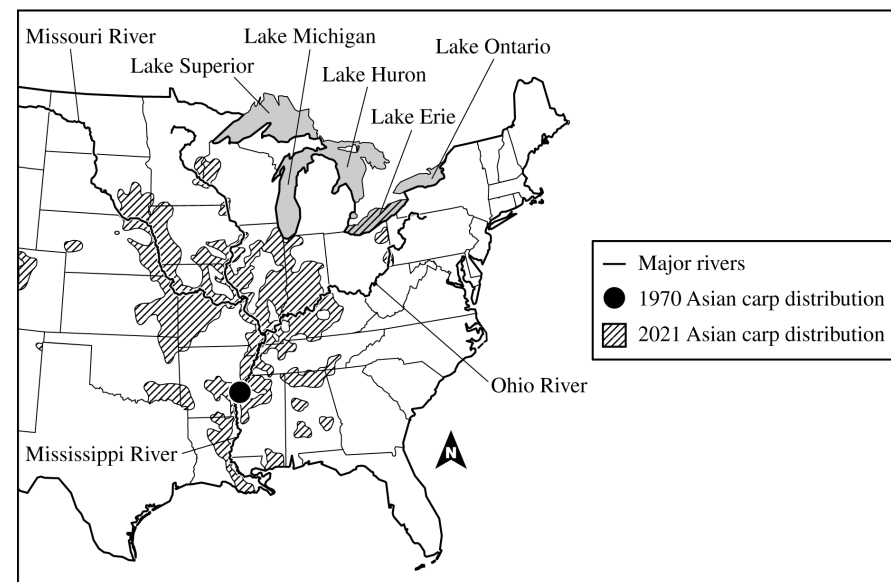
3.1 B — waste and disease can affect nearby waters.

3.2 (a) Benefit: relieves pressure on wild stocks / efficient protein; drawback: waste pollution, disease, or habitat loss. (b) Escapees can spread disease, compete with, or interbreed with wild fish, weakening wild populations.

3.3 Crowding lets pathogens and parasites spread quickly between the closely packed fish, so disease outbreaks are more likely.

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.

5.17 Sustainable Forestry

Name: _____ Class: _____ Date: _____ **Total: 9 marks****KEY WORDS** selective cutting 择伐 • clearcutting 皆伐 • erosion 侵蚀

Objective

Build the skills to answer exam questions on **sustainable forestry**.

You must be able to:

- describe sustainable practices (**selective cutting** 择伐, replanting, rotation)
- explain how they maintain forest function
- contrast with clearcutting

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.

■ Sustainable forestry

Sustainable forestry harvests timber while keeping the forest healthy and productive for the future:

- **Selective cutting** — remove only some trees, leaving the forest largely intact.
- **Replanting** — replace harvested trees.
- **Rotation** — harvest no faster than the forest regrows (sustainable yield).

■ Keeping forest function

Leaving trees standing maintains **habitat**, **soil stability**, **carbon storage**, and the **water cycle**, unlike clearcutting.

■ Certification

Certification programs label sustainably-harvested wood so consumers can support responsible forestry.

■ A worked contrast

Selective cutting keeps the forest canopy and roots, so it avoids the erosion, habitat loss, and flooding caused by clearcutting.

2 Practice

Now apply the methods above.

2.1 Name one sustainable forestry practice. [1]

2.2 Why is replanting important? [1]

2.3 How does selective cutting protect soil? [1]

3 Exam-style questions

3.1 Sustainable forestry harvests trees [1]

- **A** faster than they regrow
- **B** no faster than they regrow
- **C** only by clearcutting
- **D** never

3.2 A company switches from clearcutting to selective cutting and replanting.

(a) Explain two environmental benefits. [2]

(b) State one disadvantage compared with clearcutting. [1]

3.3 Explain how sustainable forestry maintains a forest's carbon storage. [2]

Solutions

2.1 Any one: selective cutting, replanting, rotation (sustainable yield).

2.2 It replaces harvested trees so the forest regrows and stays productive.

2.3 It leaves most trees (and roots) in place to hold the soil.

3.1 B — no faster than they regrow.

3.2 (a) Any two: less erosion, maintained habitat, kept carbon storage, protected water cycle. (b) It is slower and more expensive, yielding less timber at once.

3.3 By keeping most trees standing and replanting harvested ones, the forest continues to absorb and store CO₂, rather than releasing it as a clearcut would.

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

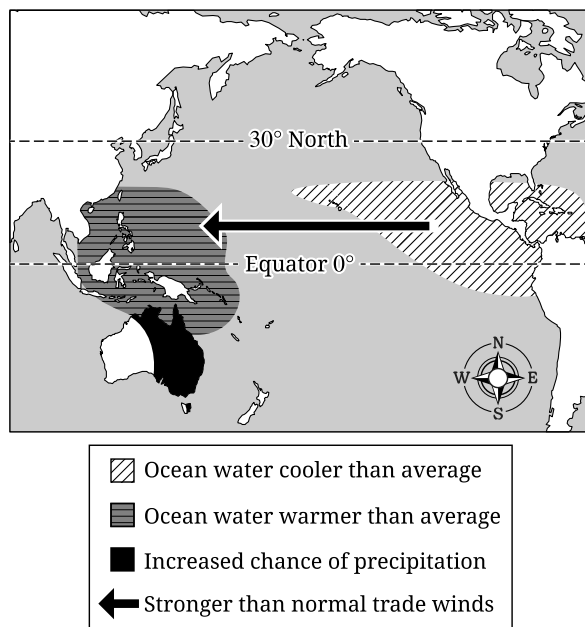
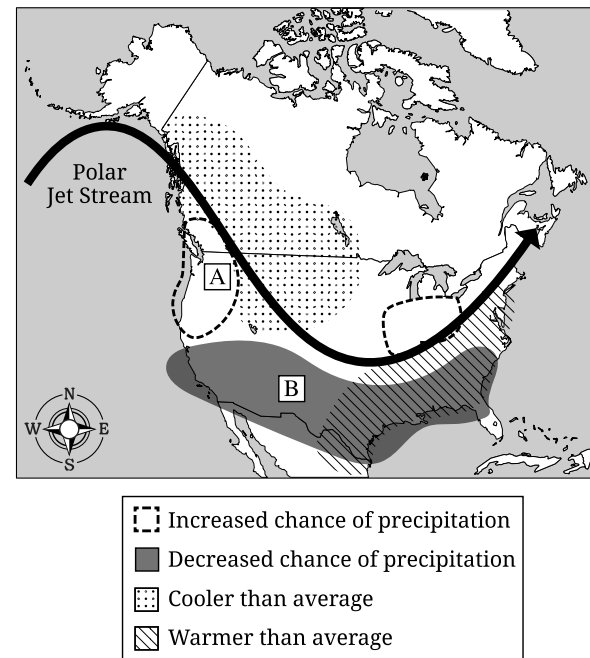


Figure 2. Polar Jet Stream and Climate Conditions in North America



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.

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

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.

3. Haiti shares a border with the Dominican Republic on the Caribbean island of Hispaniola.
- (a) The border between the two countries can be seen using satellite images because of the severe deforestation in Haiti.
 - (i) **Provide** one reason why deforestation commonly occurs in a less developed country such as Haiti.
 - (ii) **Describe** one realistic strategy to reduce deforestation in a less developed country.
 - (b) Deforestation can affect water quality. **Identify** one change that can occur in the water quality of streams within a watershed that has been deforested. **Explain** how deforestation can lead to this change.
 - (c) **Identify** TWO environmental benefits, other than those related to water quality, of maintaining forest ecosystems.

The table below contains demographic data for Haiti in 1995 and 2015.

DEMOGRAPHIC DATA FOR HAITI

Measure	1995	2015
Fertility rate (number of children per woman)	5.2	2.7
Life expectancy (years)	55	64
Infant mortality (deaths per 1,000)	85	48

- (d) **Identify** and **discuss** one factor in a less developed country that could contribute significantly to a change in life expectancy, similar to what occurred in Haiti from 1995 to 2015.
- (e) **Identify** and **discuss** one economic or cultural factor in a less developed country that could contribute significantly to a change in the fertility rate, similar to what occurred in Haiti from 1995 to 2015.