The Exam

ENVIRONMENTAL SCIENCE

Three hours are allotted for this examination: 1 hour and 30 minutes for Section I, which consists of multiple-choice questions; and 1 hour and 30 minutes for Section II, which consists of essay questions. Section I is printed in this examination booklet. Section II is printed in a separate booklet.

SECTION I

Time — 1 hour and 30 minutes

Number of questions — 100

Percent of total grade — 60

Section I of this examination contains 100 multiple-choice questions and 9 survey questions. Therefore, please be careful to fill in only the ovals that are preceded by numbers 1 through 109 on your answer sheet. No calculators may be used on this examination.

General Instructions

DO NOT OPEN THIS BOOKLET UNTIL YOU ARE INSTRUCTED TO DO SO.

INDICATE ALL YOUR ANSWERS TO QUESTIONS IN SECTION I ON THE SEPARATE ANSWER SHEET ENCLOSED. No credit will be given for anything written in this examination booklet, but you may use the booklet for notes or scratchwork. After you have decided which of the suggested answers is best, COMPLETELY fill in the corresponding oval on the answer sheet. Give only one answer to each question. If you change an answer, be sure that the previous mark is erased completely.

Example:

Chicago is a

(A) state
(B) city
(C) country
(D) continent
(E) village

Sample Answer

Many candidates wonder whether or not to guess the answers to questions about which they are not certain. In this section of the examination, as a correction for haphazard guessing, one-fourth of the number of questions you answer incorrectly will be subtracted from the number of questions you answer correctly. It is improbable, therefore, that mere guessing will improve your score significantly; it may even lower your score, and it does take time. If, however, you are not sure of the correct answer but have some knowledge of the question and are able to eliminate one or more of the answer choices as wrong, your chance of getting the right answer is improved, and it may be to your advantage to answer such a question.

Use your time effectively, working as rapidly as you can without losing accuracy. Do not spend too much time on questions that are too difficult. Go on to other questions and come back to the difficult ones later if you have time. It is not expected that everyone will be able to answer all the multiple-choice questions.

ENVIRONMENTAL SCIENCE

Section I

Time—1 hour and 30 minutes

Part A

Directions: Each set of lettered choices below refers to the numbered questions or statements immediately following it. Select the one lettered choice that best answers each question or best fits each statement and then fill in the corresponding oval on the answer sheet. A choice may be used once, more than once, or not at all in each set.

Questions 1-4 refer to the following energy efficiencies, expressed as percentages.

(A) 100%
(B) 95%
(C) 30%
(D) 15%
(E) 1%

1. Approximate efficiency of an average coal-fired power plant

2. Approximate efficiency of the conversion of light energy to chemical energy in photosynthesis

3. Approximate percentage of electrical energy converted to heat in the average incandescent lightbulb

4. The maximum efficiency possible in an energy-conversion process that is not limited by the second law of thermodynamics

Questions 5-7 refer to the following processes.

(A) Photosynthesis
(B) Eutrophication
(C) Denitrification
(D) Decomposition
(E) Transpiration

5. The rapid rate of this process in tropical forests results in low-nutrient soils

6. The process in which glucose is synthesized by plants

7. The process by which a soil nutrient is reduced and released to the atmosphere as a gas

Questions 8-11 refer to the following elements.

(A) Oxygen
(B) Aluminum
(C) Iron
(D) Nitrogen
(E) Argon

8. The most abundant element in Earth's crust

9. The most abundant element in Earth's atmosphere

10. The most abundant element in Earth's core

11. The element commercially extracted from bauxite

Questions 12-14 refer to the following processes.

(A) Nitrification
(B) Denitrification
(C) Assimilation
(D) Ammonification
(E) Nitrogen fixation

12. Ammonia is converted to nitrite, then to nitrate.

13. Plant roots absorb ammonium ions and nitrate ions for use in making molecules such as DNA, amino acids, and proteins.

14. Nitrate ions and nitrite ions are converted into nitrous oxide gas and nitrogen gas (N_2).

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Questions 15-18 refer to the following air pollutants.

(A) Sulfur dioxide
(B) Lead
(C) Ozone
(D) Hydrocarbons
(E) Particulates

15. Most often cited as the causative factor for acid deposition

16. Implicated in human neurological damage

17. Considered harmful in the troposphere but beneficial in the stratosphere

18. Is the major pollutant that electrostatic precipitators are designed to remove from power-plant smokestack emissions

Questions 19-21 refer to the following countries.

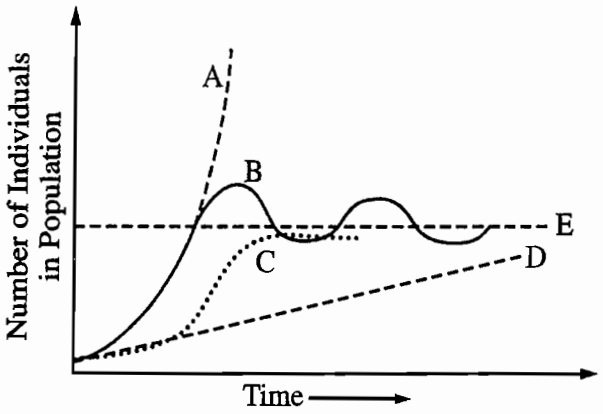
(A) Australia
(B) Brazil
(C) Chile
(D) Russia
(E) United States of America

19. Country with the largest area of boreal forests

20. Country with the greatest percentage of land area affected by desertification

21. Country with the largest area of temperate deciduous forest

Questions 22-24 refer to the figure below. A, B, C, and D represent population growth curves, E represents the carrying capacity.



22. Represents the maximum number of individuals that can be supported by a particular ecosystem on a long-term basis

23. Represents the biotic potential of the species

24. Represents the growth of a population predicted by the logistic model

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Part B

Directions: Each of the questions or incomplete statements below is followed by five suggested answers or completions. Select the one that is best in each case and then fill in the corresponding oval on the answer sheet.

25. The most commonly used measure of the economic growth of a country is which of the following?

(A) Gross national product
(B) Level of exports
(C) Level of imports
(D) Fertility rate
(E) Externalized costs

26. The factor that likely poses the greatest threat of extinction of species worldwide is

(A) weakening of environmental legislation
(B) increase in hunting and fishing
(C) aggressive collecting of specimens by museums and zoos
(D) black-market trade in endangered species
(E) increasing loss of habitat

27. Which of the following energy sources is not derived directly or indirectly from solar energy?

(A) Geothermal
(B) Photovoltaic
(C) Hydroelectric
(D) Biomass
(E) Wind

28. Which of the following best exemplifies global collaboration for a sustainable environment?

(A) The Montreal Protocol
(B) The Antarctic Treaty of 1961
(C) The Clean Air Act of 1972
(D) CERCLA (Superfund)
(E) NAFTA

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29. Which of the following is an effective alternative to chlorine for disinfecting wastewater in a municipal treatment plant?

(A) Freon
(B) Alcohol
(C) Phosphate
(D) Ammonia
(E) Ozone

30. The presence of fecal coliform bacteria in a sample of river water suggests which of the following?

(A) The pH of the river is very high.
(B) The water is contaminated with animal waste.
(C) The river is devoid of plant life.
(D) The dissolved oxygen level of the river is high.
(E) Fish caught from the river will be free of parasites.

31. Which of the following best helps to explain why phosphorus is often a limiting factor in many ecosystems?

(A) There is usually a gaseous phase in the phosphorus cycle.
(B) Phosphorus cycles very quickly through environments.
(C) Under many conditions, phosphorus forms stable insoluble compounds.
(D) Phosphate is not readily taken up by plants.
(E) There are no anthropogenic sources of phosphorus.

32. Factors contributing to the rise in world hunger include all of the following EXCEPT

(A) unequal distribution of available food supplies
(B) loss of or decline in arable land
(C) increasing rate of population growth
(D) increasing poverty in developing countries
(E) increasing consumption of vegetable protein in place of meat protein

33. If a city of population 10,000 experiences 100 births, 40 deaths, 10 immigrants, and 30 emigrants in the course of a year, what is its net annual percentage growth rate?

(A) 0.4%
(B) 0.8%
(C) 1.0%
(D) 4.0%
(E) 8.0%

34. Which of the following statements about genetic diversity is true?

(A) Genetic uniformity of a crop increases the crop's overall resistance to pests and disease.
(B) Genetic resistance to pests and diseases can be increased by crossing a crop plant with ancestral varieties.
(C) Genetic engineering technology is used to increase genetic diversity by creating new species with synthetic genes.
(D) Genetic diversity within populations of common crop species such as corn is typically high.
(E) Genetic diversity is usually high in endangered species.

35. In the United States, most municipal solid waste is disposed of by

(A) composting
(B) recycling
(C) incineration
(D) ocean dumping
(E) landfilling

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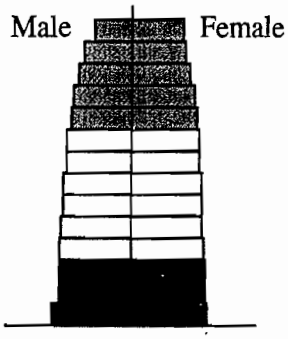
36. Negative environmental impacts associated with large-scale hydroelectric projects have been demonstrated in which of the following areas?

(A) James Bay, Quebec
(B) Three Mile Island, Pennsylvania
(C) Kissimmee River, Florida
(D) Mono Lake, California
(E) Aral Sea, former USSR

AGE DISTRIBUTION



Ages 0–14 Ages 15–44 Ages 45–85+

37. A country with an age distribution like that shown in the figure above, is most likely a country that

(A) is experiencing rapid growth
(B) is experiencing slow or no population growth
(C) is experiencing a high death rate
(D) has 40% of the population under age 15
(E) is a less-developed country

38. Which of the following factors is fundamentally responsible for seasons on Earth?

(A) The varying distance of Earth from the Sun
(B) The tilt of Earth's axis of rotation
(C) The latitudinal variation in temperature and precipitation
(D) The tidal pull of the Sun and Moon
(E) The anthropogenic greenhouse effect

39. If wastewater treatment plant effluent that contains nitrates and phosphates is allowed to flow into a body of water, which of the following may result?

(A) Chlorination
(B) Decomposition
(C) Eutrophication
(D) Oxygenation
(E) Methylation

40. Which of the following describes a fundamental characteristic of the green revolution in food resources?

(A) The application of higher levels of organic fertilizers to increase rice production
(B) Deforestation to provide field crops with increased sunlight for photosynthesis
(C) The addition of calorie, fat, and fiber percentages to the information provided on food package labels
(D) The development of new strains of crops with higher yields
(E) The discovery that chlorophyll adds nutritional value to wheat, rice, and sorghum

41. An industry uses natural gas for manufacturing and uses the waste heat to produce electricity. This is an example of which of the following processes?

(A) Cogeneration
(B) Electrolysis
(C) Gas hydration
(D) Gasification
(E) Reclamation

42. The water-holding capacity of soil is LEAST likely to be affected by the addition of which of the following?

(A) Clay
(B) Humus
(C) Manure
(D) Pesticide
(E) Sand

43. Critics of incineration of municipal solid waste suggest that it may <u>not</u> be the best solution for the future, for which of the following reasons?

(A) Incineration produces ash that increases landfill volume.
(B) Incineration generates methane.
(C) Incineration involves advanced technology.
(D) Incineration contributes to air pollution.
(E) Incineration requires large energy input.

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44. Which of the following is likely to minimize soil erosion?

(A) High-yield crops
(B) Deforestation
(C) Herbicide use
(D) Annual plowing
(E) No-till agriculture

45. A state highway was constructed over wetlands. The state obtained a permit to fill the existing wetlands in accordance with the provisions of the Clean Water Act of 1972, and agreed to create another wetland. This trade-off approach to addressing an environmental issue is known as

(A) mitigation
(B) restoration
(C) preservation
(D) remediation
(E) sustainability

46. Information gathered by a scientist about the toxicity of chemical *X* and chemical *Y* showed that they had individual safe limits for fish at particular concentrations. But when they were used together at the safe concentrations, there were extensive fish kills. This is an example of

(A) homeostasis
(B) synergism
(C) commensalism
(D) bioaccumulation
(E) antagonism

47. The polar regions radiate away more heat energy than they receive from the Sun in the course of a year. However, they are prevented from becoming progressively colder each year primarily by the

(A) absorption of ultraviolet radiation by snow
(B) transport of heat through the atmosphere and oceans
(C) concentration of Earth's magnetic field lines at the poles
(D) release of latent heat to the atmosphere when the polar ice caps melt
(E) generation of heat by glacial movement

48. An advantage of recycling aluminum rather than disposing of it in landfills is that aluminum can be

(A) produced from recycled metal using much less energy than is required for its production from aluminum ore
(B) produced from ore that is chemically reactive and dangerous to transport, store, and process
(C) produced from ore that is scarce and found primarily in remote, inhospitable regions at high latitudes
(D) absorbed by plants and then biomagnified in both terrestrial and aquatic food chains
(E) leached from landfills in the form of Al^{3+} ions that could increase the pH of lakes and streams

49. As urbanization increases and natural soil surfaces are covered, the groundwater supply is reduced due to

(A) increased evaporation and transpiration
(B) decreased surface runoff
(C) loss of recharge area
(D) confinement of aquifers
(E) capping of artesian wells

50. The current global human population is about 6.1 billion and is growing at an annual rate of 1.35 percent. If world population were to grow at this rate for the next year, approximately how many people would be added?

(A) 8×10^5
(B) 8×10^6
(C) 8×10^7
(D) 8×10^8
(E) 8×10^9

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51. Which of the following methods of agricultural irrigation results in the loss of the least amount of water by evaporation?

(A) Conventional center-pivot irrigation
(B) Drip irrigation
(C) Laser-level irrigation
(D) Flood irrigation
(E) Gravity-flow irrigation

52. Which of the following components of a wastewater treatment plant is designed to facilitate the decomposition of organic material by aerobic microorganisms?

(A) Bar screen
(B) Grit-settling tank
(C) Activated-sludge tank
(D) Chlorination tank
(E) Ultraviolet-light array

53. Ozone in the stratosphere is most important to life at Earth's surface because it absorbs

(A) gamma rays
(B) microwaves
(C) ultraviolet light
(D) visible light
(E) x-rays

54. The major source of radon in houses in the United States is

(A) furniture and carpets
(B) the underlying bedrock
(C) the troposphere
(D) nuclear power plants
(E) fossil-fuel combustion

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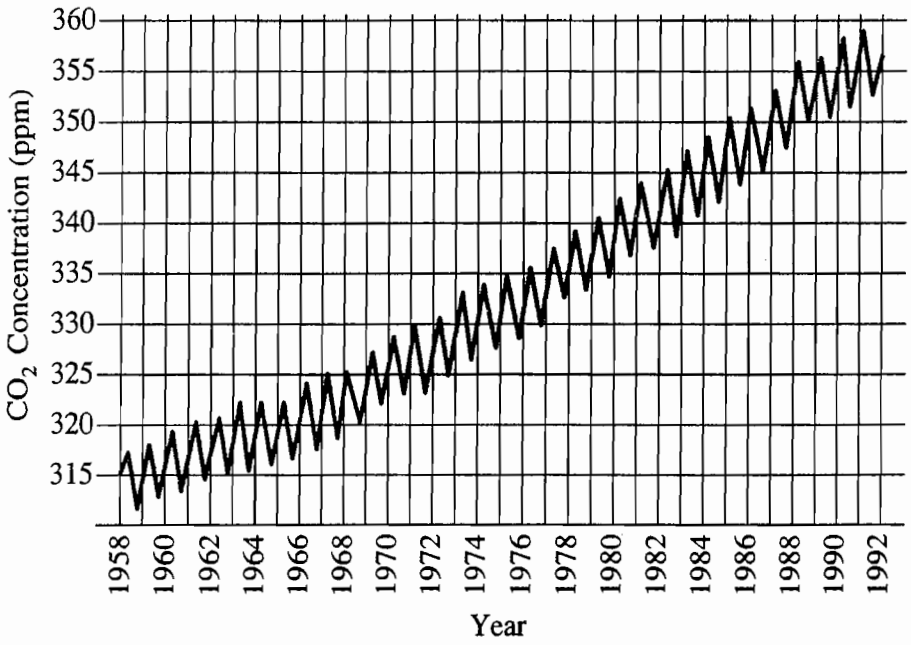
Questions 55-56 refer to the following graph.



55. The data in the graph can be useful in explaining the greenhouse effect when they are compared with

(A) volcanic activity
(B) sunspot activity
(C) mean global temperatures
(D) annual nitrous oxide production
(E) cycles of flooding and drought

56. The annual fluctuation in carbon dioxide concentration can best be explained by the

(A) seasonal use of fossil fuels
(B) regularity of volcanic activity
(C) deforestation in the tropics
(D) El Niño events
(E) seasonal photosynthetic activity of green plants

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57. Integrated waste management employs all of the following EXCEPT

(A) using refillable soft-drink bottles
(B) using disposable diapers instead of cloth diapers
(C) using reusable canvas bags instead of plastic or paper bags
(D) using tires for the construction of artificial reefs
(E) redesigning automobiles to replace steel parts with aluminum and plastic parts

Item 58 was not scored.

59. Economic benefits of building large dams include which of the following?

I. Storage of water for agriculture and domestic use
II. Controlling floods upstream
III. Production of renewable energy

(A) I only
(B) II only
(C) I and III only
(D) II and III only
(E) I, II, and III

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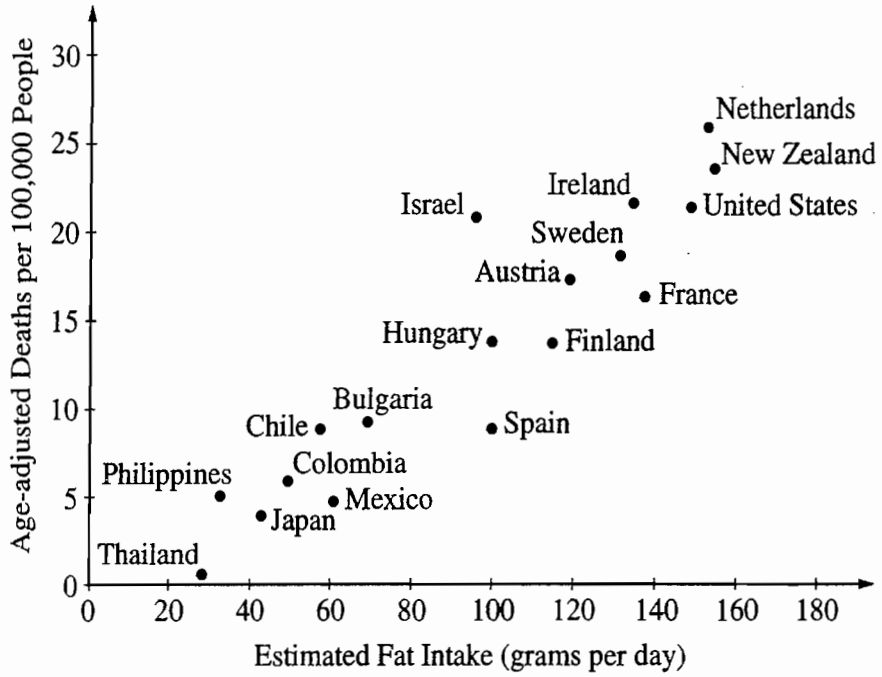
Questions 60-61 refer to the figure below, which depicts the observed relation between dietary fat intake and rate of death from breast cancer in different countries.



60. Which of the following statements is best supported by the data?

(A) Increased incidence of breast cancer is related to the average age of a country's population.
(B) The number of breast cancer deaths is proportional to the size of a country's population.
(C) Increased incidence of breast cancer is related to annual length of exposure to solar radiation.
(D) Persons who reside in colder climates are more susceptible to breast cancer than those who live in tropical regions.
(E) There is a positive correlation between breast cancer and dietary fat intake.

61. United States residents are how many times more likely to die from breast cancer than residents of Hungary?

(A) 150
(B) 21
(C) 14
(D) 7
(E) 1.5

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62. Of the following sources, which supplies the most commercial energy in the world today?

(A) Solar
(B) Oil
(C) Biomass
(D) Nuclear
(E) Hydroelectric

63. Which of the following is a greenhouse gas that is also a by-product of anaerobic respiration?

(A) Methane, CH_4
(B) Nitrogen, N_2
(C) Oxygen, O_2
(D) Nitrogen dioxide, NO_2
(E) Hydrogen sulfide, H_2S

64. If the population of a country grows at a rate of approximately 5 percent per year, the number of years required for the population to double is closest to

(A) 5 years
(B) 10 years
(C) 15 years
(D) 25 years
(E) 35 years

65. The major cause for the decline in the worldwide catch of fish since 1990 is

(A) acid deposition
(B) escalating price of fuel
(C) competition from aquaculture
(D) overfishing
(E) decline in market price

66. Which of the following will occur if the trend of global temperature increase continues?

(A) Night temperatures will decrease as day temperatures increase.
(B) Tropical areas will become cooler than they currently are.
(C) Sea levels will drop due to increased evaporation.
(D) The incidence of insect-borne diseases will decrease.
(E) The troposphere will contain more water vapor.

67. Which of the following is the primary environmental problem associated with the use of nuclear power to generate electricity?

(A) Radon leaking into buildings
(B) Production of greenhouse gases such as carbon dioxide
(C) Disposal of radioactive waste
(D) Depletion of the ozone layer
(E) Production of acid rain

68. Compared to a coal-fired power plant that produces the same amount of energy, a nuclear power plant generates more

(A) CO_2
(B) SO_2
(C) fly ash
(D) particulates
(E) thermal pollution

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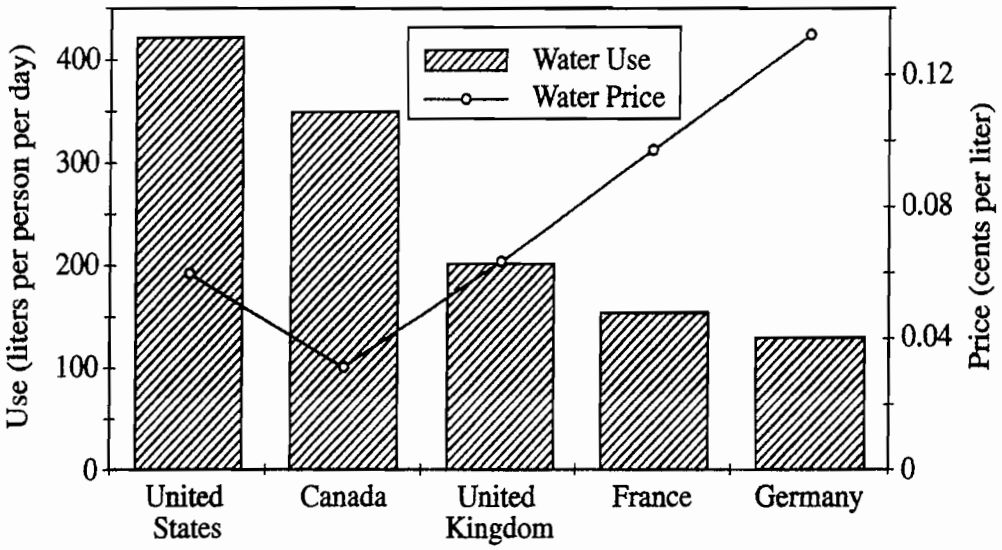
COMPARISON OF MUNICIPAL WATER PRICES AND USE IN SELECTED COUNTRIES



69. The chart above compares the daily water use per person to the price of water in selected countries. Which of the following conclusions can be correctly drawn using only the data in the chart?

(A) Water use and water price are directly proportional.
(B) Increased water use causes prices to decline.
(C) Increased prices cause water use to decline.
(D) Increased water use is generally correlated with lower water prices.
(E) Water is more plentiful in the United States and Canada than in the other countries.

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70. Which of the following identifies the two factors thought to be the most harmful to biodiversity?

(A) Acid deposition and increased use of fertilizers for agriculture
(B) Depletion of the ozone layer and oil drilling
(C) Destruction of habitat and invasion by nonnative species
(D) Changes in climate and proliferation of endemic species
(E) Global warming and decline in fisheries

71. For a certain insecticide, the LD-50 dosage level for rats is determined to be 250 milligrams per kilogram of body mass. On the basis of this information, which of the following is the best prediction regarding the consequences of receiving this dosage of the insecticide?

(A) Fifty percent of any rat population would be sickened.
(B) Fifty percent of the population of any warm-blooded animal would die.
(C) Fifty percent of any population of mosquitoes would die.
(D) Five hundred out of every one thousand people would experience acute effects.
(E) Five hundred out of every one thousand rats would die.

72. The major human health problem related to radon accumulation is

(A) lung cancer
(B) heart disease
(C) pancreatic cancer
(D) cataracts
(E) malignant melanoma

73. Why do introduced species often become pests?

(A) They displace native species.
(B) They increase biodiversity.
(C) They do not adapt well to local habitats.
(D) They contribute to habitat fragmentation.
(E) They have low biotic potential.

74. Acid rain is associated with which of the following?

(A) Formation of the antarctic ozone hole
(B) Release of PCBs into the atmosphere
(C) Damage to tropical rain forests
(D) The burning of fossil fuels
(E) The increasing pH of lake waters

75. Characteristics that tend to increase the risk of a species becoming endangered include which of the following?

I. Having a very limited distribution
II. Being a specialist at the end of a long food chain
III. Having a small population size

(A) I only
(B) II only
(C) III only
(D) II and III only
(E) I, II, and III

76. Stratospheric ozone depletion is most likely to result in which of the following?

(A) Increased growth of food crops due to increasing amounts of ultraviolet radiation
(B) Extended grazing season for cattle
(C) Disruption of photosynthesis in plants
(D) Increased movement of the human population toward equatorial regions
(E) A higher percentage of cloudless days

77. Which of the following is a process that indirectly removes carbon from Earth's atmosphere?

(A) Formation of carbonate deposits
(B) Outgassing by volcanoes
(C) Respiration by mammals
(D) Respiration by anaerobic bacteria
(E) Photodissociation by ultraviolet light

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78. Which of the following is the best explanation of the fact that agricultural production on floodplains is often relatively high?

(A) On floodplains, soils tend to be nutrient-rich and fertile.
(B) On floodplains, high water tables make irrigation unnecessary.
(C) Periodic flooding leaches toxic pollutants out of floodplain soils.
(D) Periodic flooding prevents the pH of floodplain soils from becoming too high.
(E) Floodplains are usually sparsely settled and thus more acreage is available for agriculture.

79. The increase in the size of Earth's human population in the last century has been dramatic. Which of the following identifies two major contributors to this increase?

(A) New methods of agriculture and the identification of new food crops
(B) The Industrial Revolution and modern medicine
(C) Increased emigration/immigration and decreased warfare
(D) New methods of birth control and decreased warfare
(E). Increased education for women and the development of new pesticides

80. Many scientists maintain that a rise in sea level has occurred in the last hundred years as a result of global warming. If this is true, which of the following factors best explains such a rise?

(A) Increased precipitation
(B) Increased cloud cover
(C) Increased evapotranspiration
(D) Thermal expansion of the ocean
(E) Melting of permafrost

81. Which of the following natural events would be most likely to contribute to the cooling of Earth's atmosphere?

(A) Earthquake
(B) Volcanism
(C) Hurricane
(D) Tsunami
(E) Monsoon

Item 82 was not scored.

83. At the current rate of growth, Earth's human population will double in about 50 years. Which of the following is the LEAST viable strategy for ensuring adequate nutrition for a population of this size?

(A) Increasing the number of new food crops from the great diversity of plant species
(B) Doubling the area of arable land on a global basis
(C) Developing systems for making the global distribution of food more equitable
(D) Increasing the area of land that is currently dedicated to grain production by reducing the area dedicated to meat production
(E) Assisting developing countries in using highly efficient crop irrigation systems

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84. The combustion of one gallon of automobile fuel produces about 5 pounds of carbon (in CO_2). Two autos are making a trip of 600 miles. The first auto gets 20 miles per gallon, and the second gets 30 miles per gallon. Approximately how much less carbon (in CO_2) will be produced by the second auto on this trip?

(A) 300 lbs
(B) 150 lbs
(C) 100 lbs
(D) 75 lbs
(E) 50 lbs

85. Which of the following best describes the significance of the United Nations Conference on the Human Environment, which was held in 1972 in Stockholm?

(A) Developing countries and developed countries were largely in agreement about the most important environmental problems.
(B) For the first time since the end of the Second World War, nations set aside their political differences to achieve a common objective.
(C) Environmental activists who had organized Earth Day in 1970 ran the conference.
(D) The conference provided the first global forum for dialogue on environmental problems.
(E) The delegates assembled at the conference voted in favor of controlling population growth.

86. Regulations that deal directly with the disposal of hazardous materials in the United States include which of the following?

I. RCRA
II. Clean Water Act
III. Clean Air Act

(A) I only
(B) II only
(C) III only
(D) I and II only
(E) I, II, and III

87. Which of the following is a true statement about replacement-level fertility?

(A) It equals the average number of children a woman will give birth to during her child-bearing years.
(B) It equals the annual number of live births per 1,000 people in a population.
(C) It equals the natural increase of a population in one year.
(D) It is found by subtracting the number of emigrants from the number of immigrants in one year.
(E) It is greater in countries with high infant-mortality rates than in countries with low infant-mortality rates.

88. Which of the following best illustrates the concept of the tragedy of the commons?

(A) Destruction of landscape by surface mining on private land
(B) Selective harvesting of trees by a timber company in a national forest
(C) Legislation of catch limits to avoid depletion of fish stocks in a shared lake
(D) Inadvertent destruction of beneficial species while attempting to control pests
(E) Depletion of an aquifer by regional farmers

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89. Of the following, which is the best example of reclamation of disturbed lands?

(A) Restoring vegetation to an area that has been mined
(B) Constructing a new wetland to compensate for the loss of wetlands
(C) Growing crops on land formerly used for grazing
(D) Reintroducing an endangered species into an area from which it has disappeared
(E) Regulating the use of a natural resource in order for it to renew itself

90. If the annual consumption of petroleum in the United States is about 23 barrels per capita, the total annual consumption of petroleum in the United States is closest to

(A) 12 million barrels
(B) 240 million barrels
(C) 2 billion barrels
(D) 6 billion barrels
(E) 10 billion barrels

91. One solution for reducing the amount of atmospheric carbon dioxide would be to

(A) increase oceanic temperatures to enhance carbon dioxide uptake
(B) increase the rate of removal of tropical rain forests
(C) decrease the total area of rice paddies
(D) decrease the use of fossil fuels
(E) decrease the production of chlorofluorocarbons

92. The drop in stratospheric ozone levels in the Southern Hemisphere (the "ozone hole") is most evident during which season?

(A) Antarctic spring (October)
(B) Antarctic autumn (April)
(C) Antarctic summer only (January)
(D) Antarctic winter only (July)
(E) Both Antarctic summer and Antarctic winter (January and July)

93. Uranium-235 has a half-life of 710 million years. If it is determined that a certain amount of stored U-235 will be considered safe only when its radioactivity has dropped to 0.10 percent of the original level, approximately how much time must the U-235 be stored securely to be safe?

(A) 7.1×10^6 years
(B) 7.1×10^7 years
(C) 7.1×10^8 years
(D) 7.1×10^9 years
(E) 7.1×10^{10} years

94. Which of the following would be the strongest evidence in support of a scientist's contention that a local area was experiencing acid deposition?

(A) A sudden die-off of all the fish in a local stream
(B) A gradual increase in the temperature of a local lake
(C) An increase in the rate of photosynthesis of aquatic plants in a local lake
(D) A long-term increase in the pH of a local pond
(E) An increase in the concentrations of soluble heavy metals in a local pond

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95. Which of the following is the usual cause of cultural eutrophication in surface waters of both developed and developing countries?

(A) Lack of proper filtration devices for power plant effluents
(B) Introduction of cyanobacteria to streams and rivers
(C) Runoff of metal ions in bodies of water
(D) Runoff of nitrate compounds into bodies of water
(E) Runoff of herbicides into bodies of water

96. If mean global temperature keeps on increasing as predicted by contemporary scientists, which of the following is most likely?

(A) There will be fewer insect pests and disease-carrying organisms.
(B) Specialist species living in fragile ecosystems will risk extinction.
(C) There will be an increase in sulfate concentrations in wetlands.
(D) There will be an increase in the reproductive rate of mammals.
(E) The geographical range of many plants will move toward the equator.

97. Photosynthesis is the major source of which of the following gases in Earth's atmosphere?

(A) CO_2
(B) H_2O (water vapor)
(C) O_2
(D) H_2
(E) N_2

Item 98 was not scored.

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99. Traveling southward from the Arctic regions of Canada to the tropics of Panama, one passes through several biomes—tundra, coniferous forest, temperate deciduous forest, and tropical rain forest. This pattern of change in vegetation is primarily the result of

(A) primary and secondary succession
(B) the invasion of exotic species
(C) an increase in mean annual temperature and a decrease in mean annual precipitation
(D) an increase in both mean annual temperature and mean annual precipitation
(E) an increase in the total annual hours of sunlight

100. Which statement best describes the approximate global distribution of coal supplies?

(A) Brazil and South Africa together contain 33% of proven reserves.
(B) The United States contains 40% of proven reserves.
(C) Australia, Japan, and France together contain 45% of proven reserves.
(D) The United States, the former Soviet Union, and China together contain 50% of proven reserves.
(E) Germany, Brazil, and India together contain 75% of proven reserves.

END OF SECTION I

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ENVIRONMENTAL SCIENCE
SECTION II
Time—90 minutes
Number of questions—4
Percent of total grade—40

Suggested writing time per question—approximately 22 minutes

Because each question will be weighted equally, you are advised to divide your time equally among them without spending too much time on any one question. You are expected to answer all four questions in this section. The parts within a question may not have equal weights. Suggested times will not be announced; you may proceed freely from one question to the next.

Each answer should be organized, well balanced, and as comprehensive as time permits. Answers must be in organized, well-written prose form; outline form is NOT acceptable. Do not spend time restating the questions. If a specific number of examples are called for, no credit will be given for additional examples. For instance, if a question calls for two examples, you will receive credit only for the first two examples you provide.

The questions in the green insert are duplicates of those in this booklet. Use the green insert to organize your answers and for scratchwork, but write your answers in the pink booklet. NO CREDIT WILL BE GIVEN FOR ANYTHING WRITTEN IN THE GREEN INSERT.

You are to write your answers with a pen only, preferably in black or dark blue ink. Be sure to write CLEARLY and LEGIBLY. If you make an error, you may save time by crossing it out rather than trying to erase it.

DO NOT OPEN THIS BOOKLET UNTIL YOU ARE TOLD TO DO SO.

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 the pink 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.

1. Read the following article from the *Fremont Examiner.*

FREMONT EXAMINER

Worm Invasion

A researcher studying the ecology of the deciduous forest outside of Fremont has made an alarming discovery. While taking an inventory of the species present on the forest floor, Professor Peter Tate discovered many earthworms of an Asian species not previously known to live in this area. The Asian worms, unlike native worms, have voracious appetites.

The forest floor is home to a myriad of species that live in the leaf litter, which is composed of several years' accumulation of slowly decomposing leaves. Dr. Tate explained that "the leaf litter is critical to the survival of local species of forest plants." Dr. Tate has found the Asian worms, unlike their indigenous cousins, consume the entire layer of leaf litter in a single season. He said, "This sets the stage for the takeover by invasive exotics such as Japanese stilt grass." Dr. Tate and other scientists are exploring strategies for the control of the Asian worms.

(a) Support Dr. Tate's assertion that "the leaf litter is critical to the survival of local species of forest plants." Include in your discussion the roles of leaf litter in a deciduous forest ecosystem.

(b) Describe THREE abiotic changes that would be likely to result if the exotic worms consumed all the leaf litter in a single year.

(c) For one of the changes you identified in part (b), explain how the change could set the stage for the takeover of Japanese stilt grass or other exotic species.

(d) Design a controlled experiment to determine whether the worms, in fact, do change the forest ecosystem. Identify the environmental factor you will measure, and include the specific hypothesis you will test and the data you will collect.

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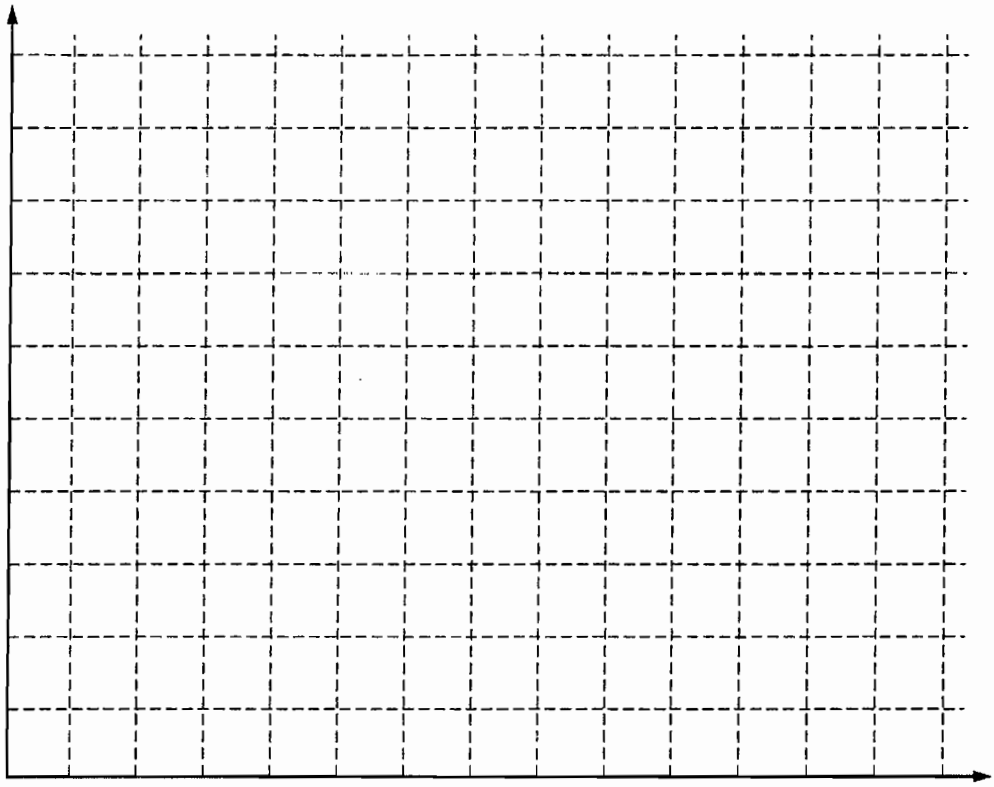
2. A certain fictional country called Industria is tracking its population data. In 1855, the first year vital statistics were reported for the country, the population was 1.6 million, with a crude birth rate of 43 per 1,000. At that time the population of Industria was growing quite slowly, because of the high death rate of 41 per 1,000. In 1875 the population began to grow very rapidly as the birth rate remained at its 1855 level, while the crude death rate dropped dramatically to 20 per 1,000. Population growth continued to increase in the small country into the late 1800's, even though birth rates began to decline slowly.

   In 1895 the crude birth rate had dropped to 37, and the death rate to 12 per 1,000. In that year (1895) a complete census revealed that the population of Industria had grown to 2.5 million. By 1950 population growth gradually began to decline as the death rate remained at its 1895 level, while the birth rate continued to decline to 22 per 1,000. In 1977 vital statistics revealed that the death rate was 10 per 1,000, and that population growth had slowed even more to an annual rate of 0.4%. By 1990 Industria had reduced its birth rate to that of its now constant, low death rate, and the population transition was complete.

   (a) On the axes below, plot the crude birth-rate data from 1855 to 1990. Now plot the crude death-rate data on the same axes. Clearly label the axes and the curves.



   (b) What was the annual growth rate of Industria in 1950 ? What was the birth rate in Industria in 1977 ?

   (c) Indicate TWO factors that might have accounted for the rapid decline in the death rate in Industria between 1855 and 1895. Indicate one specific reason why the birth rate might have been so high in 1855 and was so slow to decrease between 1855 and 1950.

   (d) Determine what the population size of Industria would have been in 1951 if the population had continued to grow at the annual rate of growth recorded for Industria in 1895.

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Section II

3. Environmental conditions in coastal estuaries vary hourly and seasonally.

(a) Discuss TWO important causes for the variation in the temperature and/or salinity of an estuary. Be sure to include the connection between each cause and temperature and/or salinity.

(b) Discuss TWO roles that coastal wetlands play that are ecologically important, and TWO roles that wetlands play that are economically important.

(c) Identify and explain THREE ways in which humans have had a negative impact on or have degraded coastal wetlands.

(d) Choose one of the negative human impacts you identified in part (c), and explain one environmental policy and one economic incentive that could have prevented it.

4. The American whooping crane and the California condor are two of North America's largest birds. Although both are rare and endangered, they are protected, and large preserves are available for them. The two species, however, seem to be responding differently to these conservation efforts.

In 1937, the whooping crane population was reduced to 14 individuals. It has since recovered; currently more than 200 birds live and breed in the wild. In the preservation of endangered species, the whooping crane is a success story. On the other hand, the California condor population declined rapidly so that no birds remained in the wild between 1987 and 1992. Condors were reintroduced into the wild after 1992 and approximately 50 condors currently live in the wild in California and Arizona. However, the recovery program cannot yet be considered a success.

(a) Identify and describe TWO major causes for the original decline of these species. (You may describe one cause for each species or two causes for one species.)

(b) Describe TWO measures that have been taken to protect these species. (Specify which of the species benefited from each measure.)

(c) Describe TWO important characteristics of an endangered species that would cause it to be slow to recover.

(d) Make one economic or ecological argument for protecting the condor, the whooping crane, or another endangered species that you identify and make one economic or ecological argument against protecting it.

END OF EXAMINATION

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AP Environmental Science

2003

APPENDIX - ANSWERS

Matching multiple-choice answers and free-response scoring follow.

Chapter III Answers to the 2003 AP Environmental Science Exam

- Section I: Multiple Choice
  - Section I Answer Key and Percent Answering Correctly
  - Analyzing Your Students' Performance on the Multiple-Choice Section
  - Diagnostic Guide for the 2003 AP Environmental Science Exam
- Section II: Free Response
  - Comments from the Chief Reader
- Scoring Guidelines, Sample Student Responses, and Commentary
  - Question 1
  - Question 2
  - Question 3
  - Question 4

Section 1: Multiple Choice

Listed below are the correct answers to the multiple-choice questions, the percent of AP students who answered each question correctly by AP grade, and the total percent answering correctly.

Section I Answer Key and Percent Answering Correctly

Item No.	Correct Answer	Percent Correct by Grade 5	4	3	2	1	Total
1	C	62	57	53	48	40	50
2	E	20	11	8	6	5	9
3	B	50	30	20	18	19	24
4	A	94	86	75	61	40	66
5	D	55	39	29	25	22	31
6	A	98	95	91	88	78	88
7	C	73	50	38	29	21	37
8	A	72	53	38	29	18	37
9	D	97	91	81	70	47	72
10	C	86	74	65	60	46	62
11	B	71	56	47	42	33	46
12	A	67	57	51	49	44	52
13	C	76	56	43	37	29	43
14	B	75	46	28	18	9	28
15	A	96	91	82	72	53	75
16	B	96	89	82	73	56	75
17	C	100	98	93	84	56	82
18	E	75	63	52	43	28	48
19	D	68	46	31	22	11	30
20	A	67	58	51	49	41	51
21	E	86	73	65	58	40	60
22	E	93	87	81	74	54	74
23	A	77	63	51	42	27	47
24	C	56	40	29	22	17	29
25	A	98	95	92	86	72	86
26	E	100	99	98	96	84	94
27	A	68	42	25	16	8	26
28	A	74	54	39	28	15	36
29	E	35	18	10	5	3	11
30	B	98	94	87	78	61	80
31	C	52	33	27	23	26	30
32	E	97	95	94	91	75	88
33	A	85	76	67	58	38	60
34	B	58	43	32	26	18	31
35	E	97	94	91	87	73	86
36	A	26	20	17	16	13	17
37	B	99	96	93	88	72	87
38	B	93	84	80	75	65	76
39	C	99	93	82	69	44	72
40	D	73	62	57	50	33	51
41	A	84	70	60	51	34	55
42	D	86	75	65	57	39	60
43	D	93	89	85	81	63	79
44	E	95	86	75	65	39	66
45	A	64	48	38	32	18	35
46	B	87	71	57	43	26	51
47	B	85	69	54	42	28	50
48	A	90	87	83	81	67	79
49	C	77	61	47	36	21	43
50	C	57	35	24	20	20	27
51	B	90	78	67	59	44	63
52	C	86	74	57	46	30	53
53	C	98	95	93	91	77	89
54	B	83	66	53	42	29	49
55	C	96	90	81	73	51	74
56	E	87	72	59	46	33	54
57	B	86	78	70	62	44	64
58*	—	—	—	—	—	—	—
59	C	58	43	33	28	19	33
60	E	99	97	94	89	65	85
61	E	89	77	66	56	35	59
62	B	89	85	80	74	53	73
63	A	80	58	42	33	22	41
64	C	77	60	44	34	22	42
65	D	95	90	84	79	62	79
66	E	76	60	45	35	20	42
67	C	100	98	94	84	56	82
68	E	96	86	71	55	35	63
69	D	68	57	48	42	28	45
70	C	99	96	93	86	60	83
71	E	88	76	61	49	26	54
72	A	77	60	49	43	39	50
73	A	97	92	83	72	42	72
74	D	72	62	54	50	35	51
75	E	97	92	83	72	50	74
76	C	70	59	52	48	37	50
77	A	61	37	22	16	14	25
78	A	95	89	83	77	53	75
79	B	91	91	89	87	66	82
80	D	71	53	42	33	23	40
81	B	52	32	20	14	10	21
82*	—	—	—	—	—	—	—
83	B	72	53	39	31	20	38
84	E	97	92	85	76	48	75
85	D	69	59	49	44	31	47
86	A	39	31	27	24	18	26
87	E	80	59	43	31	18	40
88	E	81	56	39	24	12	36
89	A	85	65	48	39	23	46
90	D	52	33	21	17	15	24
91	D	98	97	93	87	63	84
92	A	20	11	8	7	8	9
93	D	44	26	16	13	10	18
94	E	26	13	9	7	7	11
95	D	91	76	58	44	28	53
96	B	98	94	88	80	53	78
97	C	97	92	84	74	48	75
98*	—	—	—	—	—	—	—
99	D	93	90	83	76	48	73
100	D	68	58	50	46	36	48

*Although 100 multiple-choice items were administered in Section I, items 58, 82, and 98 were not used in scoring.

Analyzing Your Students' Performance on the Multiple-Choice Section

If you give your students the 2003 exam for practice, you may want to analyze their results to find overall strengths and weaknesses in their understanding of AP Environmental Science. The following diagnostic worksheet will help you do this; feel free to photocopy and distribute it to your students for completion.

1. In each section, students should insert a check mark for each correct answer.
2. Add together the total number of correct answers for each section.
3. Compare the student's number of correct answers for each section with the average number correct for that section.

In addition, under each item, the percent of AP students who answered correctly is shown, so students can analyze their performance on individual items.

This information will be helpful in deciding how students should plan their study time. Please note that one item may appear in several different categories, as questions can cross over different topics.

Diagnostic Guide for the 2003 AP Environmental Science Exam

Energy Flow, Forms, and Conversions (Average number correct: 3.0 out of 7)

Question #	1	2	3	4	27	41	62
Correct/Incorrect							
Percent of students answering correctly.	*50*	*9*	*24*	*66*	*26*	*55*	*73*

Biological Processes, Nutrient Cycles, and Biodiversity (Average number correct: 12.4 out of 22)

Question #	5	6	7	12	13	14	22	23	24	26	31	34	46	56
Correct/Incorrect														
Percent of students answering correctly.	*31*	*88*	*37*	*52*	*43*	*28*	*74*	*47*	*29*	*94*	*30*	*31*	*51*	*54*

Question #	63	70	73	75	76	96	97	99
Correct/Incorrect								
Percent of students answering correctly.	*41*	*83*	*72*	*74*	*50*	*78*	*75*	*73*

The Physical Earth and its Processes (Average number correct: 6.9 out of 14)

Question #	8	9	10	11	38	42	47	53	54	66	77	80	81	93
Correct/Incorrect														
Percent of students answering correctly.	*37*	*72*	*62*	*46*	*76*	*60*	*50*	*89*	*49*	*42*	*25*	*40*	*21*	*18*

Diagnostic Guide for the 2003 AP Environmental Science Exam (continued)

Health, Pollution, and Pollution Control (Average number correct: 15.9 out of 27)

Question #	15	16	17	18	29	30	35	39	43	46	52	55	57	60
Correct/Incorrect														
Percent of students answering correctly.	*75*	*75*	*82*	*48*	*11*	*80*	*86*	*72*	*79*	*51*	*53*	*74*	*64*	*85*

Question #	61	67	68	71	72	74	76	84	91	92	93	94	95
Correct/Incorrect													
Percent of students answering correctly.	*59*	*82*	*63*	*54*	*50*	*51*	*50*	*75*	*84*	*9*	*18*	*11*	*53*

Human Population and Resource Use (Average number correct: 10.8 out of 19)

Question #	19	20	21	32	33	37	44	48	49	50	51	62	64	69
Correct/Incorrect														
Percent of students answering correctly.	*30*	*51*	*60*	*88*	*60*	*87*	*66*	*79*	*43*	*27*	*63*	*73*	*42*	*45*

Question #	78	79	87	90	100
Correct/Incorrect					
Percent of students answering correctly.	*75*	*82*	*40*	*24*	*48*

Economics, Environmental Laws, and Issues for Society (Average number correct: 6.9 out of 14)

Question #	25	28	36	40	43	45	59	65	83	85	86	88	89	91
Correct/Incorrect														
Percent of students answering correctly.	*86*	*36*	*17*	*51*	*79*	*35*	*33*	*79*	*38*	*47*	*26*	*36*	*46*	*84*

Quantitative/Calculations (Average number correct: 3.1 out of 7)

Question #	33	50	61	64	84	90	93
Correct/Incorrect							
Percent of students answering correctly.	*60*	*27*	*59*	*42*	*75*	*24*	*18*

Graph Interpretation (Average number correct: 5.5 out of 9)

Question #	22	23	24	37	55	56	60	61	69
Correct/Incorrect									
Percent of students answering correctly.	*74*	*47*	*29*	*87*	*74*	*54*	*85*	*59*	*45*

Section II: Free Response

Comments from the Chief Reader

Thomas Mowbray
Professor
Department of Biology
Salem College
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The free-response questions on the 2003 AP Environmental Science Exam required students to demonstrate some factual knowledge of environmental science, bur they concentrated mostly on higher-level skills, such as critical reading, analysis, synthesis, and evaluation. Question 1 required students to read an article, support assertions, answer questions, and develop a hypothesis along with a design for an experiment to test that hypothesis. Question 2 asked students to organize data and present it in graphical form, to carry out computations and provide logical explanations for trends in the data, and to determine a future population by applying a suitable mathematical relationship. Question 3 required students to focus on the importance of the ecological roles of coastal wetlands and their economic importance, to explain how human impacts have damaged these wetlands, and to explain how these negative impacts could have been reduced. Question 4 asked students to demonstrate their knowledge of the causes of the decline of some classic examples of endangered species and describe measures that could have been taken to protect the species, to describe characteristics of species in general that would make them slow to recover, and to make ecological or economic arguments both for and against protecting endangered species.

Scoring Guidelines, Sample Student Responses, and Commentary

The answers presented on the following pages are actual student responses to the free-response questions on the 2003 AP Environmental Science Exam. The students gave permission to have their work reproduced at the time they took the exam. These responses were read and scored by the table leaders and readers assigned to each particular question and were used as sample responses for the training of readers during the AP Reading in June 2003. The actual scores these student responses earned. as well as a brief explanation of why, are indicated.

Question 1—Overview

This question is based on an article about the discovery of an invasive species (an Asian worm) in a deciduous forest. The question was intended to test students' knowledge of several fundamental ecological processes as well as their ability to apply that knowledge in the context of the ecological problem described in the arcicle. The question also tested students' skills in designing a controlled experiment to determine how the worms might be changing the forest ecosystem.

Scoring Guideline for Question 1

Part (a)

The student should support the assertion with information about plants for one point and another role of leaf litter for a second point.

- One point for making one statement that pertains to plants:
  - The student may use the description taken directly from the article: "This* sets the stage for the takeover by invasive exotics such as Japanese stilt grass" ***or***,
  - The student provides another supporting role of leaf litter in a deciduous forest ecosystem that is tied to *plants*.
- One point for providing another supporting role of leaf litter in a deciduous forest ecosystem (does not need to be tied to plants):
  - Serves as ground cover
  - Serves as a habitat area (e.g., soil microorganisms/nitrogen-fixing bacteria/fungi serve as a "home to a myriad of species" [this statement is in the document; a similar statement is accepted])
  - Provides shelter
  - Serves as a reservoir for many nutrients (absorbs and releases)
  - Allows germination of seedlings
  - Serves as a rooting area (especially important for shallow root perennials)
  - Helps maintain moisture/water retention
  - Assists in the infiltration and percolation of water (by absorbing it/reducing water runoff)
  - Contributes to humus production
  - Serves as a growth/overwintering area for bulbs, corms, and others
  - Provides shelter for seedlings
  - Helps reduce erosion
  - Serves as a food source (e.g., for detritus feeders ⇒ increased surface area ⇒ decomposition)

Part (b)

The student earns one point for each abiotic change described (the student must describe, not just list); only the first three are scored, for a total of three points:

- Nutrient levels in soil would change/soil fertility would be reduced
- Erosion of soil would increase
- Fluctuations in soil temperature/change in soil temperature
- Forest soil pH changes
- Soil would be more compacted/aeration would decrease
- Soil surface light levels would increase
- Decreased moisture above and below ground/drier soil/desiccated soil
- Increased evaporation

* "This" refers to the consumption of the entire layer of leaf litter in a single season.

- Loss of soil cover/less topsoil
- Increased water runoff/formation of rivulets, rills, gullies
- Increased sedimentation in local waterways ⇒ increased turbidity in local waterways from runoff
- Leaching of topsoil layers (short term; due to absence of leaf litter/humus)
- Shelter area reduced
- Ground cover reduced
- Rate of movement of pollutants into the soil would increase (would not be absorbed by leaf litter)
- Altered soil texture/changes in soil porosity/changes in soil permeability
- Decreased nutrient-holding capacity of soil/decreased ion-exchange capacity
- Decreased chemical weathering of parent material and bedrock
- Mineralization may occur (loss of humus, subsequent collapse of topsoil fertility; soil becomes gritty due to high mineral content in absence of humus)
- Decreased illuviation (long-term) (deposition of material into lower soil layers from higher soil layers via leaching)
- Reduced habitat area
- Decreased intensity/severity of forest fires

Part (c)

The answer in Part (c) must be based on an abiotic change in Part (b), and is worth one point. If Part (b) is left blank or is incorrect, no point can be carned in Part (c). Many acceptable responses are based on tolerance/range of tolerance and may include major characteristics of successful invader/exotic species, such as generalists, "early successional species," high dispersal rate, the release of growth-inhibiting hormones into the soil, r-selected species, and so on. Examples include, "The exotic species are often more tolerant than native species of drier soils, and therefore out-compete native species," "A lack of nutrients may decrease native plant growth, but not exotics," and "Exotic species can tolerate higher light levels (more intense ultraviolet light) than native species, and therefore the exotic species are at a distinct advantage in thriving in such conditions."

Part (d)

The hypothesis is worth one point, the experimental design is worth two points, and citing the data to be collected is worth one point, for a total of four points.

Hypothesis: The student states a specific, testable explanation for one point. The hypothesis *must* include the environmental factor to be measured *and* be tied to worms changing the forest ecosystem. Environmental factors that are *not* accepted (too general) are nutrients, food, and habitat.

Experiment: The student outlines a valid/reasonable procedure for a controlled experiment for two points.

- One point for outlining experimental procedures by including the following (three components are required to earn this point):
  - the control group required,
  - the experimental group required, and
  - one other from the following list required: specific time, specific area, specific materials, specific sample size.

- One point for a description of one of the following as part of the procedure (the design point above *must* be earned in order to earn this point):
  - Repeated experiments
  - Correlation to other experiments
  - How other variables are controlled or tested
  - How the experiment could be expanded or modified
  - Data analysis
  - Relate to/discuss additional research

Data collected: The student describes quantifiable data related to the dependent variable for one point.

Note: An "observational experiment" is acceptable, but it must meet the same criteria as for a more traditional type of experiment where a variable is manipulated *by the researcher* in the experimental site.

Sample Student Responses for Question 1

Student Response 1A (score of 10)

A. Some species of forest plants depend on the warmth and moisture provided by the year round leaf litter cover in deciduous forests. The leaf litter keeps moisture in the ground to aid in germination, and it keeps the ground from getting to cold. Also, as it slowly decomposes it provides nutrients for the soil that plants can use.

B The ground temperature would likely decrease along with moisture levels in the soil, and top layers of soil might erode away if all leaf litter was consumed in a single year.

C. With less moisture in the ground, more fragile native species of plants may not germinate and live and the more hearty plants like Japanese stilt grass that require less moisture could take-over.

Hypothesis: If

D. an Asian species of earthworm that consumes all leaf litter in one year is introduced into an a deciduous forest then the ground moisture will drop and result in growth of non-native species in place of native species.

deciduous (in the same area)
Isolate two section of forest in terms of their soil. Make sure worms are unable to leave the area above or below ground. Stock one isolated area of forest with native earth worms with and the other isolated forest area with non-native worms. Change only the one variable of type of worms in the area and make sure to begin experiment in both areas at the same time. Observe over a period of a year and record data. Measure the soil moisture of both area and check the amount of non-native species of plant versus native species of plant in each area.
Repeat experiment several times to improve accuracy of data. Compare results in both areas against hypothesis.

Commentary

In Part (a), one point is earned for stating that forest plants depend on the warmth and moisture provided by leaf litter, and one point is earned for the statement regarding germination. Three points are earned in Part (b), with one point each earned for describing a decrease in ground temperature, decreased moisture levels, and erosion of topsoil layers. In Part (c), one point is earned for explaining how the "more hearty plants like Japanese stilt grass that require less moisture could take over." In Part (d), one point is earned for stating a specific, testable hypothesis. One point is earned for the three required components needed to earn the design/procedural point (providing a control group, an experimental group, and a specific time component). One data collection point is earned for stating that the soil moisture levels in both areas would be measured. One final point is earned for including repetition of the experiment several times to improve accuracy.

Student Response 1B (score of 8)

a) In this particular deciduous forest, the leaf litter is home to a number of indigenous species. Deciduous forests lose their leaves every year in the Fall: the old, fallen leaves reside on the ground for habitats for many animals and protection for many new seeds. Normally, the animals don't consume all the leaf litter in one season so there is enough to protect native plant species, but the introduction of the Asian worm has upset the delicate balance. The new worms will remove all leaf litter in one season so there won't be any left to protect the local species. The native species will find it difficult to survive in the presence of the Asian worm.

b) The soil will eventually become nutrient-depleted and poor because there won't be any old leaf litter to replenish; the leaf-litter will no longer be available to protect young saplings; and a habitat would be destructed that housed other worms and insects

c) If native plant species needed the leaf-litter to act as protection for the young saplings and the leaf-litter was not present, other exotic species that didn't need protection for their early seeds could easily take over

d) Our experiment would test the rates of growth for the native plants and for the Japanese stilt grass in different conditions. The hypothesis is that the native plants grow more without the presence of Asian worms while the Jap. stilt grass would grow more with Asian worms. There would be four plots of deciduous forests all equally large: two plots of native plants, one w/ worms and one w/o, and two plots of Jap. stilt plants, one w/ worms and one w/o. [illegible]

[redacted]. The two plots w/o worms would act as a control plot. Measurements on the number of seeds germinated and length of plant would be recorded for a certain amount of time. Results would be compared to test hypothesis.

Commentary

In Part (a), one point is earned for discussing how the fallen leaves provide habitat, and one point is earned for leaf litter's role in serving as protection for species, including plant species. In Part (b), one point is earned for describing soil nutrient depletion, and one point is earned for the description of leaf litter no longer being available to protect young saplings. There is no description of a third abiotic change in Part (b). In Part (c), one point is earned for pointing out that exotic species may not require the same amount of protection that native species do. In Part (d), one point is earned for having a specific and testable hypothesis. One point is earned for including the following in the experimental design: a control group, an experimental group, and a specific size component. One data collection point is earned for stating that the number of seeds germinated and "length of plant" would be recorded for a particular time.

Student Response 1C (score of 6)

a) Leaf litte is the top layer of the forest floor. This layer of mulch provides protection and moisture for many sprouting seeds in the forest ecosystem. This layer of organic matter also provides extensive habitat for many insects and creatures. The litter provides a cushion for seeds where they can recieve a proper amount of light, air, and nutrients. The leaf litter also prevents the seeds from being washed away.

b) First, ~~water runoff would~~ The ground would absorb less water. Second, the exposed soil might be washed away, leading to soil loss & erosion. 3rd, these two factors would turn the soil that was left to dust & leach the soil of nutrients.

c) If the ground absorbs less water, many of the native plants would be unable to grow. May be Japanese stilt grass does not require as much water to grow and would then take over the area with dry soil.

Commentary

In Part (a), one point is earned for describing the protection and moisture provided by leaf litter for sprouting seeds, and one point is earned for noting that leaf litter serves as a habitat for many organisms, such as insects. In Part (b), one point is earned for each of the following descriptions: the ground would absorb less water, exposed soil might be washed away, and soil nutrients would be washed away. In Part (c), one point is earned for discussing how exotic species may not require as much water to grow and that they may be able to take over the area due to this advantage.

Question 2—Overview

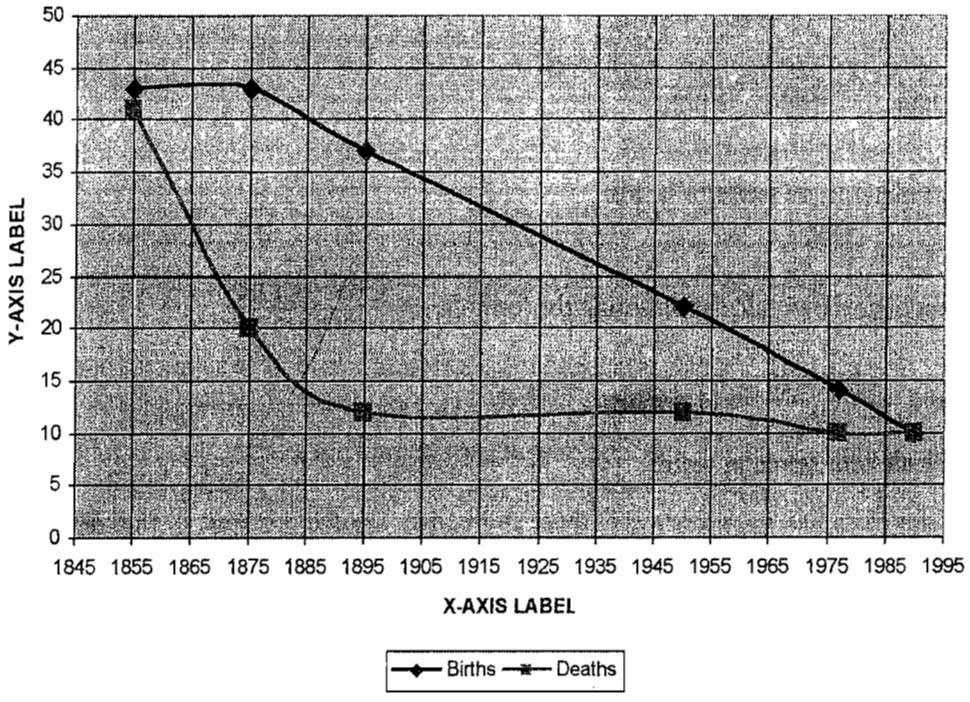
The primary purpose of this data-based question was to assess students' ability to 1) synthesize data provided in the question and appropriately construct a line graph from those data, 2) perform basic algebraic computations to solve equations, 3) provide logical explanations for the data on the basis of their understanding of the concept of demographic transition, and 4) given certain variables, to recognize and correctly apply one of several equations that could be used to determine the future size of a population.

Scoring Guideline for Question 2

Part (a)

The student scales and labels the axes for one point, plots the birth rate data for one point, and plots the death rate data for one point, for a total of three points.

- One point for correctly scaling and labeling axes; scales must include all provided data from 1855–1990.
  The scales used may be different than what appears on the graph that follows. The student may, for example, label the y-axis in increments of 10, from 0 to 100, or the x-axis in increments of 20 years:
  - Acceptable x-axis labels: year, date, or time.
  - Acceptable y-axis labels: births and deaths per 1,000, birth and death rate (percent, people per 1,000, rate per 1,000 only if curves are clearly labeled).
- One point for correctly labeling and plotting crude birth rate:
  - Five data points must be clearly shown on the graph (not including the 1977 data point).
  - The 1977 data point is optional since it was not provided in this part but is requested in Part (b).
  - If the 1977 data point is present, it must be plotted correctly at $y = 14$.
- One point for correctly labeling and plotting crude death rate:
  - Six data points must be clearly shown on the graph.



Note: Because the student is not instructed to plot a curve of best fit, either a smoothed curve or a straight-line curve is acceptable; however, if the curve(s) do not pass through all data points, zero points for labeling curve(s) are awarded. If the student truncates the x-axis or the y-axis, the data lines must also be truncated accordingly.

Part (b)

The student earns one point for the calculation of growth rate and one point for the calculation of birth rate, for a total of two points.

- One point for correct annual growth rate in 1950:
  - The student shows calculations using the formula $r = b - d$

    $$\frac{22}{1000} - \frac{12}{1000} = \frac{10}{1000}$$

    or, $2.2\% - 1.2\% = 1\%$

    or, $0.022 - 0.012 = 0.01$

    or, calculations are stated in words.

    OR,

  - The student shows calculations using the formula $r = \frac{\text{CBR} - \text{CDR}}{10}$

    $$\frac{22\% - 12\%}{10} = 1\%$$

    or, calculations are stated in words.

- One point for the birth rate in 1977, which may be determined graphically, by calculations, or as presented in words:
  - If determined graphically, the 1977 data point must be marked on the curve (a range of 12 to 17 per 1,000 is acceptable) ***or,*** the student must state that the value was obtained from the graph and the value must have been correctly interpolated. The answer must be in the same units of measurement as the axis unless clearly converted by the student.
  - The student shows calculations using the formula $r = b - d$ (which must be shown or presented in words):

    $$0.4\% = b - 1.0\% \Rightarrow 1.4\% = b$$

    or, $\frac{4}{1000} = b - \frac{10}{1000} \Rightarrow \frac{14}{1000} = b$

    or, $0.004 = b - 0.01 \Rightarrow 0.014 = b$

    or, calculations are stated in words.

    OR,

  - The student shows calculations using the formula $r = \frac{\text{CBR} - \text{CDR}}{10}$

    $$0.4 = \frac{\text{CBR} - 10}{10} \Rightarrow 14 = \text{CBR}$$

    or, calculations stated in words.

Note: Other algebraic formulas, or derivatives of those above, may be used provided all work is shown.

Part (c)

The student earns two points for two factors, one point for a reason for the high birth rate, and one point for the slow decrease, for a total of four points.

- One point *each* for identifying two factors that might have accounted for a rapid decline in the death rate. Only the first two factors provided are considered. Acceptable factors for rapid decline in death rate include:
  - Improved medical care (antibiotics are not accepted for the given time period)
  - Improved sanitation
  - Improved personal hygiene
  - Improved water supply
  - Improved food or nutrition
  - Improved agriculture or food production
  - Improved food preservation
  - Improved transportation to deliver food or to provide medical services
  - Improved prenatal or neonatal care
  - Cessation of military conflict

- One point for indicating one specific reason why the birth rate was so high. Acceptable reasons for high birth rate include:
  - To compensate for high infant mortality
  - To assure care for aging parents (including a reference to lack of institutionalized social security programs)
  - To provide a labor force
  - Cultural/religious practices that prohibited birth control
  - Cultural/religious practices that favored large families
  - Lack of contraceptives (not general statements about birth control)
  - Lack of education about family planning
  - Lack of women's rights

- One point for indicating why the birth rate was so slow to decrease. Acceptable reasons for slow decrease include:
  - Cultural/religious practices that prohibited birth control took time to change
  - Cultural/religious practices that favored large families took time to change
  - Immigration of women of childbearing age
  - Changing the status of women was slow to gain broad acceptance
  - Educational opportunities for women were slow to appear
  - Employment opportunities for women were slow to appear
  - Slow advances/technological production relating to birth control resulted in a slow decline
  - Slow implementation of government polices to reduce the need for children to provide support for their parents in their later years (e.g., social security, health care, pensions, and so on)

Part (d)

The student earns one point for correctly calculating the population size in 1951:

- The student shows calculations using the Rule of 70

  70 / 2.5 = 28 years

  1951 − 1895 = 56 years

  56 years / 28 years = 2 doublings

  $2.5\times10^6\times2=5.0\times10^6 \Rightarrow 5.0\times10^6\times2=10\times10^6$

  or, $2{,}500{,}000\times2=5{,}000{,}000 \Rightarrow 5{,}000{,}000\times2=10{,}000{,}000$

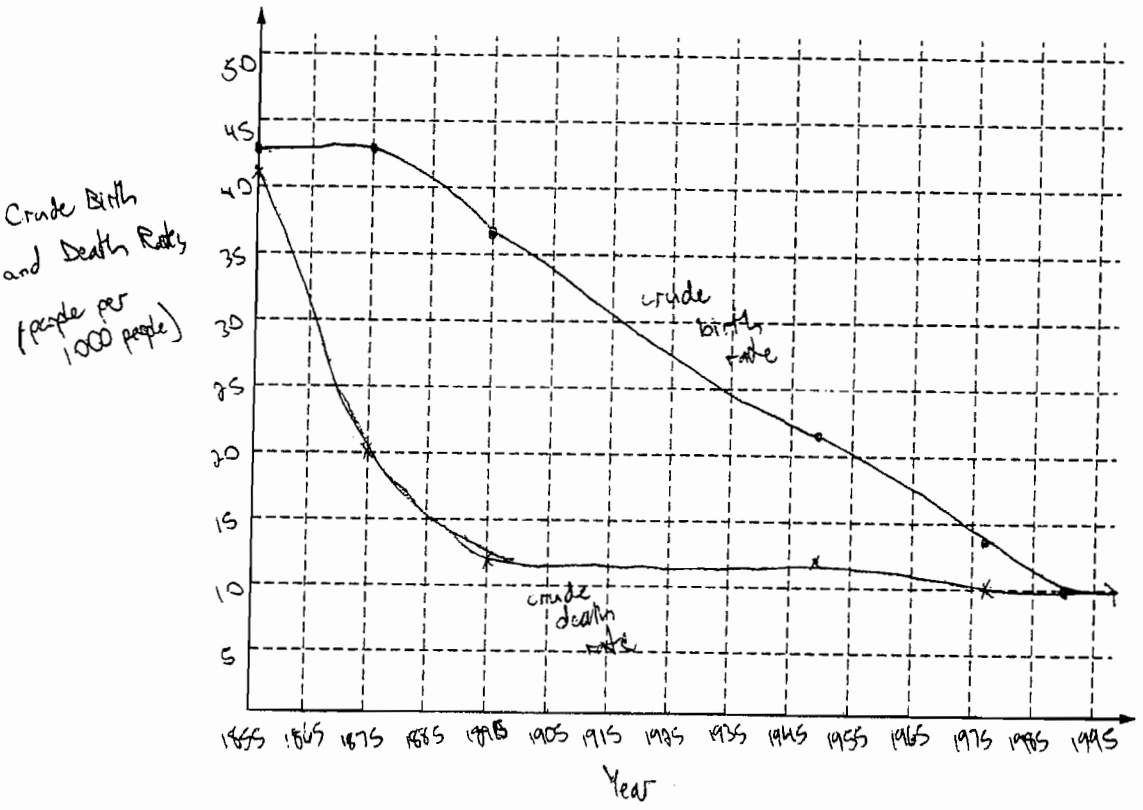
  or, calculations are stated in words.

Alternate Solutions: The student earns one point for correct set-up using the formulas $N_t = N_0e^{(rt)}$, $N_t = N_0(1 + r)^t$ ***or,*** $P = A_0e^{kt}$, even if the equation is not solved, provided that all specific values, namely N_0 or A_0, r or k, and t are correctly inserted into the equation and the derivation of "t" (which is 56) is provided.

Note: If a student recognizes that 0.025 × 56 = 1.4, and that $e^{(1.4)}$ or $2.72^{(1.4)}$ is approximately 4, and solved the equation as approximately 10×10^6 or 10,000,000, the point is awarded.

Sample Student Responses for Question 2

Student Response 2A (score of 10)



b) Annual rate of growth in 1950

$\frac{\text{crude birth rate} - \text{crude death rate}}{1000} = \frac{22 - 12}{1000} = \frac{10}{1000} = 1\%$ annual growth rate

Birth Rate in 1977

$0.004 = \frac{CBR - 10}{1000}$ $\quad 4 = CBR - 10$ crude birth rate = 14 per 1,000 people

c) The death rate in Industria could have dropped quickly for a number of reasons. The most likely is that they developed more modern medicine that could cure diseases, and save children at childbirth. This would substantially lower the death rate. Also, new technologies could have been developed in agriculture that produced higher quality food in larger quantities. A society with a good, nutritional

diet has longer lifespans and a lower death rate. The birth rate during this period was slow to decrease most likely due to cultural and family traditions. Elder generations had numerous kids to provide labor, and because a high proportion died before adulthood. In Industria's new, modern society this is not necessary, but it takes a few generations for the traditions to be broken.

d) 1895 population - 2.5 millions people

1895 growth rate

$\frac{37-12}{1000} = \frac{25}{1000} = 2.5\%$ growth rate

$2.5\overline{)70}\ 28$

-5

20

-20

0

The population in 1951

$1951 - 1895 = 56$ years

doubling time

$\frac{70}{2.5} = 28$ years to double

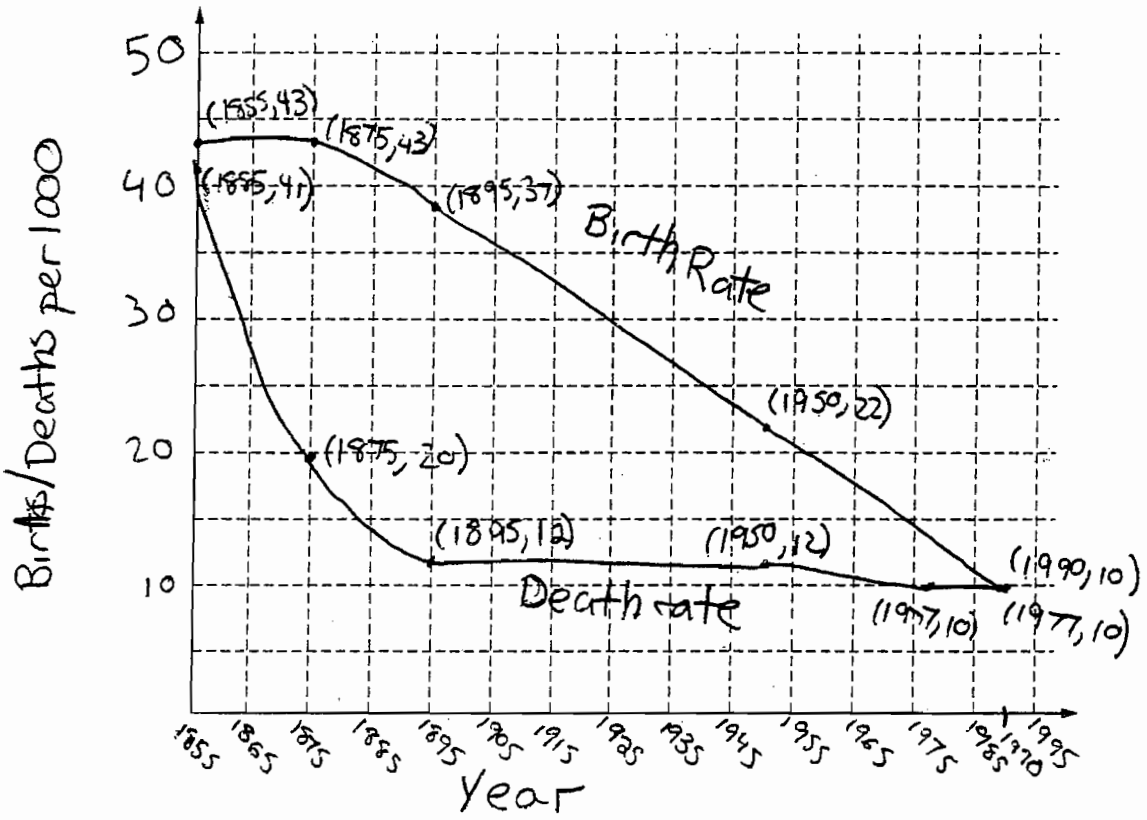
$2.5 + 4 = 10.0$ million

In 56 years, the population of Industria would double twice, so it would be 4x its 1895 level. The population would be about 10 million people.

Commentary

Three points are earned in Part (a) for scaling and labeling the axes, plotting the birth rate data and death rate data, and labeling both curves. One point is earned in Part (b) for calculating the growth rate in 1950, and one point is earned for calculating the birth rate in 1977; the work is shown for both calculations. Four points are earned in Part (c). One point is earned in Part (d) because the student solved for t and r and applied the Rule of 70.

Student Response 2B (score of 9)



b) There were 12 deaths for every 1000 people in 1950 and 22 births for every 1000 people. That means that there was a growth of 10 people for every thousand, or a 1% growth rate in 1950.
The growth rate in 1977 was 0.4%, and the death rate was 10 per 1000 people. That means that the population was growing by 4 each year, so there had to have been 4 more births than deaths for every 1000 people. That means the birth rate was 14 per 1000 in 1977.

c) An improvement in medicine which would lengthen life span is one thing that might have accounted for the

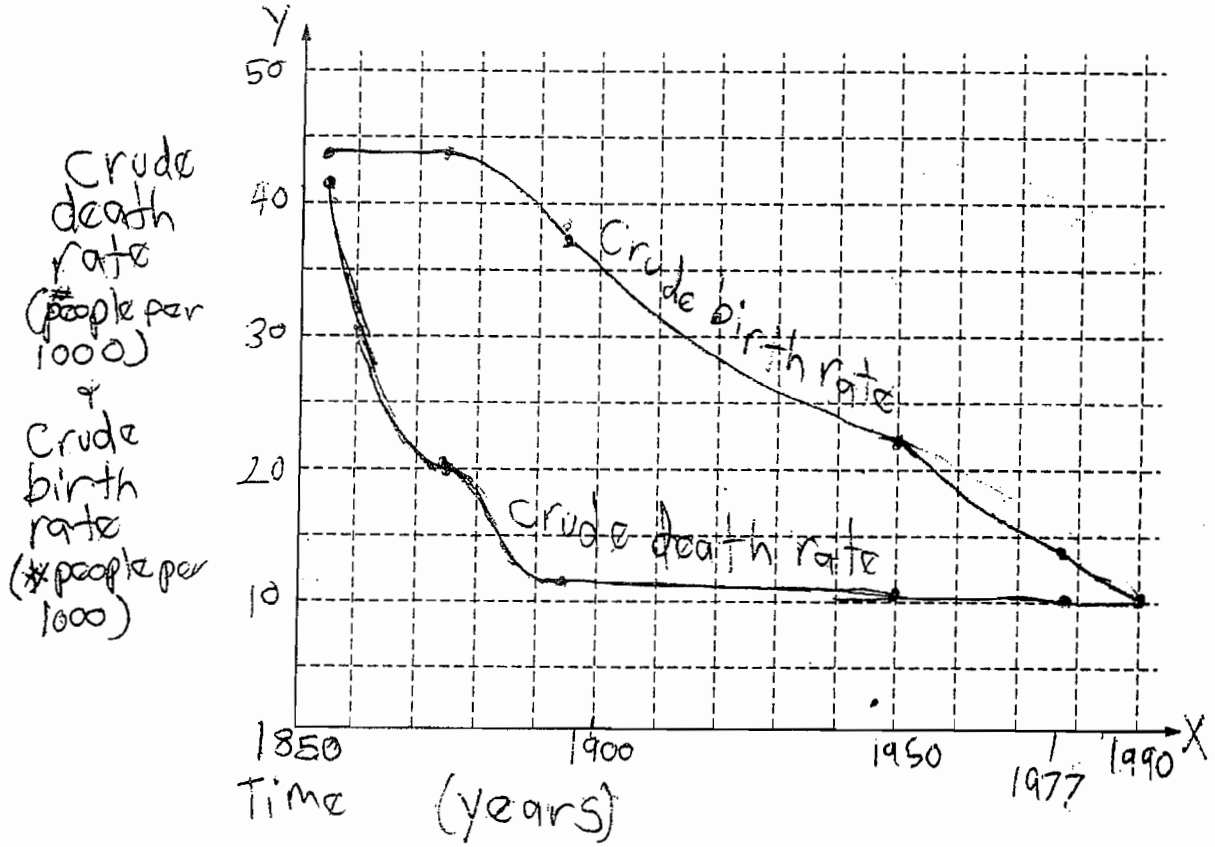
rapid decline in death rate from 1855 to 1895. Another thing could have been increased food supply, which would have led to better health, and, in turn, longer lifespans. Lack of contraceptives, birth control, and family education are all things that would lead the birth rate to be so high in 1855. It takes a long time to educate people about birth control and family planning, which would cause the birth rate to be slow to decrease between 1855 and 1950.

D) In 1895, there were 37 births and 12 deaths for every 1000 people. This means that there was a growth of 25 per 1000 or 2.5%. The population of Industria was 2.5 million in 1895. In 1951, or 56 years later, if the population would have grown at the same rate, it would have added 2.5% of its current population to the population each year.

Commentary

Three points are earned in Part (a) for scaling and labeling the axes, plotting the birth rate data and death rate data, and labeling both curves. One point is earned in Part (b) for calculating the growth rate in 1950, and one point is earned for calculating the birth rate in 1977; how the calculations were made is explained in words. Four points are earned in Part (c). No points are earned in Part (d). The growth rate and the correct value for t are calculated, but there is no indication of an equation into which these values should be inserted.

Student Response 2C (score of 7)



b. The annual growth rate of Industria in 1950 was
~~birth~~ 22 − ~~death~~ 11 = 11 births / 1000 people = 1.1% growth rate

The birth rate in 1977 Industria was 1.4%.
14 births/1000 people = 1.4% birth rate.
(look at graph)

c. The rapid decline in death in Industria between 1855 and 1895 may have been caused by several factors. One of these factors is a possible improvement in medical care over the years. Another factor is increased food quality and

quantity, which may have kept some from undernourishment and food poisoning. The birth rate was high in 1855 and slow to decrease until 1900 because people probably needed many children to assist them with their work.

d. The population of Industria would have been about 7 million if the 1895 rate of growth continued on to 1951. 2.5 million people in 1895
43-20=23 births/1000/yr 2.3% growth rate
1951-1895=56 years

Commentary

Three points are earned in Part (a) for scaling and labeling the axes, plotting the birth rate data and death rate data, and labeling both curves. One point is earned in Part (b) for calculating the birth rate in 1977, but the calculation for growth rate in 1950 is incorrect. Three points are earned in Part (c): two points for two factors that might have accounted for the rapid decline in the death rate and one point for a reason why the birth rate might have been so high. No point is earned for a reason why the birth rate was so slow to decrease. No point is earned in Part (d).

Question 3—Overview

This question was intended to test students' ability to 1) determine cause-and-effect relationships involved in patterns of variation in coastal estuaries, 2) discuss coastal wetlands in terms of their ecological and economic importance, 3) identify and explain the negative impacts of human activities on coastal wetlands, and 4) explain how the negative impacts of human activity could have been prevented or lessened through an environmental policy and through an economic incentive. Students had to correctly identify "causes," "roles," or "ways," and also discuss or explain them, to earn points.

Scoring Guideline for Question 3

Part (a)

The student earns one point for each cause and connection, for a total of two points. Two points can be earned for:

- two causes and connections for temperature ***or,***
- two causes and connections for salinity ***or,***
- one point for temperature and one point for salinity.

Cause/Variation in	Temperature Connection with Direction of Change	Salinity Connection with Direction of Change
Daily tidal cycle	Mixing of waters of different temperatures	Fluctuations due to mixing of waters of different salinities
Seasonal/diurnal flow of freshwater from rivers, streams, and runoff from land, including snow melt and ice melt	Mixing of waters of different temperatures	Fluctuations due to mixing of waters of different salinities
Suspended solids/turbidity	Increased solar absorption resulting in higher temperatures	Warmer temperatures increase evaporation which would increase salinity
Storms (rainfall), hurricanes, or typhoons	Mixing of waters of different temperatures	Influx of additional freshwater, lowering salinity levels Influx of ocean water from onshore storms, hurricanes, and typhoons, raising salinity levels
Seasonal air temperature variations Seasonal solar influx Seasonal variation in vegetation	Water is colder in the winter and warmer in the summer (shallow waters have low capacity to store heat over time)	Warmer temperatures increase evaporation which would increase salinity Warmer water has increased salt solubility
Rate of evaporation	Evaporation is a cooling process and therefore lowers the temperature of surface layers	Loss of water due to evaporation increases salt concentration

Cause/Variation in	Temperature Connection with Direction of Change	Salinity Connection with Direction of Change
Wind (seiche-wind driven tides)	Promotes mixing of the water column	Onshore wind would bring in ocean water and raise salinity Offshore wind would bring in freshwater from tributaries and lower salinity
Color of substrate	The darker the substrate, the greater the solar absorption and therefore the greater the increase in water temperature	Warmer temperatures increase evaporation which would increase salinity
Cloud cover	Greater cloud cover results in reduced solar input and cooler water temperatures	Salinity increase connected with warmer air temperature and greater evaporation OR Salinity decrease connected with increased rain or cooler water temperature and less evaporation
Diurnal air temperature variations	Solar input during the day increases water temperatures Lack of solar input at night allows cooling of the water	Warmer temperatures increase evaporation
Drought	Mixing of water of different temperatures	Decrease in freshwater flow to estuary or increased influx of ocean water will lead to increased salinity

Part (b)

The student earns one point for each ecologically important role discussed, for a total of two points, and one point for each economically important role discussed, for a grand total of four points.

Ecologically Important Roles

Ecologically Important Role	Discussion
High productivity (net primary) Carbon dioxide sink	Supports complex food webs; high rate of photosynthesis absorbs large amounts of CO_2 and releases O_2
High species diversity/biodiversity	Promotes ecosystem stability, resilience, and nutrient cycling
Nursery for fish and crustaceans	Sustains/supports marine ecosystems and life cycles
Nesting/migration sites	Sustain/support marine ecosystems and the life cycles of waterfowl, shorebirds, and other appropriate wildlife
Filters/sponges	Contribute to water quality by trapping suspended solids, sediments, sediment (toxic) pollutants (toxins), and/or nutrients

Ecologically Important Role	Discussion
Reduction of flooding	Slows the flow of water from ocean to upland ecosystems
Reduction of erosion	Absorbs erosive energy of wave action or slows the flow of floodwater
Unique habitat	Provides habitat for organisms with specific needs, such as moisture, salinity, temperature, and flat water

Economically Important Roles

Economically Important Role	Discussion
Recreational income (tourism)	Boating, fishing, hunting, bird watching, photography, and/or outdoor recreation
Property protection	Absorbs the flow of water and/or buffers shores from damage and erosion
Fishing industry	Commercial harvesting and/or processing of fish (shellfish); provides employment, tax base, or the selling of the catch
Intercoastal waterway	Protected passage for commerce which is cheaper and safer than ocean passage
Filters/sponges	Contribute to water quality by trapping suspended solids, sediments, sediment pollutants, and/or nutrients that would otherwise be subjected to water purification processes that would be supported financially by the local community
Employment opportunities	Such as wetland ecologists, wildlife managers, tour guides, and nature or recreational store owners
Sewage treatment or storm water treatment	Wastewater treatment that would otherwise be paid for by the local community
Agriculture	Haying or grazing in salt marshes, seaweed harvesting, rice paddies, and the sale of (appropriate) agricultural products
Aquaculture/mariculture	Raising, harvesting, and selling of fish and shellfish
Aesthetic value	Leads to increased property values
High biodiversity	Leads to increased bioprospecting for commercial use
Cooling of power plants/industrial facilities	Use of brackish water allows power plants to use land that is less expensive than upstream land with freshwater accessibility
Tidal power	Provides an alternative energy source in an area protected from open ocean
Carbon dioxide sink	Removes and sequesters CO_2 from the atmosphere that might otherwise be subjected to expensive removal methods
Source of methane gas	Might be collected and sold as a fuel

Part (c)

The student earns one point for each identification *and* explanation of the negative impact, for a total of three points.

Identification	Explanation
Construction/building/development	Filling in/draining of wetlands, modification of shorelines, increase in impervious surfaces causing more runoff, point and nonpoint source pollution Habitat destruction; habitat fragmentation; loss of native flora and fauna
Industrial/commercial enterprises	Point source pollution, including heavy metals, organic chemicals, thermal pollution, PCBs Acid deposition upwind of estuary causes a decrease in pH-releasing heavy metals
Housing, agriculture, golf courses, and commercial/popular-use beaches	Nonpoint source pollution such as fertilizers, pesticides, or pet waste Fertilizers lead to eutrophication; pesticides weaken or kill native species; hypoxia; habitat destruction; loss of native flora and fauna; sedimentation
Roads and bridges	Increased traffic adds NOx and particulates to the air and contributes to ground-level ozone Point and nonpoint source pollution such as heavy metals, fuel, and antifreeze. Bridges restrict the flow of water and modify sedimentation patterns; salt runoff from roadways and bridges
Dredging (deepens channels for navigation, water exchange, and species access to spawning grounds)	Sediment covers benthic vegetation and spawning sites and fouls feeding apparatus of filter feeders Habitat destruction; loss of native flora and fauna Stirring up of toxic materials and heavy metals in sediment
Petroleum drilling Transportation of petroleum	Contamination of water from oil spills degrades habitat Sediment covers benthic vegetation and spawning sites and fouls feeding apparatus of filter feeders Habitat destruction; loss of native flora and fauna
Oyster shell, aggregate, or fill material dredging (including dredging to replenish beaches)	Increased wave action contributes to erosion and/or turbidity of the water Sediment covers benthic vegetation and spawning sites and fouls feeding apparatus of filter feeders Habitat destruction; loss of native flora and fauna Stirring up of toxic materials and heavy metals in sediment
Overharvesting/overhunting of commercial and sport species	Reduction of commercial and sport species populations that may create ecosystem instability and impact food webs; decrease in biodiversity
Dam construction and water diversion projects (levees, channelization, irrigation)	Redistributes fresh water and nutrients; interferes with fish migration; restricts sediment flow

Organic matter from sewage treatment plant effluent, septic systems leakage, bilge/ ship sewage pumping, fish farms	Diminishes water quality by increasing BOD, leads to eutrophication, decreasing DO; possible fish kills; decrease in biodiversity Possible introduction of exotic species from ballast water
Boat traffic, including wave runners	Increased wave action contributes to erosion and/or turbidity of the water Noise pollution from boat engines; water pollution from engine exhaust and engine leakage of oil and gas; harm to marine animals (propellers)
Deforestation upstream	Leads to increased erosion and increased sediment load of fresh water from river; habitat destruction; loss of native flora and fauna
Increased production of greenhouse gases (CO_2, CH_4, N_2O, CFCs)	Contributes to global warming, which will raise sea levels and destroy coastal wetlands
Introduction of invasive species	Invasive species compete with and/or displace native species
Pesticide spraying to control disease spread	Pesticides weaken and kill native species; loss of native flora and fauna; decrease in biodiversity
Landfill (sanitary), illegal dumping	Leaching of toxic substances; habitat destruction; loss of native flora and fauna; decrease in biodiversity
Off-road vehicles, such as dune or swamp buggies	Air pollution from engine exhaust, engine leakage of oil and gas; habitat destruction; loss of native flora and fauna; decrease in biodiversity
Deforestation of mangrove/cypress swamps	Eliminates filtering capacity; disrupts food webs; loss of native flora and fauna; decrease in biodiversity

Part (d)

The student earns one point for the explanation of an environmental policy and one point for the explanation of an economic incentive that could have prevented the negative human impact selected from Part (c), for a total of two points. The explanation could include a specific law or policy, but just naming the law or policy is not sufficient.

- If Part (c) is unanswered, then no points are awarded for Part (d).
- If an incorrect identity from Part (c) is chosen for Part (d), then no points are awarded for Part (d).
- If a negative human impact is not specifically identified from Part (c), then no points are awarded for Part (d).

Regulations Pertaining to Wetlands	Description
Clean Water Act	Regulates placement of all dredge and fill materials, sets national water goals, requires projects to meet water quality standards, requires replacement of damaged or destroyed wetlands
Federal River and Harbor Act	Regulates construction activities in navigable waters
National Environmental Policy Act (NEPA)	Requires full disclosure of the potential effects of proposed federal action (environmental impact statement)
Coastal Zone Management Act	Federal funds will be awarded to projects that comply with the coastal zone management plan
Endangered Species Act	Prohibits any land use that will threaten the survival of an endangered or threatened species (fines, seizures, imprisonment)
"Safe Harbor Agreements"	Landowners voluntarily agree (with technical support from the government) to maintain habitats for endangered or threatened species who inhabit their land
Marine Protection Act	Regulates waste disposal into coastal waters
Fifth Amendment, Eminent Domain	Private landowners must sell property to the government if the area is needed for the public good; the property must be purchased at a fair market value
Clean Air Act	Includes provisions for primary and secondary air pollutants; trading emissions credits
Migratory Bird Conservation Act	Protects and preserves migratory bird habitats

Other Environmental Policies

- Rolling easements; prioritize public access to the shore over properties rights to build seawalls
- Zonings
- Increase number of wildlife refuges and/or coastal wetlands
- Local and regional governments adopt policies guided by the "precautionary principle" (if potential harm is suspected, then precautionary measures should be taken)
- Local/regional policies or ordinances that are applicable

Economic Incentives

- Taxes (reductions, increases, or waiving) or government-backed bonds to promote preservation of coastal wetlands
- Fines/penalties for noncompliance
- Government subsidies to promote preservation of coastal wetlands
- Land trade-offs to discourage development of coastal wetlands
- Charging user fees to discourage development of coastal wetlands

- Waiving permit fees in lieu of damaging environmental practices
- Using green taxes or effluent fees to internalize harmful environmental costs of production and consumption of industrial products
- Reduction of property taxes on wetlands maintained in their natural state
- Nontaxable profits from land sales to conservancy-based organizations
- Establishment of performance/assurance bonds to mitigate any damages to coastal wetlands that occur during the construction and/or operation of a business or industry (deposit is returned minus the actual or estimated environmental costs)
- Trading of emission credits for industries

There is a total of 11 points available in Question 3: Part (a) 2 points, Part (b) 4 points, Part (c) 3 points, Part (d) 2 points; but a student can earn a maximum of only 10 points.

Sample Student Responses for Question 3

Student Response 3A (score of 10)

a) The temperature of an estuary varies greatly according to the depth of the water. The depth of water is affected by the tides. In shallow or low water, the estuary would be about the temperature of the environment. In deeper water, the estuary would be closer to the temperature of the ocean. This occurs because shallow water is quickly warmed whereas deeper water is not. The salinity of an estuary is affected by rainfall. After a storm or heavy rains, the salinity of an estuary would be low, because rain is fresh water and would be retained by an estuaries. In a time of draught or a long time w/o rain, the estuary would have high salinity because some fresh water would have evaporated and the rain had not alluted any of the salty water.

b) Coastal wetlands serve as protection against inland flooding. They are able to absorb lots of water and they direct water to the ocean, preventing flooding from precipitation. They also keep the tides back by blocking the water (absorbing/holding it). Additionally, wetlands prevent soil erosion. The root systems of the plants that live in wetlands hold the soil together, which is especially important when the soil is subject to so many changes in the depth of the water table.

Economically, coastal wetlands are important because of their high property value. They exist in a prime location for real estate (at least from an aesthetical standpoint) and therefore sell for lots of money. The wetlands also serve as a place of great biodiversity and many interesting species. This makes them a prime location for eco-tourism (for example the Northern Australian Wetlands).

c) Humans have a great desire to live close to the water. As a result, people build homes on filled in wetlands, which destroys the habitat (and most likely ultimately the home too!). People also tend to build power plants or factories near large bodies of water because that's an easy place to dispose of liquid waste. Even if the waste has been cleaned, often thermal pollution harms the wetlands. Additionally, humans have introduced species to the wetlands that cause problems. The introduction of foreign species prevents native species from thriving, upsets the biogeochemical cycles and prevents the wetlands from performing its job.

d) A policy that would have prevented people from building homes on drained or filled in wetlands would be that people must live some number of meters or miles from the ocears edge. An economic incentive would be that taxes decreased if you lived farther inland, rather than on wetlands.

Commentary

In Part (a), the tidal cycle is identified as one cause, but there is no clear connection between the effect of the changing tides to water depth and the resulting variation in water temperature; no point is earned. The second cause addresses the impact of storms and rainfall on salinity levels, including the direction of change as a result of increased rainfall and decreased or lack of rain. This response earns one point. Because only the first two causes given are scored, no additional points are earned for evaporation. In Part (b), four points are earned for clearly identifying and discussing two ecologically important roles and two economically important roles of coastal wetlands. One of the points is earned for the discussion of flood reduction and the protection of inland regions, even though it contains some incorrect information. In Part (c), three negative impacts that humans have had on coastal wetlands are identified and explained. One point is earned for explaining the negative impact of development through habitat destruction. The negative impact of industry is discussed in terms of liquid waste (which is too vague an answer) and thermal pollution (which is an acceptable response and worth one point). The introduction of foreign species is explained in terms of their impact on native species; this also earns one point. In Part (d), two points are earned for one environmental policy and one economic incentive that could have prevented the construction of homes, which was mentioned in the discussion of negative impacts in Part (c). A total of 10 points is earned even though full credit is not earned in Part (a).

Student Response 3B (score of 7)

(a) Two causes for the variation in the salinity and temperature of an estuary include air temperature and ocean tides. The air temperature would in part determine the amount of evaporation of an estuary. The amount of evaporation of an estuary affects the salinity of that estuary. Also, the air temperature would have an effect on the temperature of the water in the estuary.

Ocean tides bring and remove saline water. When the tide is in, the estuary would be filled with a greater amount of salt water and thus, the salinity would be higher. When the tide is low, more fresh water has an opportunity to flow into the estuary, thus lowering the salinity.

In addition, ocean tides bring in cooler or warmer water that would either lower or raise the temperature of the estuary. Then, when the tide went out, the water would become warmer or cooler depending on the temperature of the departing ocean water and the weather.

(b) Coastal wetlands play two ecologically important and two economically important roles. First of all, coastal wetlands support a great number of species thus contributing to biodiversity. They also serve as sinks of important elements. Storing these elements is important in the cycles of important elements such as nitrogen and phosphorous.

Economically, wetlands are also important. They

support fish that is caught and sold to consumers. Also, wetlands serve as a tourist attraction, producing money as travelers spend money on travel, boarding, and viewing wetlands.

(c) Humans have had numerous negative impacts on coastal wetlands. First of all, ~~[illegible]~~ the human population is constantly growing at a high rate thus, humans are expanding further and developing wilderness more in order to accomidate the growing demand for houses, stores, etc. Humans have filled coastal wetlands and built developments on top of them, thus destroying all of the life that wetland once supported.

Seconaly, humans have polluted coastal wetlands during ~~[illegible]~~ recreational activities. The litter they added to the wetlands has had a negative impact on the health of species within coastal wetlands.

Also, humans have overfished and overhunted species of coastal wetlands. This has had negative impacts on the food chain of the coastal wetland and thrown the precious balance of life out of kilter.

(d) Overfishing could have been prevented. By setting strict limits on the number of fish allowed to be ~~[illegible]~~ caught, the number of fish caught would generally be lower. Also, by providing a ~~[illegible]~~ partial refund to fishermen who ~~[illegible]~~ caught and kept the accepted number of fish would have served as an economic incentive.

Commentary

In Part (a), there is an attempt to connect air temperature to the rate of evaporation and salinity; however, there is no mention of the direction of change, so no point is earned. The discussion of air temperature and water temperature also lacks direction and is a further discussion of the same cause. The second cause given is tides, and since it is clearly connected to tidal direction and specific changes in salinity, one point is earned. Again, the continued discussion of the effects of tides on water temperature is not scored since it is an additional discussion of the second cause. In Part (b), biodiversity is identified and its role in nutrient cycling is discussed, earning one point for a correct identification and discussion. There is no second ecologically important role mentioned. Two points are earned for the discussion of the economical roles of fishing and tourism. In Part (c), the response addresses the negative impact of development with the destruction of wildlife and earns one point. The second point is earned for the discussion of overfishing and its impact on food chains. The discussion of recreational activities is too vague. In Part (d), one point is earned for the proposed environmental policy that limits fish catch. The economic incentive is too vague.

Student Response 3C (score of 5)

(a) The variations in temperature and salinity of an estuary are calsed by tidal changes and seasonal charges, As tides rise more fresh water or salt water is added to an estuary. This will either decrease or increase the salinity of the water. The increse in water during high tide also changes the temperture of esturian water. Seasonal changes will determine the temperture of the water in an esteary. During winter water will have a decreased temperture and during summer the temperatures will increse Slightly.

(b) Coastal wetland provide shelter to many young speeies befere they move on to larger bodies of water. Without the protection ~~of~~ that the wetlands provide these young species would die befer they cald reproduce. Wetlands also act as a buffer zone between coastlines and waves. Wetlands prevent beach erosion because of plants such as mangrooves that have large roots that help cateh sand. Wetlands are also ~~[illegible]~~ economically important. Wetlands

(c) Humans have negativly impacted or degraded coastal wetlands through development, hunting, and pollution. Developing on or near coastal wetland destroys the balance of that ecosystem. Hunting has depleted animals such as alligaters that thrive in wetlands. Keystore speais like the alligater are needed to

maintain a wetland. Pollution has destroyed many native wetland plants and animals. Runoff from agriculture adds chemicals to the wetlands water and cause fish kills.

D) In order to stop development on coastal wetland one environmental policy is to not allow for development on wetlands, or to require the creation of a new wetland to replace one that may be developed on. An economic ~~incentive~~ incentive could be to give developers subsidies if they find other land to develop on besides wetlands or if the replace wetlands for the ones they developed on.

Commentary

In Part (a) of this response, there is an attempt to explain changes in salinity using tidal change; however, it is unclear as to whether a rising tide adds more freshwater or saltwater to the estuary, and whether that raises or lowers the salinity levels. Because the answer lacks the direction of change, no points are earned. The changes in temperature alluded to in reference to high tide is not scored because it is related to the same cause. The second cause indicated is seasonal change, but the discussion is too vague, so no points are earned. In Part (b), two points are earned for the discussion of two ecologically important roles of wetlands. In Part (c), the student identifies three ways that humans have negatively impacted coastal wetlands, but only one point is earned. The negative impact of development is not clearly explained and pollution is too vague a term. The explanation is also too vague. One point is earned for the discussion of hunting and its impact on animal populations. The response indicates an understanding that the alligator is important for maintaining the structure and function of the wetland ecosystem. In Part (d), one point is earned for describing an environmental policy that suggests land mitigation, and one point is earned for an economic incentive that involves subsidies. These are clearly tied to development, correctly identified in Part (c).

Question 4—Overview

The purpose of this question was threefold: to assess students' ability to 1) distinguish between natural and anthropogenic causes for the decline in populations of different species, 2) examine the causes of species endangerment and the remediation of the problem, and 3) develop an argument both for and against a particular position on a topic in environmental science. To earn points, students had to develop their ideas into descriptions or arguments. Students who lacked familiarity with the two example species in the first two parts of the question could still make inferences based on the species with which they were familiar.

Scoring Guideline for Question 4

Part (a)

The student earns one point for each identification of a cause of a specific bird's decline and a proper description of the decline (no points earned without proper description), for a total of two points.

If habitat is mentioned, it must be tied to a specific type of habitat loss and be appropriate to the species and the correct effect on the decline of the species. Two different causes for the decline must be identified if the student uses one cause per species (i.e., the student cannot use habitat loss due to urbanization for both species but could use habitat loss due to urbanization for the condor and habitat loss due to wetland draining for the whooper).

Whooping Crane	California Condor
Habitat loss due to: Urbanization Wetland destruction Agricultural modification of flyway Mineral fossil fuel extraction Natural disaster leading to: ■ loss of food resources ■ food web disruption ■ loss of breeding/nesting/migration habitat or cover Hunted for feathers, meat, eggs, skin, trophies, sport, or unintentionally due to mistaken identification	*Natural Causes:* Climate change Loss of ice age megafauna Restricted range due to shifting vegetative zones *Anthropogenic Causes:* Habitat loss due to urbanization, limiting range Grassland (agricultural conversion or fire suppression), old growth forest removal leading to: ■ loss of food resources ■ food web disruption ■ loss of breeding/nesting/habitat or cover ■ reduction of food source (bison/deer/elk) ■ lead poisoning from shotgun pellets in carrion ■ incidental poisoning due to predator control Hunted for eggs, skin, trophies, sport, or unintentionally due to mistaken identification

Part (b)

The student earns one point for each measure.

The student must specify the species. Unless specified below, these measures apply to either bird. There is a potential elaboration point for detailed description of protection methods.

Legislative Measures: The student can list law/policy/practice with an explanation or simply a description of how it protects the species without stating the law:

- Lacey Act—Prohibits transport of live animals, dead animals, or animal parts across state lines without a federal permit
- Endangered Species Act—Cannot be hunted, killed, collected, harmed, or injured
- Listed on CITES—Cannot be traded commercially as live specimens or wildlife products
- Clean Water Act (whoopers only)—Protects wetlands
- Migratory Bird Treaty (whoopers only)—Agreement between the United States and Canada to protect migratory birds
- Migratory Bird Conservation Act (whoopers only)—Protects migratory species
- Wetland preservation measures (whoopers only)
- Creation of wildlife refuges/establishment of critical habitat
- Restriction of construction in flyways and migratory areas (whoopers only)
- Ban of use of specific pesticides, such as DDT
- Ban of use of lead bullets/shot

Artificial Population Measures

- Captive breeding/incubation of eggs, including:
  1. Establishment of experimental populations
  2. Hazard avoidance measures
  3. Teaching of alternative flyways using ultralights (whoopers only)
- Public education (to raise public awareness of the endangered status of the species)
- Research into life history of the species
- Population monitoring, including:
  1. Tagging
  2. GPS/radio telemetry
  3. Public reporting of sightings

Example of Elaboration: Whoopers—removal of extra egg, captive incubation, and artificial imprinting on puppets/models/stuffed birds; release and teaching of alternative flyways.

Note: If a student uses the term "preserve," since it is given within the text of the question, the student must specifically explain *how* the preserve serves to protect the species; the term "preserve" is not enough.

Part (c)

The student earns one point each for a description or specific example linked to the slow recovery of the species, for a total of two points:

- Low fecundity/reproductive success
- Late reproduction/sexual maturity
- Specialized mating, including rituals (nest building, dancing, mating for life); limited breeding/nesting habitat
- Specialized feeding requirements
- Long-term parental care
- High infant mortality rate
- Low population density (difficult to find mates)
- Genetic drift (limited gene pool)
- May have minimum viable population
- Species with maladaptive behavior (slow to recognize environmental hazards)
- Carnivores/predators, including disruption of food chain biomagnification/bioaccumulation
- Large body size
- Large range requirements
- Limited or specialized habitat/range due to competition
- Long/fixed migration routes
- High sensitivity to environmental conditions

Note: The terms "specialist" or "*K* strategist" alone are not sufficient as descriptors.

Part (d)

The student earns one point for each argument for and against and one point for the additional support of each of the arguments, for a total of four points.

The answer must be connected to whooper, condor, or specific endangered species, and each argument must be for the same species. Species accepted were those on state/provincial, national, or international recognized endangered or threatened species lists.

An argument must include an identified economic or ecological factor with the economic or ecological impact (one point) linked with at least one supporting detail (one point) within the context of a paragraph. If the student does not clearly identify the argument as for or against, the response will be scored in the order of for or against.

Economic

For	Against
Ecotourism Reestablish population for commercial harvest Economic sanctions against countries that are not enforcing CITES Debt for nature swap (e.g., land bank, tax relief, etc.)	Expensive due to: ■ Allocation of funds to protect species ■ Developmental restrictions ■ Decreased value of land ■ Loss of tax revenue on protected land Useful economically for a specific purpose tied to economic benefit (e.g., selling the endangered eastern prairie fringed orchid for profit) Goods produced have value (e.g., ivory, skins, etc.) Funding priorities based on emotion or aesthetics, not importance of organism's ecological role No allocation of money to save organisms that will inevitably become extinct

Ecological

For	Against
Maintain biodiversity linked to: ■ Evolutionary value ■ Genetic diversity ■ Synergism with other species ■ Keystone species Niche value: ■ Matter cycling (scavenger/decomposer) ■ Trophic level ■ Pollination ■ Soil formation ■ Pest control	Background extinction Focus is on species instead of on habitat Protection stresses another species that might have a chance for recovery Other species may occupy the same fundamental niche

Sample Student Responses for Question 4

Student Response 4A (score of 10)

a) California condor: Lead poisoning. Birds are vulnerable to any toxins But since condors are scavengers, they eat dead animals. Many ate animals shot by hunters, and those animals had lead in them from bullets. The lead led to bioconcentration of the toxin in condors, and so they died off rapidly.

② Habitat fragmentation hurt CA condor population Few condors live in an expanse area of land, one of the features of a species vulnerable to extinction The development of human cities, towns, and residences infringed on the condors' habitats so that they could not roam freely any longer.

b) ① Captive breeding: Humans took it upon themselves to save the CA condors from extinction. They took baby condors and raised them in clean, safe environments. Then when the condors matured, they were released

② Egg snatching: Brave condor-lovers have flown by helicopter to the isolated nests of CA condors. They take the real CA condor egg, *(go to arrow) ~~with~~ ~~[illegible]~~ one. Because animals and especially other birds eat condor eggs, humans have incubated the condor eggs in safety, and when the ~~baby~~ chick hatches, it is placed in the same condor's nest, and the mother condor accepts it as her own.

> because observation has proven that when a condor egg goes missing, the parents lay a new egg, interminably. This constant egg-laying

allows condor population, if fostered by human interventron, to grow.

c) ~~Fixed migratory pattern: An example is the blue whale.~~ ① Small litter size: If an endangered species typically has only ~~one~~ one offspring at a time, rehabilitation of numbers is very difficult.

② Long time to get to reproductive maturity: ~~As~~ species that takes a long time to grow to reproductive maturity can't have more offspring to replace older members if the older ones get killed off first. Suppose a species were hurt and many were killed off. If the only survivors are too young to reproduce, the species can't bounce back in numbers

d) ~~Ecological~~:

Ecological argument for

The Grey Wolf is a keystone species! If it is not protected, the ecosystems where ~~#~~ it lives will fall. It controls deer population by keeping the sick and mutated deer from reproducing. Even if it kills some, it makes the deer population healthy, prevents an overshoot of a deer population and consequently an irruptive bottom-up cycle of grass/plant overconsumption and deer die-off.

-Economic argument against:

The grey wolf is a danger to humans! They kill livestock from farms! Sheep and cattle are killed by grey wolves, and that hurts the ranching economy. We humans can't afford to ~~lose~~ lose our livestock because some animal-lovers want to protect this beast from angry cattle ranchers like ourselves. (sorry, exagerration, but it's fun to read).

Commentary

One point is earned in Part (a) for linking the idea of population decline with lead poisoning in carrion, but no second point is earned in this part because the response is not specific about how the large territory impacts population. Three points are earned in Part (b): one for the concept of captive breeding, another for the description of egg collection from the wild, and a third (an elaboration point) for the description of how eggs are obtained and used. Two points are earned in Part (c) for linking the concept of small clutch size to a slow rate of population increase and for the concept of late reproductive maturity to fewer offspring for population replacement. In Part (d) four points are earned for an outstanding job of developing arguments for and against the protection of the grey wolf. The premise that the wolf is a keystone species was supported by a description of how it controls deer populations and the consequences of its absence. The premise that the wolf is a danger to humans was supported by a comment on its destruction of livestock and the subsequent effect on the ranching economy.

Student Response 4B (score of 8)

4.

a) Habitat distruction and unmonitored hunting of the California condor led to it's decline. Urban sprawl took away from its natural habitat and the birds had little room to reproduce. Many people also hunted the birds because of their big size. They were seen as easy targets and respected trophies.

b) Both species have been placed on the Endangered Species List and protective laws and fines have been placed on the birds and those who ~~kill~~ purposfully harm an individual. The Whooping Crane is protected by the legislation to keep coastal wetlands clean (Clean Water Act) and the Condor is protected by sanctuaries and Wildlife Protection funds.

c) A species that is slow to reproduce and that is a specialist species would be slow to recover.

2 The natural time it takes for reproduction of the Condor is slow and so protection benefits would take many years to be noticed. The Condor also has specific survival requirements that are difficult to maintain. Space and food requirements and temperature requirements can cause an endangered species to recover slowly.

d) The African elephant should be protected because it provides food and habitat for the other organisms of the African plains. By uprooting or tearing down trees the smaller grazers can have access to leaves that were once too high to reach and small reptiles and rodents can make their homes in the branches and

trunks of fallen trees. However, some say the elephants should not be protected because herds can destroy a farmers field. They wander into farming land because of habitat loss and eat and destroy the vital crops. Farmers are then out of business and can't make enough money to survive.

Commentary

Two points are earned in Part (a): one for attributing habitat destruction to urban sprawl and associating that with the lack of room to reproduce, and the other point for the concept of trophy hunting. One point is earned in Part (b) for the effects of the Endangered Species list. No point is earned for the reference to the Clean Water Act since there is no mention of a specific consequence of that legislation. In Part (c) one point is earned for the development of the idea of a specialist species. No point is earned for the vague treatment of "slow to reproduce." Four points are earned in Part (d) for an excellent development of both arguments. The premise that the African elephant is important to the maintenance of a stable ecosystem was supported by a reference to its specific role and its impact on the landscape. The opposing argument was supported by a practical observation and further commentary.

Student Response 4C (score of 7)

a) One cause for the decline of both species is extreme over-hunting. During the 50's and some of the 60's, it was considered extremely fashionable and in good taste to wear hats with feathers in it. The more beautiful the feathers, the more valuable and good looking the hat was. Since the whooping crane had beautiful and elegant feathers, they were hunted, without regret or thought for their future, almost to the brink of extinction. A species of crane almost became extinct because people believed it was beautiful to adorn themselves with feathers! Imagine that! Another major reason for a decline in the whooping crane population was the complete and utter destruction of most of their habitat. Urbanization is the main culprit for the loss of habitat.

b) One major effort that the whooping crane greatly benefited from was a conservation effort. In this effort, part of the whooping crane's habitat was reconstructed and designated a wildlife preserve; this was also done to most of the whooping crane's original habitat. One other measure taken to protect both species was in the passage of the endangered species act. With the passage of the act, it was now illegal to kill either the crane or the condor, due to their low numbers, or interfere with their lives in any way. Both species benefited from this act.

c) One characteristic of an endangered species that would cause it to be slow to recover would be if each breeding pair had few offspring and if each offspring took alot of time and care to be raised. This falls under a

slow reproductive rate. Another characteristic of an endangered species that would make it slow to recover would be if the species lived in a very specific habitat and had specific requirements in order to remain an active breeding population. In other words, the species would be slow to recover because it was not flexible and couldn't adapt to new surroundings easily.

d) The california condor should be protected at all costs because it is a key link in maintaining a stable ecosystem in california. It helps along the cycle of recycling matter and also [redacted] it helps to keep the landscape and environment clean and pristine.

On the other hand, since the decline in the california condor population happened, the ecosystem seems to be handling it very well. Detritus has not been rampant across the landscape; obviously nature has found an alternative method to the california condor to use as its' top recycler. Why should [redacted] we bother to harbor and protect a species [redacted] whose numbers have dwindled so drastically that they're practically extinct?

Commentary

One point is earned in Part (a) for the reference to hunting the animals for feathers. The habitat section is too vague to earn the second point. One point is earned in Part (b) for the effects of the Endangered Species Act. The reference in that section to the preservation of the whooping crane habitat does not link this to a specific benefit to the population and did not earn a point. Two points are earned in Part (c) for a specific treatment of the concept of slow reproductive rate and for mentioning a particular facet of specialized habitat requirements. Three points are earned in Part (d): one point for the concept of the condor's role in the ecosystem and two points for the better-developed argument against preservation.