

# Free-Response Section

## Scoring Guidelines

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### Question 1: Design an Investigation

10 points

Learning Objectives: ERT-2.E EIN-4.A STB-4.H ERT-2.A STB-1.C

#### General Scoring Note:

When scoring questions with multiple correct answers, only score the first response given.

- (A) **Describe** TWO characteristics of invasive plants that help them outcompete native plants. **1 point**  
1.A  
ERT-2.E
- Accept one of the following:**
- Invasive species generally have a greater range of tolerance than native species (such as increased drought tolerance, tolerance to soil disruption and changes in nutrient availability, tolerance to temperature fluctuations).
  - Invasive species are often generalist species and are advantaged in habitats that are changing.
  - Many invasive species are r-selected species so they generally
    - propagate more quickly than native species
    - germinate more quickly than native species
    - produce more seeds than native species
    - reproduce more quickly or have shorter reproductive cycles than native species
  - Invasive species often have longer growing seasons than native species.
  - Invasive species often lack natural predators or viruses in the ecosystem.
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- Total for part (A) 2 points**

- (B) The research findings are summarized in the graph above.
- (i) Based on the data in the graph, **identify** the year in which the abundance of native plants versus invasive plants is nearly equal. **1 point**  
5.A  
EIN-4.A
- Accept one of the following:**
- 2001
  - 2002
- (ii) **Describe** the change in overall plant abundance from 2000–2012, using the data in the graph. **1 point**  
5.B  
EIN-4.A
- Accept one of the following:**
- Plant abundance decreases from approximately 340 plants/100 m<sup>2</sup> to 300 plants/100 m<sup>2</sup>.
  - Plant abundance decreases approximately 10 percent.
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- (iii) **Explain** what the trend in relative abundance of native hardstem lovegrass and the invasive fountain grass over the 12-year period implies about each species' ability to withstand drought conditions. **1 point**

5.E

EIN-4.A

**Accept one of the following:**

- Over the 12-year period of drought, the relative abundance of native hardstem lovegrass decreased, while the abundance of invasive fountain grass increased. This would imply that the invasive fountain grass is more drought tolerant than the native hardstem lovegrass.

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**Total for part (B) 3 points**

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- (C) **Explain** how a loss of species diversity would affect the stability of an ecosystem. **1 point**

1.B

ERT-2.A

**Accept one of the following:**

- The greater the species diversity of an ecosystem, the better it can withstand environmental stressors. A loss of biodiversity means the ecosystem would be more likely to be damaged (or have additional species loss) during times of environmental stress.
- Ecosystems that have a larger number of species have a greater chance to recover more quickly from a disruption than those with a smaller number of species.
- For plant species (or producers) in particular, the greater the biodiversity, the greater the ecosystem productivity and the more stable the trophic structure.

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**Total for part (C) 1 point**

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- (D)** Based on the data in the graph, the Forest Service decides that a coordinated attempt should be made to remove the non native fountain grass from Mauna Kea to protect the native hardstem lovegrass, following an Integrated Pest Management (IPM) approach.
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- (i)** **Describe** the process of IPM as an environmental solution. **1 point**  
**7.B**  
**STB-1.C**
- Accept the following:**
- Integrated Pest Management is a combination of methods used to effectively control pest species, while minimizing the disruption to the environment, especially limiting the introduction of chemicals into the environment. These methods include physical, biological, and limited chemical methods.
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- (ii)** The ecologists want to begin their IPM program with physical control in a managed area and establish a 10-hectare plot in which they will test their efforts. Based on the data in the graph and the information provided, **identify** a testable scientific question that the ecologists could use to guide their physical control efforts **1 point**  
**4.A**  
**STB-1.C**
- Accept the following:**
- How will the physical control or removal of invasive fountain grass affect the relative abundance of native hardstem lovegrass?
  - Which physical control or removal methods of fountain grass will be most effective in controlling its recurrence in the test plot?
  - How can the effectiveness of physical control or removal efforts of fountain grass be measured?
  - How will the local environment respond to the physical control or removal of fountain grass?
  - Will the physical control or removal of invasive fountain grass aid in the reestablishment of native hardstem lovegrass?
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- (iii)** **Describe** a reasonable research method that the ecologists could use in their physical control efforts. **1 point**  
**4.C**  
**STB-1.C**
- Accept one of the following:**
- Physically remove the fountain grass on an identified schedule and do nothing to the hardstem lovegrass.
  - Physically remove the fountain grass and reseed the area with hardstem lovegrass.
  - Physically remove both types of grasses from the test plot at the beginning of the trial.
  - Physically remove both types of grasses from the test plot at the beginning of the trial and reseed the area with hardstem lovegrass.

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**Total for part (D) 3 points**

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After four years of physical control efforts, the ecologists evaluate the abundance of each type of grass in the test plot. They discover that, although there is less fountain grass in their test plot than when they began, there has not been a significant increase in native hardstem lovegrass.

(E)

Assuming the ecologists wish to continue with an IPM approach and continue their removal efforts on the test plot for another four years, **explain** one modification that could be made to the research method you identified above that could alter their results.

**1 point**

**4.E**

**STB-1.C**

**Accept one of the following:**

- Reseed the areas from which the fountain grass was removed with native hardstem lovegrass.
- Replant mature native hardstem lovegrass from other areas in the areas from which the fountain grass was removed.
- In addition to physical control, add biological or limited chemical control to the removal regimen, consistent with IPM.
- Test soil in removal area to be certain it is appropriate for native hardstem lovegrass; amend if necessary to return ideal conditions for native hardstem lovegrass (some invasive species release chemicals into soil that make the area inhospitable for other species).

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**Total for part (E) 1 point**

**Total for question 1 10 points**

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## Question 2: Analyze an Environmental Problem and Propose a Solution

10 points

Learning Objectives: EIN-2.M EIN-3.D STB-2.C STB-2.B STB-1.B

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### General Scoring Note:

When scoring questions with multiple correct answers, only score the first response given.

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As the human population grows, more individuals are moving into urban areas.

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- (A) **Describe** one negative human health effect associated with urbanization. **1 point**
- Accept one of the following:**
- Urban areas can have high concentrations of air pollutants (such as particulate matter) that can lead to respiratory issues, cardiovascular issues, and/or cancer (especially lung cancer).
  - Urban food deserts without access to high-quality fresh food can lead to health issues such as diabetes, hypertension, and/or obesity.
  - Close proximity to other people in urban areas can lead to an increased spread of infectious disease.
  - Overcrowded living conditions can lead to increased noise pollution in urban areas, which can lead to physiological stress.
  - In less developed countries, urban areas that lack sanitary waste disposal/lack clean drinking water have increased incidences of certain infectious diseases (such as dysentery).
- Total for part (A) 1 point**
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- (B) **Describe** TWO environmental benefits of urbanization. **2 points**
- Accept one of the following:**
- High-density areas make public transportation more viable, decreasing personal vehicle use/combustion of fossil fuels.
  - Urban living encourages walking/cycling rather than driving, which reduces the carbon footprint.
  - Condensed/small living space reduces energy needs.
  - Individual living spaces in cities are more compact, allowing for natural areas to be conserved (compared with private property sizes in suburban or rural areas).
- Total for part (B) 2 points**
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Geographic features and climatological factors can make some locations more prone to the effects of air pollution. The diagram below illustrates a city of millions of people and its surrounding geography. Human activities in urban areas can release pollutants into the air that lead to ground-level ozone and smog formation.

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**(C)** Describe how a thermal inversion would form in the city shown in the diagram. **1 point**

**2.A**

**Accept one of the following:**

**STB-2.C**

- The temperature gradient of the atmosphere is altered when the cool ocean breezes bring air to Earth's surface that is cooler than the air at higher altitudes.
  - A thermal inversion forms when a warm layer of air traps a cooler layer of air close to Earth's surface. The cold air ends up at the surface when the mountains block the morning sunlight from warming the floor of the valley or particulate pollution blocks sunlight from reaching the surface.
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**Total for part (C) 1 point**

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**(D)** Describe the relationship between a thermal inversion and pollution. **1 point**

**1.B**

**Accept the following:**

**STB-2.C**

- A thermal inversion traps pollutants close to the ground, especially smog and particulates.
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**Total for part (D) 1 point**

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**(E)** Explain how one factor related to climate could make the city shown in the diagram susceptible to prolonged periods of ground-level ozone and smog. **1 point**

**2.C**

**Accept one of the following:**

**STB-2.C**

- If the city receives abundant sunlight, the sunlight increases the formation of ground-level ozone and smog. A clear sky or lack of cloud cover/more sunlight provides the energy for photochemical reactions to occur.
  - If the city experiences periods of high temperatures, the high temperatures increase the formation of ground-level ozone and smog. Increased temperatures increase the reaction rate for photochemical reactions to occur.
  - If the city experiences periods of no wind, ground-level ozone and smog that forms will be concentrated.
  - If the city experiences high levels of rainfall, the pollutants are more likely to be removed from the atmosphere and deposition can occur.
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**Total for part (E) 1 point**

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<b>(F)</b>	<p>Explain how a geographical feature could make the city shown in the diagram susceptible to prolonged periods of ground-level ozone and smog.</p> <p><b>Accept one of the following:</b></p> <ul style="list-style-type: none"> <li>• The city is surrounded by mountains, forming a basin that can prevent pollutants from dispersing.</li> <li>• The city is surrounded by mountains that can contribute to the development of thermal inversions, which can trap pollutants.</li> <li>• The cold ocean water contributes the cool air necessary to form an inversion layer that traps pollutants.</li> </ul>	<p><b>1 point</b></p> <p><b>2.C</b></p> <p><b>STB-2.B</b></p>
<b>Total for part (F)</b>		<b>1 point</b>

<b>(G)</b>	<p><b>Propose</b> a solution to reduce the formation of ground-level ozone or smog resulting from human activities in the city.</p> <p><b>Accept one of the following:</b></p> <ul style="list-style-type: none"> <li>• Use public transportation/carpool/walk to decrease personal vehicle use, reducing emissions released from vehicles</li> <li>• Use electric cars/transportation instead of gasoline-powered cars/transportation to reduce emissions released in the city from vehicles.</li> <li>• Use electric lawn equipment instead of gasoline-powered lawn equipment to reduce emissions that lead to formation of smog.</li> <li>• Publicize ozone action days to decrease emissions on days when ozone concentrations will be higher from sunlight.</li> <li>• Ban burning (use of fireplaces/outdoor fire pits/trash combustion) on high-ozone days to decrease emissions.</li> </ul>	<p><b>1 point</b></p> <p><b>7.E</b></p> <p><b>STB-1.B</b></p>
<b>Total for part (G)</b>		<b>1 point</b>

<b>(H)</b>	<p>Air pollution such as smog and ground-level ozone are not the only problems associated with urbanization. Human-made structures in urban areas can increase the amount of runoff reaching streams and lakes.</p>	
<b>(i)</b>	<p><b>Propose</b> a solution to reduce the effects of urban runoff.</p> <p><b>Accept one of the following:</b></p> <ul style="list-style-type: none"> <li>• Replace traditional pavement with permeable pavement/reduce impervious surfaces and/or increase the amount of vegetated land cover.</li> <li>• Plant trees or other plants to reduce stormwater runoff/capture rainfall/promote infiltration of rainwater into the soil.</li> <li>• Build up, not out, to maintain undeveloped areas/green spaces that can reduce stormwater runoff/capture rainfall/promote infiltration of rainwater into the soil.</li> <li>• Reduce use of fertilizers, pesticides, and herbicides in public and private gardens/green spaces/lawns.</li> <li>• Post signs in parks to encourage pet owners to pick up after pets/keep pets out of streams and waterways/properly dispose of pet waste.</li> </ul>	<p><b>1 point</b></p> <p><b>7.E</b></p> <p><b>STB-1.B</b></p>

- (ii) **Justify** the solution proposed in (h)(i) by describing an additional benefit, other than reducing the effects of urban runoff. **1 point**

7.F

STB-1.B

**Accept one of the following justifications.**

Solution proposed in (h)(i).	Justification of Solution with an Additional Benefit
Replace traditional pavement with permeable pavement/reduce impervious surfaces and/or increase the amount of vegetated land cover.	<ul style="list-style-type: none"> <li>• Helps to replenish the groundwater supply as water percolates through</li> <li>• Provides an economic benefit because permeable materials are often less expensive per square foot and labor is less intensive than for asphalt or concrete</li> </ul>
Plant trees or other plants to reduce stormwater runoff/capture rainfall/promote infiltration of rainwater into the soil.	<ul style="list-style-type: none"> <li>• Provides aesthetic benefits for humans</li> <li>• Creates urban green spaces that can provide habitat for a variety of organisms</li> <li>• Helps to replenish the groundwater supply as water percolates into the soil</li> <li>• Lowers air temperatures in urban areas/reduces the urban heat island effect</li> <li>• Reduces air pollutants (particulate matter, volatile organic compounds) that can cause human health issues</li> <li>• Reduces global climate change through forest sequestration of carbon</li> <li>• Encourages and protects pollinator populations</li> </ul>
Build up, not out, to maintain undeveloped areas/green spaces	<ul style="list-style-type: none"> <li>• Provides aesthetic benefits for humans</li> <li>• Provides habitat for a variety of organisms in urban green spaces</li> <li>• Can reduce exposure to noise pollution/air pollution/excessive heat in urban areas</li> </ul>
Reduce use of fertilizers, pesticides, and herbicides in public and private gardens/green spaces/lawns.	<ul style="list-style-type: none"> <li>• Economic benefits of using fewer chemicals to maintain lawns</li> <li>• Increased safety for children and pets who may ingest chemicals</li> <li>• Protection of pollinator species through insecticide avoidance</li> </ul>
Post signs in parks to encourage pet owners to pick up after pets/keep pets out of streams and waterways.	<ul style="list-style-type: none"> <li>• Increased safety for children and pets who may be exposed to wastes</li> <li>• Decreased spread of disease in pets and wildlife</li> </ul>

**Total for part (H) 2 points**

**Total for question 2 10 points**



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**Question 3: Analyze an Environmental Problem and Propose a Solution  
(doing calculations)**

**10 points**

**Learning Objectives:** ERT-3.F EIN-1.A EIN-1.C EIN-2.I STB-1.A

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Birth rates, infant mortality rates, death rates, and a variety of other factors affect whether the size of a human population is growing or declining. Demographic changes have important environmental, social, and economic implications.

**(A)** **Identify** one factor that contributes to the high crude death rate in countries that have never experienced the changes that result from a demographic transition. **1 point**

**1.A**

**Accept one of the following:**

**EIN-1.C**

- Unsafe drinking water/lack of access to clean drinking water
- Loss of agriculture land for crops and livestock
- Lack of access to health care
- High rates of diseases such as heart disease, respiratory infections, HIV/AIDS, malaria, tuberculosis
- High infant mortality
- Risk of death during pregnancy (from lack of quality health care)

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**Total for part (A)** **1 point**

**(B)** **Describe** a typical age structure diagram for a developing country. **1 point**

**1.B**

**Accept one of the following:**

**EIN-1.A**

- A rapidly growing population will have a higher proportion of younger people than will a stable or declining population.
- A rapidly growing population will have more individuals in younger cohorts/prereproductive stage than individuals in older cohorts/reproductive and postreproductive stage.
- A developing country often has a pyramid-shaped age structure diagram, with more individuals in younger cohorts at the broad base.

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**Total for part (B)** **1 point**

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<b>(C)</b>	Use the data in the table to answer the following questions.	
<b>(i)</b>	<p><b>Calculate</b> the percent of the global population that was living in more developed countries in 2018. <b>Show</b> your work.</p> <p><b>1 point</b> for correct setup to calculate the percent of the global population</p> <ul style="list-style-type: none"> <li><math>\frac{1,266 \text{ million people in more developed countries}}{7,621 \text{ million people in the world}} \times 100</math></li> </ul> <p><b>1 point</b> for the correct calculation of the percent of the global population</p> <ul style="list-style-type: none"> <li>16.6%</li> </ul>	<p><b>2 points</b></p> <p>6.B 6.C EIN-1.C ERT-3.F</p>
<b>(ii)</b>	<p><b>Calculate</b> the population growth rate (as a percent) for less developed countries. <b>Show</b> your work.</p> <p><b>1 point</b> for correct setup to calculate the population growth rate (as a percent)</p> <ul style="list-style-type: none"> <li>population growth rate = <math>\left( \frac{21 \text{ births}}{1,000 \text{ individuals}} - \frac{7 \text{ deaths}}{1,000 \text{ individuals}} \right) \times 100</math></li> </ul> <p><b>1 point</b> for the correct calculation of population growth rate (as a percent)</p> <ul style="list-style-type: none"> <li>1.4%</li> </ul>	<p><b>2 points</b></p> <p>6.B 6.C EIN-1.C ERT-3.F</p>
<b>Total for part (C)</b>		<b>4 points</b>

<b>(D)</b>	As countries change during a demographic transition, there is often a growing demand for meat in human diets. It takes an estimated 1,750 liters of water to produce 113 grams of beef. The average person in a more developed country consumes 85 grams of beef per day.	
<b>(i)</b>	<p><b>Calculate</b> the amount of water needed, in liters per year, to produce the beef consumed by one person in a more developed country. <b>Show</b> your work.</p> <p><b>1 point</b> for correct setup to calculate the amount of water needed</p> <ul style="list-style-type: none"> <li><math>\frac{85 \text{ grams of beef}}{1 \text{ day}} \times \frac{365 \text{ days}}{1 \text{ year}} \times \frac{1,750 \text{ liters of water}}{113 \text{ grams of beef}}</math></li> </ul> <p><b>1 point</b> for the correct calculation of the amount of water needed</p> <ul style="list-style-type: none"> <li>480,476 liters of water per year</li> <li><math>4.80 \times 10^5</math> liters of water per year</li> <li><math>4.8 \times 10^5</math> liters of water per year</li> </ul>	<p><b>2 points</b></p> <p>6.B 6.C EIN-2.1</p>
<b>(ii)</b>	<p><b>Make a claim</b> to propose a solution that would reduce the amount of water required to produce enough food for individuals.</p> <p><b>Accept one of the following:</b></p> <ul style="list-style-type: none"> <li>Eat lower on the food chain/reduce consumption of animal protein.</li> <li>Produce plant-based sources of protein.</li> <li>Implement efficient irrigation for growing crops.</li> <li>Plant local crops that do not require as much water.</li> <li>Plant genetically modified crops that do not require much water.</li> <li>Discourage the production of beef in favor of production of less water-intensive livestock such as chicken.</li> <li>Discourage the use of feedlots, which can lead to soil compaction and increase runoff.</li> </ul>	<p><b>1 point</b></p> <p>7.E STB-1.A</p>

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(iii) **Describe** one environmental disadvantage associated with increasing the amount of meat in human diets, other than associated with consumption of water. **1 point**

7.A

EIN-2.1

**Accept one of the following:**

- More land is required to produce the same number of calories from meat as from plants.
- Use of animal feedlots to raise animals generates large amounts of organic waste, which can contaminate ground and surface waters.
- Use of animal feedlots to raise animals increases the incidence of disease in livestock, has an unpleasant odor, and/or increases water pollution.
- Overgrazing can occur when too many animals feed on a particular area of land, which can increase soil erosion.
- Overgrazing can occur when too many animals feed on a particular area of land, which can lead to desertification.
- Cattle release greenhouse gases such as methane, which can exacerbate global climate change.

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**Total for part (D) 4 points**

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**Total for question 3 10 points**