

Question 2: Analyze an Environmental Problem and Propose a Solution **10 points**

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

- 50 m²

(b) Based on the information provided, **identify** the type of survivorship curve exhibited by the darkling beetle. **1 point**

- Type III

(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. **1 point**

Accept one of the following:

- Darkling beetles reproduce quickly, which allows for a large amount of protein to be produced in a short period of time.
- Darkling beetles have many offspring, which allows for a large amount of protein to be produced in a short period of time.

(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. **1 point**

Accept one of the following:

- Chicken production has a lower global warming potential than pork production, so it would cause less environmental damage because chicken production releases less greenhouse gas.
- Chicken production has a lower land use than pork production, so it would cause less environmental damage because there would be less deforestation/habitat destruction/soil erosion/fossil fuel use.

(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. **1 point**

Accept one of the following:

- Beef has a larger impact because methane has a high global warming potential.
 - Beef has a larger impact because methane is a greenhouse gas.
 - Beef requires more land use, which results in loss of forests/habitat/grasslands leading to release of CO₂/reduction in carbon storage.
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(f)	Describe how water quality can be altered by cattle grazing that occurs near a stream or river.	1 point
	Accept one of the following:	
	• Cattle cause erosion, which increases sedimentation/turbidity in water. • Cattle feces can add nutrients/nitrogen/phosphorus to waterways. • Cattle feces may contaminate waterways with bacteria.	
(g)	Propose a solution to reduce the negative impacts on waterways that result from cattle grazing, while still allowing cattle to graze.	1 point
	Accept one of the following:	
	• Practice rotational grazing/alternate grazing parcels. • Eat a diet with less meat/beef. • Fence/barricade the riparian zone. • Provide other water sources for the cattle.	
(h)	Crop production can cause soil erosion. Describe a sustainable agricultural practice used to reduce soil erosion.	1 point
	Accept one of the following:	
	• Switch crops to perennial plants. • Plant crops on terraces. • Implement contour plowing/farming. • Use no-till farming/cover crops.	

- (i) **Justify** the use of the sustainable practice described in part (h) by describing an additional advantage, other than the reduction of soil erosion. **1 point**

Accept one of the following:

Solution proposed in (h)	Justification of solution with additional advantage other than the reduction of soil erosion
Switch to perennial plants	• Reduces the use of fossil fuels. • Reduces the cost of farming. • Increases/maintains carbon storage in soils. • Preserves habitats for organisms in soils.
Plant crops on terraces	• Allows areas to be farmed that are otherwise too steep. • Sediments and other contaminants settle out behind the terrace ridge reducing the amount of soil that runs off. • Increases groundwater absorption.
Implement contour plowing/farming	• Allows areas to be farmed that are otherwise too steep. • Increases groundwater absorption.
Use no-till farming/cover crops	• Reduces the use of fossil fuels. • Reduces the cost of farming. • Increases/maintains carbon storage in soils. • Preserves habitats for organisms in soils. • Cover crops can be used as green manure.

- (j) Crop production around the world is affected by climate change. **Describe** how crop production could be negatively affected by climate change. **1 point**

Accept one of the following:

- Crop production/yields could decrease because of:
 - Increased drought
 - Increased flooding
 - Increased insect infestation from warmer temperatures
 - Increased temperature
 - Changes in seasonal rain patterns (or temperatures)
 - Expansion of geographic range of invasive pests/species
 - Climate may be outside range of tolerance of crops

Total for question 2 10 points

Question 3: Analyze an Environmental Problem and Propose a Solution Doing Calculations

10 points

(a) **Identify** a fuel used in a nuclear power plant. 1 point

Accept one of the following:

- Uranium
- U-235
- Plutonium

(b) **Describe** a negative environmental impact on nearby bodies of water that is caused by using water for cooling in nuclear power plants. 1 point

Accept one of the following:

- Thermal pollution raises water temperature outside range of tolerance of organisms.
- Thermal pollution decreases dissolved oxygen.
- Water temperature increases, which decreases dissolved oxygen.
- Organisms can be wounded or killed at water intake.
- Water loss through evaporation can decrease stream flow/volume of water.

(c) In 2021, 4.1×10^{12} kilowatt hours (kWh) of commercial electricity was generated in the United States. Nuclear power accounted for 18.9% of the total commercial electricity. **Calculate** the amount of electricity in kWh generated by nuclear power in the United States in 2021. **Show** your work. 1 point

One point for the correct setup to calculate the amount of electricity generated by nuclear power in 2021:

Accept one of the following:

- $(4.1 \times 10^{12} \text{ kWh}) \times 18.9\%$
- $(4.1 \times 10^{12}) \times 0.189$
- $\frac{4.1 \times 10^{12}}{100} = \frac{x}{18.9}$

One point for the correct calculation of the total amount of electricity generated by nuclear power in 2021: 1 point

Accept one of the following:

- 774,900,000,000
- 7.749×10^{11}
- 7.75×10^{11}
- 7.7×10^{11}

Total for part (c) 2 points

(d)	In addition to reducing greenhouse gas emissions, describe how switching from coal-burning power plants to natural gas power plants will improve air quality. There is less NO_x/SO_x/ash/particulates/toxic metals/smog formed from the burning of natural gas compared to coal.	1 point
(e)	Justify the proposed solution by explaining an additional advantage, other than the reduction of atmospheric greenhouse gases. Accept one of the following: - Trees can provide forest habitat/increase biodiversity/diversify niches in the area. - Creates jobs for planting trees/recreational industries/harvesting wood. - Trees create a more aesthetically pleasing environment/enhance cultural ecosystem services. - Planting trees can decrease soil loss/erosion/sedimentation in waterways. - Trees can provide shade/decrease ambient temperature. - Planting trees slows water runoff/reduces flooding.	1 point
(f)	7.4×10^7 cubic meters of natural gas were extracted from a large deposit in 2020. An average of 4.76 kWh of electricity can be generated from each cubic meter of natural gas combusted. In 2020, an average home consumed 10,715 kWh of electricity. Calculate how many homes could have been provided with electricity by natural gas extracted from the large deposit in 2020. Show your work. One point for the correct setup to calculate how many homes could have been provided with electricity by natural gas: Accept one of the following: $(7.4 \times 10^7 \text{ m}^3) \times \frac{4.76 \text{ kWh}}{1 \text{ m}^3} \times \frac{1 \text{ home}}{10,715 \text{ kWh}}$ $(7.4 \times 10^7 \text{ m}^3) \times \frac{4.76 \text{ kWh}}{10,715 \text{ kWh}}$ $(7.4 \times 10^7) \times \frac{4.76}{10,715}$ One point for the correct calculation of how many homes could have been provided with electricity by natural gas: Accept one of the following: 32,874 32,873 33,000	1 point
	Total for part (f)	2 points

- (g) In 2021, 8.99×10^{11} kWh of electricity was generated through the combustion of coal. **1 point**
 One kilogram of carbon dioxide is produced per kWh of electricity generated by combusting coal, while 0.42 kilograms of carbon dioxide is produced by combusting natural gas. **Calculate** how much less carbon dioxide would have been produced in 2021 if all coal-burning power plants were replaced with natural gas-burning power plants. **Show** your work.

One point for the correct setup to calculate how much less carbon dioxide would have been produced in 2021:

Accept one of the following:

- $\frac{(1.0 \text{ kg} - 0.42 \text{ kg})}{1 \text{ kWh}} \times (8.99 \times 10^{11} \text{ kWh})$
- $(1.0 \text{ kg} - 0.42 \text{ kg}) \times (8.99 \times 10^{11} \text{ kWh})$
- $(1.0 - 0.42) \times (8.99 \times 10^{11})$
- $\left(\frac{8.99 \times 10^{11} \text{ kWh}}{1} \times \frac{1 \text{ kg}}{\text{kWh}} \right) - \left(\frac{8.99 \times 10^{11} \text{ kWh}}{1} \times \frac{0.42 \text{ kg CO}_2}{\text{kWh}} \right)$, THEN
 $8.99 \times 10^{11} \text{ kg CO}_2 - 3.776 \times 10^{11} \text{ kg CO}_2$

One point for the correct calculation of how much less carbon dioxide would have been produced in 2021: **1 point**

Accept one of the following:

- 521 billion kg
- 521,420,000,000 kg
- $5.2142 \times 10^{11} \text{ kg}$
- $5.21 \times 10^{11} \text{ kg}$
- $5.2 \times 10^{11} \text{ kg}$

Total for part (g) 2 points

Total for question 3 10 points

Question 3: Analyze an Environmental Problem and Propose a Solution Doing Calculations**10 points**

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- (a) **Describe** one environmental problem associated with the release of methane into the atmosphere. **1 point**

Accept one of the following:

- It traps heat effectively leading to climate change/global warming.
- The greenhouse effect is enhanced, increasing global temperatures/warming.
- It is a greenhouse gas, which leads to climate change/global warming.
- It is a greenhouse gas, which leads to melting ice/rising sea levels.

-
- (b) **Describe** one factor that could affect the decomposition of the solid waste in a landfill. **1 point**

Accept one of the following:

- The amount of/percentage of organic material in the solid waste.
- The amount of/percentage of non-degradable material in the solid waste.
- Conditions of the landfill (such as concentration of oxygen, population of microbes/decomposers, temperature, moisture).
- Environmental conditions of the area (such as temperature, amount of rainfall, climate, weather, etc.).

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- (c) **Propose** a solution to decrease the amount of methane released from landfills into the atmosphere. **1 point**

Accept one of the following:

- Incinerate waste.
 - Compost waste.
 - Recycle/reuse non-synthetic organic waste (paper, textiles).
 - Install/Use methane collection systems.
 - Burn off/Combust the methane coming from the landfill.
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- (d) **Justify** the solution proposed in part (c) by describing an additional advantage, other than decreasing the amount of methane released from landfills. **1 point**

Accept one of the following:

Solution proposed in part (c)	Justification of solution with additional advantage
Incinerate waste.	• Extends the lifetime of the landfill. • Reduces the amount of waste going to the landfill. • Can be used to generate electricity/heat. • Can generate income. • Reduces land area needed for landfills.
Compost waste.	• Extends the lifetime of the landfill. • Produces effective, inexpensive fertilizer. • Reduces land area needed for landfills.
Recycle/Reuse non-synthetic organic waste (paper, textiles, etc.).	• Reduces land needed for landfills. • Reduces energy/resources needed for new products. • Reduces trees cut for new paper.
Install/Use methane collection systems. Burn off/Combust the methane coming from the landfill.	• Can be used to generate electricity. • Can be used to heat buildings. • Can generate income. • Can be used as fuel. • Reduces the need for other energy sources.

- (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 one year. **Show** your work. **1 point**

One point for the correct setup to calculate the amount of methane released in one year:

Accept one of the following:

- $\frac{150 \text{ L methane per day}}{\text{cow}} \times 31,200,000 \text{ cows (cattle)} \times \frac{365 \text{ days}}{1 \text{ year}}$
- $31,200,000 \times \frac{150 \text{ L}}{\text{cow}} \times 365 \text{ days}$
- $150 \times 31,200,000 \times 365$

One point for the correct calculation of the amount of methane released in one year: **1 point**

Accept one of the following:

- 1,708,200,000,000 L
- $1.7 \times 10^{12} \text{ L}$

Total for part (e) 2 points

- (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. **1 point**

One point for the correct setup to calculate the number of hectares of pasture to support cattle:

Accept one of the following:

- $\frac{11.8 \text{ kg}}{\text{cow}} \times \frac{1 \text{ ha}}{26.2 \text{ kg}} \times 31,200,000 \text{ cows (cattle)}$
- $31,200,000 \times \frac{11.8 \text{ kg}}{26.2 \text{ kg}}$
- $\frac{11.8}{26.2} \times 31,200,000$

One point for the correct calculation of the number of hectares of pasture to support cattle: **1 point**

Accept one of the following:

- 14,051,908
- 1.4×10^7
- 14.1 million

Total for part (f) 2 points

- (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. 1 point

One point for the correct setup to calculate the change in the number of people:

Accept one of the following:

- $\frac{(30,400,000 \text{ kcal} - 2,700,000 \text{ kcal})}{1 \text{ ha}} \times \frac{1 \text{ person}}{2,250 \text{ kcal}} \times 150 \text{ ha}$
- $(30,400,000 - 2,700,000) \times \frac{1 \text{ person}}{2,250 \text{ kcal}} \times 150$
- $\left(\frac{30,400,000}{2,250} \times 150\right) - \left(\frac{2,700,000}{2,250} \times 150\right)$
- $\frac{(30,400,000 - 2,700,000)}{2,250} \times 150$

One point for the correct calculation of the change in the number of people:

1 point

Accept one of the following:

- 1,846,667
- 1.8×10^6

Total for part (g) 2 points

Total for question 3 10 points

2019

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Scoring Guidelines

2019 SCORING GUIDELINES**Question 1**

(a) Use the maps provided to answer the following questions.

(i) **Identify** the preferred nesting habitat for piping plovers.

(1 point for the correct identification of a preferred nesting habitat for piping plovers)

- Unvegetated sand
- Sandy areas/open sandy beaches
- Washovers

(ii) **Describe** the change in the number of piping plover nests in Assateague Island between 1999 and 2009.

(1 point for the correct description of the change in the number of piping plover nests)

- The number of nests decreased by almost half (43%).
- The number of nests decreased from 44 to 25.
- There were 19 more nests in 1999 than in 2009.

(iii) **Describe** one likely reason for the change in the number of piping plover nests between 1999 and 2009.

(1 point for the correct description of a likely reason for the change in the number of piping plover nests)

- The preferred habitat was reduced because of a decrease in unvegetated sandy areas.
- The preferred habitat was reduced because of an increase in the amount of vegetation/revegetation.

(b) Coastal species are affected by more than just natural events.

(i) 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.

(1 point for the correct description of a restriction that could reasonably be implemented to help prevent the destruction of plover nests by human activity)

- Post warning signs/fencing/barrier tape/boardwalks around the nesting area.
- Place wire enclosures/other barriers over active nests.
- Limit specified recreational activity on beaches with plover nests (prohibit kite flying, fireworks, etc.).
- Implement motor vehicle restrictions (limit times, size of vehicles, raking, etc.).
- Require pets to remain indoors or on leashes.

2019 SCORING GUIDELINES**Question 1 (continued)**

- (ii) 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.

(1 point for the correct explanation of one way that features of barrier islands help to preserve and protect the environment in coastal regions)

- They block/buffer the wind and/or waves, which mitigate beach erosion.
- They reduce storm surge, which protect the interior coastline from flooding.
- They block/buffer the waves and create wetland ecosystems/pools, which serve as habitat for a variety of species (fish, turtles, migratory birds, etc.).
- They trap sediments/pollutants in wetland habitats/marsh grasses, which filter the water.

- (iii) **Identify** one human action that directly threatens coastal habitats and **describe** one impact on species, other than the piping plover, that use the habitat.

(2 points; 1 point for the correct identification of a human action that directly threatens coastal habitats and 1 point for the correct description of the impact of human activity on species that use the habitat)

Identify one human action that directly threatens coastal habitats	Describe one impact on species that use the habitat
Tourism/Recreation	• Beachgoers accidentally step on or crush nests of species on the beach. • Unleashed pets on beaches may cause stress and/or disrupt nesting, survival, etc. of coastal species. • Vehicles on beach can disrupt nesting, survival, etc. of coastal species habitat. • Beachgoers leave food/garbage that attracts predators/harbors pathogens of coastal species. • Sunscreen washes off and can be toxic to coral or other coastal marine organisms.
Coastal Development	• Development (commercial, residential, recreational) can lead to the loss of suitable habitats of coastal species. • Development near beach may increase noise pollution or light pollution, which disrupts nesting/migration/survival of coastal species. • Development near beach may provide food/garbage that attracts predators/harbors pathogens of coastal species.
Littering/Solid Waste Disposal	• Coastal species get tangled up in trash (plastic) on the beach or in coastal water. • Coastal species ingest trash, which fills or blocks respiratory/digestive tract.
Offshore Oil Drilling	• Spilled oil coats coastal marine organisms, impacting survival. • Spilled oil can be toxic if ingested by coastal marine species.
Commercial Fishing	• Dredging or trawling can destroy coral/habitat for bottom-dwelling organisms. • Overharvesting can dramatically decrease coastal populations of fish or shellfish. • Coastal species can unintentionally get trapped in fishing gear.

2019 SCORING GUIDELINES**Question 1 (continued)**

(c) **Identify** one economic impact on coastal communities that has resulted from rising sea levels.

(1 point for the correct identification of one economic impact on coastal communities that has resulted from rising sea levels)

- Decrease of tourist revenue
- Decrease of property value
- Increase in damage to property, land, or infrastructure requiring repair or replacement
- Increase in insurance costs
- Loss of agricultural land or aquaculture operations resulting in financial loss
- Loss of fish nurseries in wetland areas leading to less revenue for commercial fisheries
- Increase in jobs in infrastructure/construction to repair damaged structures and properties
- Increase in costs associated with preventative measures (building sea walls, raising building, etc.)

(d) **Describe** TWO methods that may be used locally to protect coastal communities from rising sea levels.

(2 points; 1 point for each correct description and method that may be used locally to protect coastal communities from rising sea levels)

- Raise structures to reduce or prevent water damage.
- Move/build structures back from the beach (setbacks) to reduce or prevent water damage.
- Install pumps to reduce flooding.
- Build structures, such as sea walls, to protect area from wave action/storm surge/flooding/erosion.
- Plant vegetation along appropriate shoreline to decrease erosion.
- Replenish sand to address problems from erosion or to increase width of beach.
- Build jetties/groins to act as a barrier from waves.

2019 SCORING GUIDELINES**Question 2**

As conventional sources of crude oil are depleted, unconventional sources such as oil sands (also known as tar sands) are being utilized. Oil 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.

(1 point for the correct identification of an ecological benefit provided by forests)

- Absorb carbon dioxide/produces oxygen (gas exchange)
- Maintain ecological and/or species diversity
- Provide food for organisms
- Moderate/regulate (local) climate
- Purify/filter water or air
- Reduce soil erosion
- Absorb/store/regulate water
- Help maintain stream temperature/stream flow
- Aid in nutrient cycling
- Aid in soil formation

(b) **Identify** one economic benefit that is provided by forests.

(1 point for the correct identification of an economic benefit provided by forests)

- Source of forest products (timber, medicine, nuts, crops such as shade-grown coffee, etc.)
- Tourism
- Jobs in recreation/tourism/forestry
- Reduction in air pollutants, which can
 - reduce health care costs
 - improve crop yields

(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.

(2 points; 1 point for each correct description of an environmental consequence that results from the extraction of bitumen or the transport of synthetic oil to customers)

- Release of greenhouse gases/air pollutants such as NO_x from fossil fuel combustion that powers equipment/transportation/oil processing
- Release of air pollutants (NO_x, SO_x, or particulates) during mining operations or oil processing
- Storage and disposal of large amounts of solid/liquid mining waste, which can be toxic to organisms
- Pollution of surface water and/or groundwater from oil spills/leaks during transport
- Sediment pollution in surface water and/or groundwater from strip mining
- Disturbance from pipelines, such as habitat fragmentation, disruption of migratory routes, etc.
- Noise pollution from use of machinery during processing or transport
- Diversion/use of water from surface water and/or groundwater for processing oil

2019 SCORING GUIDELINES**Question 2 (continued)**

- (d) Assuming the above extraction rate, **calculate** how many days will be needed to extract the recoverable volume of bitumen from the oil sands.

(2 points; 1 point for the correct setup and 1 point for the correct answer)

$$7.3 \times 10^{10} \text{ barrels of bitumen} \times \frac{1 \text{ day}}{1.0 \times 10^6 \text{ barrels of bitumen}}$$

$$= 7.3 \times 10^4 \text{ days}$$

$$= 73,000 \text{ days}$$

(Note: Units are not required in the answer)

- (e) **Calculate** how many years will be needed to fully extract the recoverable volume of bitumen from the oil sands.

(2 points; 1 point for the correct setup and 1 point for the correct answer; incorrect answer from (d), used correctly, can still earn points in part (e))

$$7.3 \times 10^4 \text{ days} \times \frac{1 \text{ year}}{365 \text{ days}}$$

$$= 2 \times 10^2 \text{ years}$$

$$= 200 \text{ years}$$

(Note: Units are not required in the answer.)

- (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.

(2 points; 1 point for the correct setup and 1 point for the correct answer)

$$\frac{3 \times 10^7 \text{ barrels of synthetic oil}}{1 \text{ month}} \times \frac{2 \text{ barrels of fresh water}}{1 \text{ barrel of synthetic oil}} \times \frac{12 \text{ months}}{1 \text{ year}}$$

$$= 7.2 \times 10^8 \text{ barrels of fresh water}$$

$$= 720,000,000 \text{ barrels of fresh water}$$

(Note: Units are not required in the answer)

2019 SCORING GUIDELINES

Question 3

The graph shows measurements of atmospheric levels of carbon dioxide (CO_2) at Mauna Loa Observatory, Hawaii, and the measurements of pH levels in the ocean nearby at Station ALOHA. Measurements of pH began in 1992.

(a) Use the graph above to answer the following questions.

(i) **Determine** the concentration of CO_2 (in ppm) recorded at Mauna Loa in 2005.

(1 point for identifying from the graph the correct value of concentration of CO_2 recorded at Mauna Loa in 2005)

380 ppm (+/-5 ppm)

(ii) **Determine** the pH recorded at Station ALOHA in 2005.

(1 point for identifying from the graph the correct value of pH recorded at Station ALOHA in 2005)

8.08 (+/- 0.02)

(b) Changes in atmospheric carbon dioxide affect Earth's oceans.

(i) **Predict** the effect of increased concentration of atmospheric CO_2 on the concentration of CO_2 in the ocean.

(1 point for correctly predicting the effect of an increase in concentration of CO_2 in the ocean)

- Oceanic CO_2 will increase.
- Dissolved oceanic CO_2 will increase.

(ii) Based on the data, **identify** the relationship in the concentration of atmospheric CO_2 and the pH of the ocean water.

(1 point for correctly identifying the relationship between the concentration of atmospheric CO_2 and the pH of ocean water based on data)

- As atmospheric CO_2 increases, pH decreases.
- As more CO_2 dissolves in the water, it becomes more acidic/less alkaline.
- As atmospheric CO_2 increases, H_3O^+ or H^+ ions increase.

(iii) **Provide** the complete chemical equation that represents the reaction between oceanic carbon dioxide (CO_2) and water (H_2O).

(1 point for the correct balanced chemical equation that represents the reaction between oceanic carbon dioxide and water)

- $\text{CO}_2 + \text{H}_2\text{O} \rightarrow \text{H}_2\text{CO}_3$ (carbon dioxide plus water produces carbonic acid)
- $\text{CO}_2 + \text{H}_2\text{O} \rightarrow \text{H}^+ + \text{HCO}_3^-$ (carbon dioxide plus water produces one hydrogen ion and one bicarbonate ion)
- $\text{CO}_2 + \text{H}_2\text{O} \rightarrow 2\text{H}^+ + \text{CO}_3^{2-}$ (carbon dioxide plus water produces two hydrogen ions and one carbonate ion)

2019 SCORING GUIDELINES**Question 3 (continued)**

- (iv) **Identify** the specific environmental problem that directly results from the decrease in pH of Earth's oceans.

(1 point for correctly identifying the specific environmental problem that directly results from the decrease in pH of Earth's oceans)

Ocean Acidification

- (c) Changes in pH in the world's oceans pose a risk to many marine organisms.

- (i) **Explain** why certain organisms, in particular those with calcium carbonate shells or exoskeletons, are threatened by the decreasing pH levels measured in seawater.

(2 points; 1 point for correctly explaining the impact of a decrease in pH on shells or exoskeletons and 1 point for an impact on survival of organisms)

Chemical impact on shell/coral formation	Impact on survival of organism
A decrease in pH levels could • Cause shells/exoskeletons to dissolve • Prevent the growth of new coral/shells • Prevent renewal/maintenance of existing coral/shells	Organisms, such as mollusks and coral, would be threatened with • Reduced fitness/decreased number of offspring • Increased predation risk • Increased threat of disease

2019 SCORING GUIDELINES**Question 3 (continued)**

- (ii) Other than threats posed by decreasing pH, **identify** an additional anthropogenic threat to the world's coral reef ecosystem and **describe** how the threat damages the coral reefs and coral reef ecosystems.

(2 points; 1 point for the correct identification of an additional anthropogenic threat to the world's coral reef ecosystem and 1 point for correctly linking a description of the identified threat to the damage to coral reefs and coral reef ecosystems)

Identify one additional anthropogenic threat to the world's coral reef ecosystems	Describe how the threat damages coral reefs and coral reef ecosystems
Increased ocean temperature	• Coral bleaching (loss of the algal symbiont) • Reduction of dissolved oxygen concentration
Recreational activities, such as watercraft, scuba, snorkeling, swimming, etc.	• Physical damage to/destruction of coral reefs
Fishing practices, such as bottom trawling, dynamite fishing, overfishing, etc.	• Physical damage to/destruction of coral reefs • Removal of key species disrupts the food web/causes a trophic cascade
Nutrient pollution (from agricultural runoff, wastewater treatment plants, etc.)	• Cultural eutrophication and eventual decrease in dissolved oxygen levels • Excessive algal growth reduces light penetration
Sediment pollution (from logging operations, mining, etc.)	• Increased turbidity/reduction in light penetration • Deposited sediments cover/smother coral reefs
Chemical pollution, such as oil spills, pesticide runoff, sunscreen, etc.	• Disruption of reproduction and growth cycles • Disruption of metabolic processes • Endocrine disruption/DNA damage • Reduction in light penetration
Plastic/solid waste pollution	• Physical damage to/destruction of members of the coral reef ecosystem • Reduction of light penetration
Introduction of invasive species (lionfish/turkey fish, Philippine mantis shrimp, etc.)	• Invasive species can outcompete native species

2019 SCORING GUIDELINES**Question 4**

One reason that people visit national parks is to view the scenery. Visibility at the four parks in the graph has been reduced over time so that by 2015 the visibility was an average of 70 miles less than the historical visibility. Regional air pollutant sources are commonly located over 100 miles away from national parks.

- (a) Based on the data provided in the graph, **identify** the national park that had the greatest loss of visibility as of 2015 when compared with the historical natural visibility.

(1 point for the correct identification of the national park that has had the greatest loss of visibility)

Sequoia National Park

- (b) Visibility in national parks can be affected by many different air pollutants.

- (i) **Identify** a primary air pollutant.

(1 point for the correct identification of a primary air pollutant)

- Carbon dioxide (CO_2)
- Carbon monoxide (CO)
- Nitrogen oxides (NO_x)
- Nitrous oxide (N_2O)
- Particulate Matter (PM)
- Sulfur dioxide (SO_2)
- Methane (CH_4)
- Volatile organic compounds (VOCs)

- (ii) **Describe** how a primary air pollutant becomes part of the atmosphere.

(1 point for the correct description of how a primary air pollutant becomes part of the atmosphere)

- Primary pollutants are released directly from a specific source, such as a smokestack, tailpipe, leaking pipelines, etc.
- Primary pollutants are released from the combustion of fossil fuels.
- Some pollutants (CO, PM) are a result of incomplete combustion of hydrocarbons.
- Some pollutants (methane, nitrous oxide, ammonia) are released directly from a biological source, such as cows, swamps, etc.

- (iii) **Identify** a secondary air pollutant.

(1 point for the correct identification of a secondary air pollutant)

- Ozone (O_3)
- Sulfuric acid (H_2SO_4)
- Sulfur trioxide (SO_3)
- Nitric acid (HNO_3)
- Peroxyacyl nitrates (PANs)
- Nitrogen dioxide (NO_2)
- Aldehydes

2019 SCORING GUIDELINES**Question 4 (continued)**

(iv) **Describe** how a secondary air pollutant is formed within the atmosphere.

(1 point for the correct description of how a secondary air pollutant is formed within the atmosphere)

- Secondary air pollutants are formed when primary pollutants react with other compounds.
- Ozone (O_3) forms when primary pollutants such as NO_x and VOCs react with oxygen in the presence of sunlight.
- Sulfuric acid forms when SO_x reacts with water.
- Nitric acid forms when NO_x reacts with water.

(c) In 1990 Great Smoky Mountains National Park had a visibility of 25 miles. Visibility data for 2015 can be determined from the graph above.

(i) **Calculate** the percentage of increase in visibility from 1990 to 2015.

(1 point for the correct calculation of the percentage of increase in visibility from 1990 to 2015. Students are not required to show work.)

$$80\% \text{ increase in visibility } \left(\frac{45 \text{ miles} - 25 \text{ miles}}{25 \text{ miles}} \times 100 = 80\% \right)$$

(ii) **Discuss** TWO specific actions that the state or federal government could take or encourage to further improve the visibility in Great Smoky Mountains National Park.

(2 points; 1 point for each correct and realistic discussion of a specific action the state or federal government could take or encourage to further improve the visibility in Great Smoky Mountains National Park)

- Require or offer incentives for utilities/corporations to reduce emissions by specific methods, such as cap-and-trade, pollution-prevention control devices, alternative energy sources, environmental standards on new equipment, etc.
- Limit vehicle traffic in the park through increased parking fees, free/required shuttles, HOV priority parking, etc.
- Enact stricter standards for emissions on motor vehicles.
- Offer incentives to switch from gasoline-powered vehicles to electric vehicles or natural-gas powered vehicles.
- Offer tax credits or subsidies to homeowners to increase the use of renewable energy sources.
- Limit incineration practices/prohibit campfires to reduce air pollutants.

2019 SCORING GUIDELINES**Question 4 (continued)**

(d) Excluding air pollution, **discuss** TWO additional ways national park ecosystems are being degraded by high levels of visitor use.

(2 points; 1 point for each correct discussion of an additional way national park ecosystems are being degraded by high levels of visitor use)

- Littering or inappropriate disposal of trash can negatively impact the health of wildlife.
- Littering or inappropriate disposal of trash can negatively impact water quality.
- Infrastructure construction/maintenance can result in habitat fragmentation.
- Driving or walking off road/path damages vegetation, increases erosion, or increases soil compaction.
- Noise pollution can adversely impact wildlife by disrupting mating, ranging, foraging, etc.
- Light pollution can adversely impact wildlife by disrupting mating, ranging, foraging, etc.
- Interactions with humans or pets adversely impacts wildlife by disrupting mating, ranging, foraging, etc.
- Visitors transporting nonnative species to the park results in an increase in invasive species.
- Camp fires from visitors can lead to wildfires.
- Removal of individual organisms for food, trophies, or human use can disrupt the food web.
- Water used for bathing and sanitation can lead to pollution of water resources.