

ENVIRONMENTAL MANAGEMENT

Paper 8291/11 Principles of Environmental Management

Key messages

In **Section A**, candidates should pay close attention to the number of marks allocated to each part-question and tailor the length and depth of their responses accordingly. This helps ensure that the level of detail provided aligns with the expectations of the question.

In **Section B**, candidates must clearly indicate whether they are answering **Question 5** or **Question 6**. They should avoid writing broad, general introductions and instead focus directly on strategies that relate specifically to the chosen question. For each strategy, candidates should explain the benefits and limitations, demonstrating clear understanding. Conclusions should synthesise the key points made, rather than repeating them or offering a generalised summary.

It is essential that candidates follow all instructions carefully and understand the distinctions between command words such as *state*, *suggest*, *predict*, *justify*, *describe*, *explain*, *compare*, and *evaluate*. Misinterpreting these can limit access to higher-level marks.

Candidates should also make efficient use of examination time by avoiding unnecessary repetition of the question within their answers.

General comments

There was generally a strong response across the paper, with most candidates demonstrating sound understanding of the key concepts. However, **Question 4** — which covered the structure of the atmosphere, ground-level ozone and its impacts on human health, the role of stratospheric ozone, and the process of ozone depletion was found to be more demanding than the rest of **Section A**.

Many responses showed good understanding of key terms and strong attention to detail, often supported by effective use of exemplar material. The strongest answers made accurate and purposeful use of well-chosen examples to illustrate key points. These candidates supported their ideas with precise detail and appropriate terminology, demonstrating both clarity of thought and depth of understanding.

Comments on specific questions

Section A

Question 1

This question assessed candidates' understanding of population density and the factors that influence it, population structures and income groups, and the impacts of an ageing population.

- (a) (i) Many candidates described the distribution of population density in **Fig. 1.1** only in relation to global lines of latitude such as the Equator and the Tropics, using terms like 'above', 'below', or 'between', which was not sufficient for credit. More successful responses provided precise descriptions of low, medium, or high population density with reference to specific continents or countries.
- (ii) This question was generally well answered. Most candidates correctly stated that Peru and Brazil have a medium population density and used this as evidence for the conclusion that 'the number of people per km² in Peru and Brazil is the same'. Some candidates strengthened their answers by

stating that medium density is defined as 10–199 people per km², which showed evidence that did not support the conclusion and therefore gained full credit.

- (iii) The majority of candidates successfully used the data in Table 1.1 to calculate Botswana's population density in 2023 as 4 people per km² and correctly identified this as low density using the key in Fig. 1.1.
- (b) Candidates generally found this question more challenging, as they were required to state one example each of environmental, economic, and social factors influencing population density within a country. Responses were often vague, repetitive, or mismatched to the category. Common correct environmental factors included natural disasters, food availability, or reference to topography. Job opportunities was the most frequent correct example for economic factors, while references to culture were the most common correct social examples.
- (c) (i) Many candidates found this question difficult. Some correctly identified the income group of the country in Fig. 1.2 as a MIC, although many incorrectly selected LIC.
 - (ii) This part was more challenging and generally less well answered. Few candidates referred directly to the shape of the population structure. Successful responses described the wide base and gradual narrowing with age, recognising that this indicates a decreasing number of older people.
- (d) Many candidates demonstrated a clear understanding of the impacts of an ageing population, though some answers lacked the precision required for credit. Stronger responses included impacts such as fewer people in the workforce, increased pension spending, greater pressure on healthcare services, and potential increases to the retirement age. References to higher taxes or an increased dependency ratio did not gain credit, as these are not necessarily direct impacts.

Question 2

This question assessed candidates' understanding of long-term energy security, the effects of piracy on energy security, reliance on fossil fuels as a strategy for managing energy security, and how increasing access to electricity impacts people.

- (a) (i) Candidates found this question challenging, and many were unfamiliar with the definition of long-term energy security. Weaker responses tended to describe it simply as "access to energy for a long time" or provided a definition of sustainability, which was insufficient. Successful candidates correctly referred to reliable access to affordable energy while considering environmental impacts. Higher-level responses also linked long-term energy security to enabling economic development.
 - (ii) Many candidates gained credit for stating that piracy decreases energy security. Stronger responses explained that piracy involves stealing from, or taking control of, ships transporting oil or coal, preventing energy sources from reaching their destination and therefore disrupting supply. A significant number of candidates did not demonstrate understanding of the term 'piracy', with many not recognising that it involves hijacking tankers or pipelines. A notable proportion of candidates did not attempt the question.
 - (iii) Some candidates lacked knowledge of the benefits of reliance on fossil fuels as a strategy for managing energy security, and very few achieved full credit. Common misconceptions included the idea that fossil fuels are renewable, or that they are replenished naturally over time. Weaker answers were vague or repeated information from the question. Correct benefits commonly identified were that fossil fuels are relatively cheap and widely available. Correct limitations included that fossil fuels are non-renewable and will eventually run out, and that their use releases carbon dioxide, contributing to climate change.
- (b) (i) Most candidates were able to plot a line graph accurately using the data in Table 2.1 and obtained much of the available credit. Frequent errors included drawing a bar chart instead of a line graph, omitting axis labels, or selecting non-linear or impractical scales which made accurate plotting difficult. Although not penalised, many candidates did not begin the y-axis at 0, which is considered best practice where appropriate. Accuracy could have been improved in some cases by using a sharp HB pencil and a ruler.
 - (ii) This question was well answered. Most candidates correctly estimated that 45% of the population had access to electricity for at least four hours per day.

- (iii) Successful candidates explained specific increases or decreases resulting from improved access to electricity, such as increased employment opportunities, longer working hours, improved education, better healthcare, increased internet access, or reductions in poverty.. A common error was simply listing household appliances or stating that people could “run daily household objects”. Many did not recognise that the question referred to an increase in access to electricity.

Question 3

This question assessed candidates’ understanding of hydroponics, including how hydroponic systems reduce competition, the benefits and limitations of hydroponic growing, the concept of food security, and strategies for managing food security.

- (a) (i) This question was generally well answered, with many candidates able to use **Fig. 3.1** and apply their knowledge to explain how the hydroponic system reduces competition between strawberry plants. However, very few achieved full credit. Weaker responses simply listed factors that affect competition, rather than explaining how the system actually reduces competition for those factors. Common correct responses included the idea that water is evenly distributed through the pipes and that plants are spaced evenly, giving each plant enough room to grow. Stronger candidates demonstrated good understanding of hydroponics, mentioning that nutrients dissolved in the water are supplied at optimum concentrations and that growing plants on a slope prevents shading and maximises light.
 - (ii) Many candidates were able to use the information in **Fig. 3.1** to suggest several plausible benefits or limitations of hydroponics beyond reduced competition. Despite this, very few gained full credit, indicating that hydroponic systems remain an area for further study. Weaker responses tended to give vague or generalised ideas, such as stating that hydroponics “increases food security” or “is a controlled environment”, which were insufficient. A common misconception was the belief that the absence of soil means plants do not receive nutrients, which is incorrect. Successful candidates suggested two benefits and two limitations. The most common correct benefits were increased yields, the ability to grow crops all year round and reduced need for pesticides. The most frequent correct limitations were the high cost of installation and the system being labour intensive.
- (b) (i) Most candidates demonstrated a generally good understanding of the definition of food security and were able to gain some of the available credit. Successful answers recognised the idea that people must have access to enough food, with many candidates further describing adequate nutrition. Candidates who defined food insecurity rather than food security were unable to gain the first marking point.
 - (ii) This question was generally well answered, with most candidates able to access some credit. Common correct strategies, other than hydroponics, for managing food security included rationing, reducing food waste and the use of GM crops.

Question 4

This question assessed candidates’ understanding of the structure of the Earth’s atmosphere, the effects of ground-level ozone on human health, the protective role of stratospheric ozone, and the process of ozone depletion.

- (a) (i) Most candidates were able to use **Fig. 4.1** to correctly determine the maximum altitude of the troposphere.
 - (ii) Most candidates correctly identified the letter **A** on **Fig. 4.1** as the layer containing the ozone layer.
- (b) (i) There was a general lack of knowledge and understanding of how ozone can harm human health, and many candidates did not recognise that the question referred specifically to ground-level ozone. Successful responses identified that ground-level ozone forms photochemical smog and can cause respiratory or eye irritation. Many weaker answers confused this with ozone layer depletion, and some made general references to climate change or the greenhouse effect, which were not relevant to the question.
 - (ii) Candidates generally understood that the ozone layer shields the Earth’s surface from UV radiation, though few used the precise term ‘absorb’. Many responses simply described the “protective nature” of the ozone layer without specifying the mechanism or referring to human health, which was

insufficient for credit. Some candidates incorrectly linked the ozone layer to global warming. Stronger answers correctly identified that the ozone layer prevents health issues such as skin cancer and cataracts.

- (c) (i) This question was generally well answered. Most candidates recognised that the mean area of the Antarctic ozone hole showed a fluctuating trend or correctly described it as increasing and decreasing between 1980 and 2022.
- (ii) Candidates found this question challenging, with few able to correctly calculate the percentage increase in the mean area of the Antarctic ozone hole between 1980 and 2000 as 1150%. Some gained partial credit by correctly identifying the values of 2 and 25 from **Fig. 4.2**.
- (d) The process of ozone depletion was not well understood, and most candidates found this question difficult. Successful responses explained that CFCs, when exposed to UV radiation, break down to release a chlorine atom which then reacts with ozone, leading to its depletion. Candidates with partial knowledge were often able to refer to CFCs from aerosols or refrigerants.

Section B

Significantly more candidates chose to answer **Question 5** rather than **Question 6**, and most candidates clearly indicated which question they were answering.

The questions in **Section B** assess two skill areas: AO2 (Information Handling and Analysis), worth 8 marks, and AO3 (Investigation Skills and Making Judgements), worth 12 marks. These are combined to give a total mark out of 20.

Overall, most candidates were awarded Level 2 for both AO2 and AO3, typically achieving between 8/20 and 12/20. A small number of candidates were limited to Level 1 for AO2 because they provided no examples to support their points, and Level 1 for AO3 because their answers were largely descriptive and did not include any judgements. A few candidates did not answer either question in **Section B**.

Question 5

Many candidates were able to demonstrate their understanding of the impacts of human activities on tropical rainforests and the impacts of climate change on tropical forests, evaluating whether local human activities have a greater impact on tropical forests than climate change. Successful responses described a range of local human activities including deforestation for agricultural development and urbanisation, logging for timber, mineral extraction and exploitation of species. Candidates with a strong grasp of the content also explained specific impacts of climate change on tropical forests, such as changes in biodiversity, the spread of fungal diseases and pests, changes in species composition, and effects on photosynthesis. These were more effective than general references to global temperature rise, sea-level rise or flooding.

Higher-level responses made purposeful use of case study material, often including examples such as the Amazon Rainforest with reference to hunting and the illegal trade in exotic animals, pollution of the Amazon River from gold and silver mining, the construction of the Bakun Dam in Borneo, and the decline in forest cover threatening orangutans. These candidates typically achieved Level 3 for AO2 due to the accuracy, specificity and relevance of their examples.

Less successful responses tended to focus narrowly on deforestation without considering a wider range of human activities, and discussed climate change only in general terms. Some answers included material unrelated to the question, such as references to international agreements like the Paris Treaty or the Montreal Treaty. Many candidates also used examples that were not applicable to tropical rainforests, such as littering and tourism, or selected inappropriate case studies such as Californian wildfires or the Everglades in Florida. Conclusions often repeated previous points rather than drawing them together to make a clear judgement.

Most candidates described only one side of the argument, and conclusions were divided evenly between those who stated that human activities have a greater impact and those who argued that climate change has a greater impact. This limited responses to Level 2 for AO3. A minority of candidates provided balanced reasoning and clear evaluative judgements, allowing them to achieve Level 3 or Level 4 for AO3.

Question 6

For this question on legislation and protocols as methods of conserving biodiversity, candidates were required to demonstrate an understanding of the importance of biodiversity, describe unsustainable and sustainable harvesting, and outline relevant legislation and international protocols. Well-prepared candidates described in detail the importance of biodiversity, including ideas such as maintaining genetic variation, preventing extinction, sustaining food chains, and providing potential sources of medicines, food and raw materials. These candidates also showed strong knowledge of appropriate legislation and protocols, referring confidently to CITES, IWC, EUCFP, ITTO and IUCN, as well as other conservation approaches such as the EDGE awareness programme and the establishment of national parks. However, very few candidates described examples of sustainable and unsustainable harvesting, which limited access to the full range of marks available.

Higher-level responses made effective use of correct terminology and integrated a range of relevant case studies to illustrate different methods of conserving biodiversity. CITES was frequently referenced, often with examples involving species such as the Snow Panda in Japan and the White Rhino, and many also discussed the roles of the IWC and ITTO. These candidates evaluated the success of the legislation or protocols they had selected, demonstrating analytical understanding. Such responses typically achieved Level 3 for AO2.

Less successful responses made only vague references to habitat loss, deforestation and species extinction, and a significant proportion of candidates included large amounts of irrelevant material. Many discussed ozone depletion, the Montreal Protocol and restrictions on CFCs, or focused on climate change and the Paris Agreement, none of which were directly applicable to the question. Others concentrated on local legislation related to littering, beach cleans, plastic pollution, turtles, or the Burmese Python in the Everglades, which again lacked relevance to biodiversity legislation and protocols at the required scale.

Most candidates achieved Level 2 for AO2, and few moved beyond Level 2 for AO3 because their evaluations were predominantly one-sided, arguing either that the legislation and protocols were entirely successful or entirely unsuccessful. Very few candidates presented balanced evaluations and well-reasoned judgements for both sides of the argument, which are required to access Level 3 or Level 4 for AO3.

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Key messages

It is important that candidates read each question carefully. For example, in **Question 1(a)(ii)**, where the question required a description of *only one* category, many candidates described additional categories, which could not be credited. Candidates must also ensure they provide the correct units in calculation questions and follow instructions on rounding to the required number of significant figures.

Candidates would benefit from further practice in responding to questions about questionnaires, particularly in explaining their benefits and limitations. The benefits of recycling were generally well understood.

General comments

Overall, there were some very strong responses in both **Section A** and **Section B**.

In **Section A**, candidates would benefit from further practice in understanding the interactions within ecosystems, particularly the relationships between abiotic and biotic factors. Strengthening knowledge of CITES and improving the application of this understanding to unfamiliar contexts involving conservation of biodiversity would also be advantageous. In **Question 2**, responses indicated that managing air pollution and the chemical processes involved in its formation are areas that require development.

There were many excellent responses in constructing a linear graph, with a significant number of candidates achieving full credit. For a minority, additional practice in selecting an appropriate linear scale would support clearer and more accurate presentation.

In **Section B**, candidates generally organised and structured their responses securely. **Question 6** was slightly more popular than **Question 5**, and candidates achieved a slightly higher average mark on this question. Both questions elicited clear, succinct and commendable responses from many candidates.

Comments on specific questions

Section A

Question 1

- (a) (i) This question required candidates to define the term ecosystem. Most candidates were able to describe the idea of a community of living organisms. However, a significant number were unable to access further credit because they did not refer to the interaction of organisms with their environment or the interaction between abiotic and biotic components. These elements were essential for full credit.
- (ii) Very few candidates achieved full credit for naming and describing the two types of competition: inter-specific and intra-specific. Credit was awarded for correct descriptions of intra-specific competition such as competition within a species for light, water or other factors and for inter-specific competition between different species for resources such as nutrients or water. However, many responses lacked precision or only partially addressed the requirements.
- (b) (i) Candidates generally performed well on this question and were able to differentiate between abiotic and biotic components.

- (ii) This question was not answered particularly well. While candidates were often able to link photosynthesis to productivity, many showed limited applied understanding of how low light levels affect plant growth. Credit was awarded for responses describing reduced glucose production, lower rates of respiration and less energy released from respiration. References to reduced carbohydrate production were less frequently seen.
- (iii) Full credit was commonly awarded as many candidates successfully suggested ways forests could be managed to reduce light competition between trees. Responses frequently referred to thinning dead trees and sustainably harvesting mature trees. Credit was also given for suggestions such as planting trees at wider spacing to reduce shading.
- (c) Many candidates demonstrated limited knowledge of what fragmentation means in the context of forests. Stronger responses identified effects such as changes in biodiversity, increased soil erosion and the separation of populations of species.

Question 2

- (a) (i) Most candidates were able to make clear comparisons between the two pH values and the two plant species. Responses commonly noted that germination increased at higher pH values and that radish showed higher germination rates at both pH levels. Candidates also demonstrated strength in extracting data from the table and using it effectively to support their comparative statements.
- (ii) Correct responses referred to reduced yield, lower germination or defoliation. However, most candidates needed to develop their explanations further, and very few fully applied the knowledge gained from **Question 2(a)** to access the highest level of credit.
- (b) Knowledge of wet acid deposition from nitrogen was limited. Many candidates described it incorrectly as a reaction between nitrogen, oxygen and water, without recognising that nitrogen oxides are formed at high temperatures in vehicle engines. Some candidates also confused wet acid deposition with the formation of smog. Credit was most commonly awarded for reference to the formation of nitric acid.
- (c) (i) Many candidates achieved full credit for suggesting both benefits and limitations of the polluter pays principle. Strong responses included the idea that it serves as a disincentive to polluters, while also noting challenges such as the difficulty of enforcing the legislation. Overall, however, candidates' understanding of managing air pollution would benefit from further development.
- (ii) This question was answered very well. Common correct responses included the use of catalytic converters, reduced use of fossil fuels, and the use of scrubbers, all of which were credited.

Question 3

- (a) (i) Candidates demonstrated a very good ability to use data and construct a line graph. Axes were generally labelled correctly, and most candidates plotted points accurately and used a ruler to produce straight, well-presented lines. The main area for development for a minority of candidates is selecting a sensible linear scale so that the data occupy more than half of the graph paper, ensuring clearer presentation.
- (ii) Many candidates correctly calculated the mean annual change in global production of biodegradable plastics. Those who did not reach the correct answer were often still awarded credit for showing appropriate working.
- (b) (i) This question was answered very well. Common responses included air, water and noise pollution, disruption to animal migration and loss of habitat. Many candidates linked the impacts together, demonstrating a strong understanding of the wider environmental effects of industrialisation.
- (ii) Candidates showed good knowledge of composting as a sustainable method of waste disposal. Responses frequently referred to reductions in landfill use and the value of compost as a fertiliser. The idea of composting producing biogas as an energy source was rarely mentioned.
- (iii) Candidates were required to suggest two limitations of using waste food as animal feed, and many demonstrated strong application of knowledge. Common correct responses included imbalanced nutrient content and the potential for transmitting infections to animals.

Question 4

- (a) (i) This question was answered well, with most candidates able to recognise the leg rings on the kagu in the image. Responses typically demonstrated secure observational skills.
- (ii) Candidates showed a good understanding of the threats faced by the kagu population, and many responses achieved full credit. Climate change was frequently cited, alongside loss of habitat, predation and the introduction of invasive species. These points were generally explained with clarity.
- (b) Candidates were required to explain how nature reserves could help conserve the kagu. A significant number were able to do so successfully, demonstrating sound understanding of conservation strategies. However, many responses did not fully apply knowledge to this specific context. Suggestions involving legislation to control hunting, poaching or human activity were common. The idea of providing food for kagu appeared frequently but did not gain credit, as it is not an appropriate method of conservation in this context.
- (c) (i) There was a significant lack of understanding of the role of CITES. Credit was occasionally awarded for recognising that CITES controls trade in endangered species or for mentioning its lists of protected species. Overall, candidates would benefit from developing stronger knowledge and understanding of the purpose and functioning of CITES.
- (ii) Most candidates acknowledged that a lack of enforcement often contributes to the ineffectiveness of CITES in preventing illegal trade. Many also recognised the influence of high profits in the black market for endangered species. Understanding in this part was generally stronger than in 4(c)(i).
- (d) Responses demonstrated a generally good understanding of the benefits and limitations of captive breeding programmes. Most candidates were able to access credit, and knowledge of limitations tended to be stronger than knowledge of benefits. Common benefits included reducing the risk of extinction and enabling research opportunities. Common limitations cited were limited genetic diversity or gene pool, and low survival rates when individuals are released back into the wild.

Section B

Question 5

This question was chosen slightly less often than **Question 6**. However, there were some very strong responses in which candidates applied their knowledge effectively and provided highly relevant examples. Stronger candidates referred to the use of geospatial satellites to collect and record data, as well as tracker devices used to monitor different types of organisms. Credit was also awarded for references to using mobile phones to collect questionnaire data or the use of AI in data handling.

Some candidates discussed appropriate examples of technology but also included non-technological data-collection methods, such as capture–mark–recapture. While this did not fully meet the requirements of the question, it did allow for discussion of limitations such as time constraints. A small number of stronger responses recognised the non-invasive nature of technological data-collection methods for monitoring animal populations. Many candidates also discussed the power of computers in analysing large datasets compared with the limitations of human processing, which was a key aspect of the question.

The use of drones was frequently highlighted, particularly for monitoring herd numbers, and candidates also referred to the use of sensors in rivers to measure variables such as turbidity or pH over time. The development of new technology was commonly included, with candidates explaining how improvements have increased accuracy in data collection. Satellite imagery was also mentioned as a means of monitoring changes in land mass over time. A small number of responses drew attention to the ability of technology to collect data in remote or inhospitable locations that would be inaccessible to humans. Stronger conclusions provided a clear and balanced summary and addressed the “to what extent” aspect of the question, demonstrating evaluative judgement.

Question 6

Overall, candidates demonstrated a reasonably good knowledge of hydroelectric dams as a renewable energy source. Stronger responses often began by defining energy security before going on to describe what

hydroelectric energy is, establishing a clear foundation for their argument. Many candidates showed strength in applying relevant examples, referring to countries with significant hydroelectric power production and linking this to issues such as increased incidences of drought affecting generation capacity. A small number of candidates confused tidal energy with hydroelectric energy, while others incorrectly suggested that hydroelectric power involves combustion or that steam is required to turn the turbines.

Candidates generally accessed a reasonable level of credit for evaluating the strengths and weaknesses of hydroelectric power. The strongest responses went further and assessed the effectiveness of alternative energy sources from a holistic, global perspective. Some candidates also discussed the role of international agreements in maintaining global energy security and highlighted the potential for conflict over energy resources. These points were creditworthy and demonstrated strong awareness of global context.

The structure and organisation of points were very good in many responses. Strong conclusions summarised ideas constructively and provided a clear and succinct perspective on whether hydroelectric energy can contribute effectively to achieving global energy security.

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Paper 8291/13
Principles of Environmental
Management

There were too few candidates for a meaningful report to be produced.

ENVIRONMENTAL MANAGEMENT

Paper 8291/21 Management in Context
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Key messages

Care should always be taken to read each question carefully and note the number of marks available for each part before responding, as this indicates the amount of content and detail expected. Under time constraints, bulleted answers for structured questions can often be the clearest and most efficient way to demonstrate knowledge.

It is important that instructions are followed precisely and that candidates fully understand the meanings of command words.

Repeating the question within an answer wastes valuable examination time, as the context of a clear response will be understood without doing so. If an answer needs to be rewritten, crossing out the incorrect passage with a single line is sufficient.

Where only one mark is available, only the first response is assessed under the list rule. Additional correct answers written after an incorrect answer will not be credited.

Candidates should avoid vague terms such as “resources”, “pollution”, “environmentally-friendly”, “harms”, “affects” or “impacts” unless they are clearly qualified. For example, “resources” could be specified as food, water or energy, and “pollution” could be identified as atmospheric or water pollution.

Candidates must also avoid using alternative or non-geographical words to describe compass directions on a map. For example, in **Question 2(b)**, answers that attempted to describe areas south of the Equator using terms such as “below”, “under” or “in” the Equator were not awarded credit.

General comments

A number of syllabus topics would benefit from further consolidation. In particular, some candidates found the Lincoln Index in **Question 2(a)(ii)**, the movement of energy through a food chain in **Question 3(a)(iii)**, and the workings of a gravity-fed scheme for supplying safe drinking water in **Question 5(f)** more challenging. Concepts such as *crowd sourcing* in **Question 3(c)(iii)**, the method of kick sampling in **Question 4(a)(ii)**, and the formation of acid deposition in **Question 4(c)(i)** were also less familiar to many. In addition, a number of candidates would benefit from further practice in constructing line graphs, as seen in **Question 5(c)(i)**.

There were, however, many strong responses across the paper. The most successful answers showed a confident understanding of key syllabus terms and themes. Where appropriate, candidates made effective use of information provided in photographs, tables, charts and figures, and many strong responses included well-chosen examples to support and illustrate key points.

Comments on specific questions

Question 1

This question examined candidates’ understanding of sources of atmospheric methane as a greenhouse gas. Candidates were provided with graphical information showing the atmospheric methane budget from a computer model and were asked to complete a bar chart and suggest reasons why different models may produce different results.

- (a) (i) Most candidates recognised that a greenhouse gas is connected to heat retention in the atmosphere, though fewer were familiar with the precise idea that a greenhouse gas absorbs infrared radiation. Strengthening accuracy in definitions would support candidates in achieving full credit.
- (ii) Candidates engaged well with the question, though many held misconceptions, often linking methane to effects such as ozone destruction or cancer. Only a small number referred to the property that methane can be flammable or explosive. Continued practice in distinguishing between the characteristics and impacts of different atmospheric gases would be beneficial.
- (b) (i) Some candidates produced well-drawn bars and were able to access full credit through accurate plotting and consistent bar width and spacing. Where lines were less steady or widths unclear, this sometimes made the graphical communication less precise. Using a sharp pencil and a ruler continues to be good practice in ensuring clear and unambiguous presentation. A noticeable proportion of candidates did not attempt this part.
- (ii) Many candidates were successful in manipulating the data from **Fig. 1.1** and correctly calculated the difference between total methane emissions and total methane removal. This demonstrated strong numerical handling of environmental data.
- (iii) Candidates approached this part with enthusiasm, although many drew directly from the information in **Fig. 1.1** or selected examples that could not be credited. The most frequent creditworthy suggestion was animal waste, and some candidates gave this accurately.
- (iv) Responses varied. Several candidates provided thoughtful comments about differences in computer software or improvements in modelling techniques over time. Many answers touched on similar ideas in different ways. Concepts such as uncertainties in data, feedback mechanisms or differences in methane sources and sinks were mentioned less often but, when included, were credited positively.

Question 2

This question focused on rhinoceros distribution and conservation. Candidates worked with data from a graph showing rhinoceros numbers in a national park in Nepal, climate data from the same area, a world map of Black Rhinoceros distribution, and terms used in the Lincoln Index for estimating population size.

- (a) (i) Many responses showed awareness of possible impacts of marking an animal, though some answers were too general to gain full credit. The strongest answers clearly indicated how the rhinoceros might be affected, such as becoming stressed or frightened, or that a marked individual could become more visible to predators or experience reduced breeding success.
- (ii) Understanding of the Lincoln Index varied. Only a minority of candidates demonstrated confident knowledge of the formula terms, while others applied ideas more closely related to the Simpson's Index of Diversity or offered abiotic factors, which were not applicable here. Further familiarity with population-estimation methods would help candidates access more credit in future questions of this type.
- (b) Descriptions of the global distribution of Black Rhinoceros from the world map were generally clear. The strongest responses correctly identified South Africa or southern Africa as areas with the highest populations. Fewer candidates consistently used compass directions, and continued practice in describing locations using north, south, east and west would be beneficial. For example, identifying rhinoceros populations as being "south of the Equator" was credited, whereas terms like "below the Equator" were not. Candidates may also describe patterns as occurring "on" or "along" the Equator or the Tropic of Capricorn where appropriate.
- (c) (i) Candidates engaged well with the graph, although many selected the steepest slope visually rather than performing the required calculation. Understanding that percentage change can represent both increases and decreases, and reading the request for a calculation carefully, are helpful strategies for questions that combine graphical and numerical skills.
- (ii) There were some strong answers identifying reasons for increases in rhinoceros populations, such as bans on hunting. A number of responses, however, were general in nature. Suggestions such as "more breeding" required greater specificity—such as captive breeding—to be credited.

Similarly, broad references to “conservation efforts” were insufficient, whereas specific examples such as the creation of national parks or the role of the IUCN Red List gained credit.

- (d)(i) Most candidates correctly identified March as the month with the greatest temperature range.
- (ii) Approximately half of the responses identified the correct temperature range for September. Others referred to rainfall data instead. Carefully checking keys and axes when graphs present mixed data will support accuracy.
- (iii) Many candidates gained partial credit for explaining that high rainfall could lead to flooding. A small number also suggested that high temperatures may lead to baked soil, reducing water absorption. Full credit required reference to both the rainfall and temperature data.
- (iv) Some candidates correctly identified that the mounds provided higher ground for rhinoceros during flooding. A frequent alternative suggestion was that the mounds absorb water, which was not creditworthy.
- (v) A number of responses gained partial credit for recognising that predation could reduce the success of rhinoceros relocation as a conservation strategy. Other responses were less specific and therefore did not meet the requirements for credit.

Question 3

This question focused on the Arctic walrus, including energy flow in a food chain, the impact of melting sea ice on walrus behaviour, and the use of crowd sourcing to determine walrus populations from satellite imagery.

- (a) (i) Most candidates correctly identified phytoplankton as the producers in the food chain, showing good understanding of trophic levels.
- (ii) The majority also recognised the Arctic walrus as the secondary consumer, demonstrating secure application of food-chain terminology.
- (iii) This part proved more challenging. Many candidates attempted to describe what happens to energy in a food chain, but responses were often general or lacked specificity. A common misconception was that “10% of energy is lost” rather than recognising that approximately 10% is passed on at each trophic level. Stronger responses identified at least one way in which energy is reduced between trophic levels, such as through excretion, respiration or incomplete digestion.
- (b) (i) Most candidates correctly suggested that the sea ice had melted. Answers referring to climate change without explaining its effect on sea ice did not meet the requirements of the question, as the link needed to be explicit.
- (ii) Many candidates gained some credit by suggesting that walruses could become exhausted or use up energy reserves when forced to come ashore due to melting sea ice. These responses showed good application of ecological knowledge.
- (c) (i) There were some strong responses to this question. Candidates frequently identified the involvement of non-experts in crowd-sourced data or suggested that satellite imagery can be expensive to obtain. Other responses tended to be too general to gain credit; for example, stating that “mistakes are made” required clarification, such as miscounting walruses due to movement or individuals being hidden from view.
- (ii) This question was answered well by many candidates, with the most frequent correct suggestion being that using satellites is less time-consuming than carrying out fieldwork. Some responses discussed accuracy or ease of use but needed more specific explanation to access credit.
- (iii) Crowd sourcing as a method of data collection was less familiar to many candidates. Further familiarity with how large groups of volunteers can support ecological research, particularly through image classification, would help strengthen responses in similar questions.

Question 4

This question assessed candidates' understanding of the method of kick sampling in a river, using mayfly nymphs as an example, alongside fieldwork safety, interpretation of data on mayfly nymph populations and water pH, and knowledge of the formation and impacts of acid deposition.

- (a) (i) There were many thoughtful responses, with candidates showing awareness of key safety considerations when carrying out fieldwork in a river. Common correct suggestions included wearing appropriate safety clothing and being mindful of river depth, both of which demonstrated sound understanding of safe practice.
- (ii) Knowledge of the kick-sampling method was varied. While some candidates recognised that the method involves disturbing the riverbed to dislodge organisms into a net, many responses offered explanations that were too general or focused on why kick sampling is used rather than how it is carried out. Further familiarity with the steps of this sampling technique would help strengthen responses.
- (b) This question was generally answered well. Many candidates were able to make a reasoned judgement about the conclusion, using appropriate evidence from **Fig. 4.3** and **Fig. 4.4**. Most were able to access some credit, and responses were often well structured. Continued care in selecting precise values from graphs will support even stronger evidence-based explanations.
- (c)(i) A number of candidates did not attempt this question, and many who did would benefit from further consolidation of how acid deposition forms from the combustion of fossil fuels. Some responses focused on carbon dioxide or on unrelated atmospheric processes. The strongest answers explained that burning fossil fuels releases sulfur dioxide and nitrogen oxides, which react with water and oxygen in the atmosphere to form acids.
- (ii) Candidates showed a range of understanding in describing impacts of acid deposition beyond aquatic environments. Some correctly identified effects such as reduced crop yield. Answers referring to "damage to buildings" required further specificity, as credit is given when the building material, such as limestone, is named. A number of candidates gained partial credit by identifying at least one appropriate impact.

Question 5

This question examined candidates' ability to construct a line graph from raw data on annual industrial water use in the USA from 1990 to 2010. Candidates were also assessed on wider aspects of water management, including methods for reducing agricultural water use and the workings of gravity-fed water schemes.

- (a) (i) Responses showed a range of understanding. The most common suggestion was that treated toilet waste is reused or recycled, which gained partial credit. Fewer candidates mentioned that treated waste improves sanitation and reduces disease risk, or that it prevents contaminated water from entering water bodies, points that would have strengthened answers. A clear understanding of water security would have supported deeper responses here.
- (ii) Those who gained credit typically identified that the Firelight Toilet system can provide a source of electricity. A few mentioned the use of ash as a fertiliser, which was credited when clearly qualified. References to water security were not relevant to the question. To access full credit, candidates needed clearer application of their understanding to the specific features of the system.
- (b) This question was generally answered well. Most candidates correctly described the contrasting trends.
- (c)(i) Line-graph construction varied considerably. Many candidates would benefit from further practice in choosing a suitable linear scale so that data points occupy at least half of the grid. Starting the y-axis at zero often led to data clustering near the axis, making accurate plotting more difficult. The strongest line graphs used a scale beginning at around 240 and increasing by 10 per five small squares, producing clear, well-spaced plots. Fully labelled axes and the use of a sharp pencil for plotting and joining points further improved clarity.
- (ii) Responses were mixed. Some candidates gained credit by noting limitations such as the data representing only one country or that patterns in other countries, particularly non-HICs, may differ.

A few recognised that external events can be unpredictable. More general statements required further development to access credit.

- (d) Although there were some broader responses, many candidates were able to suggest effective strategies such as recycling water, rainwater harvesting, or improvements in irrigation systems such as trickle or drip irrigation. Only a small number achieved full credit by combining accurate examples with clear explanation.
- (e) Sources of sub-surface freshwater were less familiar to many candidates. A number of responses referred to unrelated ideas such as seawater sources. Reviewing freshwater sources, including groundwater and permafrost (which can be both surface and sub-surface), would support stronger answers in future.
- (f) Understanding of gravity-fed water schemes was limited, with many answers lacking sufficient detail for credit. Candidates would benefit from reviewing case studies such as community water systems in Ethiopia or Malawi, which provide accessible and clear examples of how water can travel from higher to lower ground without the need for pumping.

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Key messages

Care should always be taken to read each question carefully and note the number of marks available before responding, as this gives a clear indication of the level of detail expected. Under timed conditions, bulleted answers for structured questions can often help candidates present their knowledge clearly and efficiently.

It is important that candidates follow instructions closely and understand the meanings of command words.

Repeating the question in an answer uses valuable examination time unnecessarily; the context of a well-written answer will always be understood. If candidates need to rewrite part of an answer, drawing a single line through the incorrect section is sufficient.

Candidates should show all working in calculation questions, as credit may be awarded for a correct method even if the final answer contains an error that has been carried forward.

Unqualified terms such as *resources*, *pollution*, *environmentally-friendly*, *harms*, *affects* or *impacts* generally do not gain credit unless they are made specific. For instance, “resources” could be stated as *food*, *water* or *energy*, and “pollution” could be identified as *atmospheric pollution* or *water pollution*.

Candidates should avoid using alternatives to compass directions when describing locations on a map. For example, in **Question 4(a)**, descriptions of areas “above” or “over” the Tropic of Cancer could not be credited. Compass directions should always be given using geographical terms such as *north*, *south*, *east*, *west*, or descriptive forms like *western* or *north-eastern*. When appropriate, it is acceptable to refer to features being *on* or *along* latitude lines such as the Equator or the Tropic of Cancer or Capricorn.

General comments

Candidates demonstrated many strengths across the paper, particularly where they engaged confidently with familiar syllabus content and made thoughtful use of key terms and examples. Many responses showed clear understanding of core ideas, and a number of candidates made effective use of the information provided in tables, charts and figures to support their reasoning. It was also encouraging to see that extended answers were presented neatly and correctly in additional answer booklets, and this good practice should continue.

There are still opportunities for candidates to enhance their performance further. Many would benefit from making more active and purposeful use of the resources provided in the examination. For example, **Question 5(e)**, which introduced the J-OP sewage waste treatment system, required candidates to apply familiar concepts in a new context, and those who used the given material effectively were able to construct strong and well-supported answers.

A small number of syllabus areas continue to present challenges, such as the concepts of bioaccumulation and biomagnification, the idea of crowd-sourcing, the calculation of percentage change, the sources of surface freshwater, and the way an artesian well functions. Simpson’s Index of Diversity was also an area where many candidates would benefit from further consolidation. Strengthening understanding in these topics will help candidates respond with greater confidence when these ideas appear in future assessments. Overall, there were many positive performances across the paper. With continued attention to precise use of terminology, thoughtful application of examples and more consistent use of the resources provided, candidates will be well placed to build on the good work already evident in many scripts.

Comments on specific questions

Question 1

This question assessed candidates' understanding of population density and population trends, using Bangladesh as an applied example. Candidates were required to complete a bar chart and construct a line graph showing Bangladesh's readiness to adapt to climate change over a 20-year period, based on a series of given scores.

- (a) (i) Most candidates calculated the population density correctly, demonstrating secure understanding of the required method.
- (ii) Many candidates produced thoughtful explanations of environmental factors that influence population density. A large proportion gained partial or full credit, and the strongest responses clearly linked each factor to either an increase or a decrease in population density, showing well-developed reasoning and accurate terminology.
- (b) Performance was generally strong. Most candidates completed the bar chart accurately, plotting values for both males and females correctly and using an appropriate bar width. Many presented neat work using a ruler and a sharp pencil, and this good practice should continue.
- (c) Responses were mixed. Many candidates offered sensible explanations for population growth up to 2060 and the projected decrease afterwards. Others gained limited credit because they focused on only one part of the trend. Careful reading of the question remains essential for addressing all required elements.
- (d) (i) This question was challenging for most candidates. Some gained credit by suggesting relevant climate-change impacts for Bangladesh, such as sea-level rise. Very few, however, recognised that Bangladesh's low ranking means that significant improvement in its readiness score will take many years, which is concerning given that climate-change impacts are already ongoing.
- (ii) Some candidates produced clear and well-constructed bar charts with accurate plotting and neat presentation. The strongest responses selected a scale beginning at 34 on the y-axis and increasing by one unit every five small squares, allowing the data to be displayed clearly. Many other candidates chose less suitable scales, particularly those starting at zero, which compressed the data and made accurate plotting difficult. Candidates are reminded to fully label both axes and choose scales that allow data to be presented effectively.

Question 2

Skills were assessed in interpreting a food web involving albatrosses, understanding how the IUCN Red List helps protect these birds, explaining why their nests may be at risk from climate change and evaluating the benefits and limitations of satellite monitoring. Candidates were also required to record a tally from an image and apply knowledge of bioaccumulation and Simpson's Index of Diversity.

- (a) Some candidates demonstrated a clear understanding of the role of the IUCN and its Red List. Responses overall were varied, and some lacked the precision needed for credit. A common misconception was that the IUCN creates laws or passes legislation. Candidates should recognise that only governments can enact laws, while organisations such as the IUCN provide advice and guidance to policymakers.
- (b) There were many strong answers linking climate-related events to risks to albatross nests. Candidates who related increased flooding or stronger winds to nests being washed or blown away performed well. Others correctly identified that drought could result in insufficient mud for building nests or cause existing nests to crack.
- (c) Interpretation of **Fig. 2.2** showed that the food web contained a single food chain with four trophic levels, beginning with the producer and ending with the albatross. The majority of candidates answered correctly. Marks were often lost where candidates included more than four levels, omitted arrows between trophic levels, or drew arrows in the wrong direction.
- (d) (i) This question was challenging for many candidates. Some incorrectly suggested that mercury is stored only in feathers, while others gave vague answers such as "it is easy" or "it is quick".

Candidates should understand that toxins move through food chains by bioaccumulation and may be present throughout an animal's body. The presence of mercury in feathers allows sampling without the need to harm the bird.

- (d)(ii) Responses were mixed. Some candidates correctly recognised that biomagnification results in increasing toxin concentrations up a food chain, leading to a predicted mercury level in albatrosses higher than that of their prey (3.88 μg per g). Others confused biomagnification with the transfer of energy and chose lower values, assuming mercury would decrease as energy does.
- (e) Most candidates recognised that a tag or tracker should be attached to the bird, but only a few noted the essential requirement for a GPS or satellite-based system. Several confused satellite tracking with radio tracking, which uses ground-based receivers and would be unsuitable for albatrosses that travel over 1500 km per day over the ocean.
- (f) (i) Many candidates correctly recorded the tally. Miscounts were also common, highlighting the importance of checking work carefully. Some candidates wrote the digits "34" rather than a tally, which did not meet the requirements of the question.
 - (ii) Crowd sourcing was not well understood. A frequent error was describing the counting of crowds of albatrosses. Candidates should know that crowd sourcing involves gathering data from large numbers of people or members of the public.
 - (iii) There were some well-developed answers that provided at least one clear benefit or limitation of satellite monitoring. Common benefits included the speed of data collection and the reduced disturbance to birds. Many candidates also correctly identified high cost as a limitation. Few responses gained full credit, indicating that candidates would benefit from a deeper understanding of how satellites are used to monitor environmental data.
- (g) Some candidates showed good understanding of Simpson's Index of Diversity and gained full credit. Others confused this index with the Lincoln Index, which estimates population size rather than diversity. Candidates should be confident in distinguishing the two and in interpreting what each component of the index represents. Worked examples can support consolidation of these ideas.

Question 3

Candidates were asked to describe how a pitfall trap could be built and used to investigate insects on a sand dune. They were then assessed on sampling methods using the trap, followed by interpretation of a line graph showing mean insect numbers in relation to distance from the sea.

- (a) Many candidates gave clear and accurate descriptions of how to build and use a pitfall trap on a sand dune. Stronger answers described the essential steps, such as digging a hole and placing a container inside so that its rim was level with the ground surface. Responses lacking the initial step of digging the hole could not access full credit. Candidates should also be aware that fieldwork methods must avoid harming wildlife. A number of responses described adding antifreeze or water to kill the insects, which is inappropriate. A well-constructed pitfall trap safely contains the insects without causing harm, and they should always be released alive after observation.
- (b) Most candidates performed well when identifying where each community was located along the transect shown in **Fig. 3.2**. Many demonstrated good understanding of zonation on a sand dune. However, some candidates did not draw label lines, as the question required, and therefore did not gain full credit despite placing the labels correctly.
- (c) This question required candidates to explain why it is good practice to take more than one sample at each sampling location. Instead, a number of responses focused on why there were six pitfall traps along the transect or misinterpreted **Fig. 3.3**. Candidates should understand that multiple samples at a single location increase reliability and reduce the impact of anomalies.
- (d)(i) The majority of candidates correctly identified species D as having the largest mean number of insects.
 - (ii) Many candidates did not recognise that sampling point P6 was the closest to the sea, as shown in **3(b)**. As a result, they misinterpreted **Fig. 3.4** and concluded that insect numbers increased further

from the sea, when the opposite was true. Some responses referred only to changes from P1 to P6, which was not what the question asked, and therefore did not gain credit. Careful reading of the question is essential.

- (iii) Around half of all candidates successfully calculated the range for the mean values at sampling point P5 as 25. Others made errors from misreading the data in **Fig. 3.4**.
- (iv) Percentage change was not well understood by many candidates, some who understood the calculation method made errors by misreading the graph values. Accurate reading of data is essential when performing calculations.

Question 4

Skills were assessed in describing the global distribution of countries with high drought risk from a world map, understanding primary productivity, and explaining the impacts of drought and soil type in a grassland biome. Candidates also interpreted rainfall and temperature data from an Australian weather station.

- (a)(i) Some candidates gave clear and specific descriptions of regions within Europe or Asia, such as Eastern Europe or Southeast Asia, and several correctly named relevant countries. Many responses, however, lacked geographical precision and did not use compass directions as required. Descriptions such as “above the Tropic of Cancer” or “in the Equator” did not gain credit. Answers referring to areas north of the Tropic of Cancer or countries bordering or lying along the Equator would have been appropriate.
- (ii) Many candidates showed sound understanding of the impacts of drought. Common correct responses included water insecurity and reduced crop yields. Some candidates also recognised that reduced river flow during droughts can decrease hydroelectric power generation. These answers demonstrated good appreciation of how drought affects both ecosystems and human activity.
- (b)(i) Most candidates correctly identified 32°C as the highest mean temperature. A small number misread the data by using the wrong y-axis or confusing temperature data with rainfall data. When graphs present multiple datasets, it is good practice to recheck values to ensure accuracy.
- (ii) Nearly all candidates correctly identified the months with the highest mean rainfall.
- (iii) Responses were mixed. Many candidates recognised the months with the lowest rainfall, gaining credit. Fewer were able to extend their answer to explain why this would reduce primary productivity. Candidates would benefit from revisiting the requirements for photosynthesis, and particularly the role of water as a limiting factor, which drives primary production.
- (c) Many candidates provided accurate descriptions of soil characteristics in grassland biomes. The most frequent correct answers highlighted soil fertility and moisture content. These responses demonstrated an understanding of key abiotic features of grassland ecosystems.
- (d) This question was generally well answered. Many candidates clearly explained how invasive species reduce biodiversity, often noting that native species may be outcompeted for resources or displaced, leading to food chain disruption. Most candidates correctly concluded that biodiversity is lowered as a result.

Question 5

Candidates were assessed on their knowledge of freshwater and water security, alongside skills in interpreting graphical and diagrammatic information. A line graph showing freshwater use by Germany over a 25-year period tested understanding of the limitations of data. Candidates were also examined on freshwater sources, artesian wells and strategies for managing water security. In addition, they interpreted a diagram of the J-OP sewage waste system and answered questions based on its features.

- (a) Many candidates found it difficult to explain the limitations of using the dataset to predict the annual global volume of freshwater extraction for 2030. The question was frequently misread, and responses that focused only on Germany did not gain credit. Credit was awarded to those who recognised that predictions for global freshwater use cannot be made reliably from data representing a single country or a high-income country alone.

- (b) Knowledge of surface freshwater sources was weak. Very few candidates were able to name a correct source, and many responses lacked precision. Candidates would benefit from revising key examples of surface freshwater sources. It should be noted that permafrost is a source of both surface and subsurface freshwater.
- (c) Artesian wells were not well understood. Most candidates either gave vague descriptions or referred to open wells accessed by a bucket, which did not meet the requirements of the question. Another common misconception was that natural filtration through rock layers makes groundwater safe to drink; groundwater must always be treated before consumption. Artesian wells have distinctive geological features: water within a confined aquifer, held within a permeable rock layer between impermeable layers, rises naturally to the surface under pressure once tapped. Reviewing well-known examples such as the Great Artesian Basin in Australia, Artois in France and regions in Florida and Georgia (USA) would help develop understanding.
- (d) Managing water security was generally well answered. Many candidates correctly identified strategies such as rationing and improved irrigation, and several gained full credit by including others such as reducing water pollution or repairing leaks.
- (e)(i) Responses were mixed. Many candidates gained some credit by noting that the steam can create safe drinking water or generate electricity. Others found interpreting **Fig. 5.2** challenging. Candidates should be reminded that familiar scientific ideas can be applied effectively even in unfamiliar contexts.
- (ii) Most candidates performed well, recognising that sewage must be heated to very high temperatures to kill bacteria that could otherwise spread disease.
- (iii) Answers varied, with around half of all candidates correctly performing the calculation. Others found the information challenging to interpret, and a significant number gave no response.

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There were too few candidates for a meaningful report to be produced.