HL Paper 3

Discuss how crop plants obtain the phosphorus that they need to grow and whether the supply of phosphorus to crops is sustainable.

Markscheme

Natural cycle

a. plants absorb phosphorus from the soil by the roots

b. soil phosphorus comes from weathered «phosphate» rocks

c. «soil/organic» phosphorus «also» comes from humus/plant/animal residues/guano/microorganisms

d. phosphorus is a limiting «macronutrient» factor in plant growth
OR
phosphorus is necessary for vital functions/ATP/DNA
OR
deficiency of phosphorus «in soil» limits plant growth/production

Sustainability

e. «natural» phosphorus cycle is slow/not sustainable with increased crop production

f. phosphorus is replenished «in the soil» by use of mineral/organic fertilizers

g. phosphorus/phosphate is «mainly» mined from «phosphate» rocks

h. rocks are becoming used up/inaccessible so non-sustainable/non-renewable
OR
the use of fertilizers is non-sustainable «with increased crop production»

i. increased demand for food/meat/dairy/grain increases demand for fertilizers

j. runoff/erosion/leaching of fertilizers decreases potential supply for crops/OWTTE

Examiners report

[N/A]

Discuss international measures that would promote the conservation of fish stocks.

Markscheme

large areas of ocean under no government control therefore need for international agreement/legislation;

fish stocks are a renewable resource if managed properly/should not be overexploited;

total allowable catches/quotas to limit maximum catch;

regulation of mesh sizes/selective fishing gear/limit size of fish caught/ban drift nets;

limit fishing effort by reducing the number of fishing days at sea of fishing vessels;

fix the number and type of fishing vessels authorized to fish;

cooperation may be difficult as most laws made at national level;

closed areas/total ban on fishing in threatened areas;

closed seasons banning fishing during breeding season;

use of fish farms;

Examiners report

Many candidates made a list of measures rather than their "discussion". Answers tended to score well compared to other options, although in the future no mark shall be given if a full discussion is not given.

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a.i. Define fundamental niche. [1]

a.ii. Outline a reason for organisms seldom occupying their entire fundamental niche. [1]

b. Describe the relationship between *Zooxanthellae* and reef-building coral species. [2]

Markscheme

a.i. the potential/full range of conditions under which an organism can live

a.ii. competition for resources/named resource

OR

competitive exclusion «limits the niche»

b. a. «endo»symbiotic/mutualistic relationship

b. zooxanthellae/photosynthetic algae/dinoflagellates live in coral tissues

c. coral provides protection for algae/dinoflagellates

d. algae/dinoflagellates provide minerals/products of photosynthesis/oxygen/sugars to coral

[Max 2 Marks]

Examiners report

a.i. [N/A]
a.ii. [N/A]
b. [N/A]

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b. Define indicator species. [1]

c. Indicator species may be affected by biomagnification. Discuss biomagnification using a **named** example of a pollutant. [3]

e. Determine whether islands are open or closed ecosystems. [1]

Markscheme

b. organism that is present/absent when specific environmental conditions exist

OR

organism used to assess a specific environmental condition

c. a. example eg: DDT / mercury / cadmium

b. substance accumulates in «fat» tissue/not excreted «when consumed»

c. contaminated organisms consumed «in large quantities» by higher level consumers

d. pollutant becomes more concentrated at each higher trophic level / through the food chain

e. some pollutants are more likely to be biomagnified «accumulate in fat tissue»
OR
some organisms are more likely to be affected by biomagnification than others
OR
biomagnification not the same at each trophic level

*Only **[2]** if verified example not given*.

e. closed because islands do not exchange matter/nutrients with surroundings

OR

open because islands do exchange matter/nutrients with surroundings

Examiners report

b. [N/A]
c. [N/A]
e. [N/A]

Evaluate the methods used to estimate populations of marine organisms.

Markscheme

Sampling does not count every organism so may not be a true estimate

Highly mobile marine animals unevenly distributed so difficult to estimate population size

Transects/quadrats used to estimate populations of stationary organisms

Useful on rocky shores/beaches/intertidal zones/reef

Estimation of mobile larval stages of stationary organisms/coral more difficult

Capture-mark-release-recapture useful for mobile animals in restricted environments (V*ice versa*)

Example of organism can estimate by this technique

Drawback of technique

Echolocation/sonar used to estimate the population size of fish that form shoals

Echolocation cannot distinguish between species (*Accept other valid limitation*)

The age structure of «commercially» caught fish can be used to estimate population size

Restricted-age fish «as bycatch» dumped before landing so biased estimates

OR

Depends on accuracy/honesty of those catching fish

Examiners report

This seemed to be the lowest scoring of the longer response questions at the end of each option. Candidates found this question very difficult, not knowing how to approach it. They did not seem to have the content knowledge required nor did they know how to 'evaluate' the methods used to estimate population size. Many did nothing more than describe a few steps in the capture-mark-release-recapture technique. Others mentioned the general difficulty of collecting data of populations in the ocean. Some mentioned echolocation/sonar with some evaluation as well as the use of the age structure of fished populations, but very few were able to achieve all 6 marks.

Forest fires are very common in the Amazon forest. A study was performed to see the relationship between forest fragmentation, fire and management

a. Describe **one** method that could have been used to estimate the population size of a given tree in a forest after fire damage had occurred. [3]

b. Outline how the edge effect can affect diversity in forests. [3]

c. The number of plants in two fields of approximately the same size was counted. [2]

Type of plant	Field 1	Field 2
Daisy (*Bellis perennis*)	307	18
Dandelion (*Taraxacum officinale*)	332	48
Buttercup (*Ranunculus repens*)	361	934
Total	1000	1000

Compare and contrast the richness and the evenness of the two fields.

Markscheme

a. ***ALTERNATIVE 1***

a. transect through a given area

b. trees counted on transect

c. calculation of total population considering area

ALTERNATIVE 2

d. random sampling using quadrats

e. trees counted in quadrat

f. population calculated using area

ALTERNATIVE 3

g. GPS/Google Earth used to map individuals of a tree species

h. data base of data obtained

i. population density calculated using area

b. a. edge effect are the changes in community structures that occur at the boundary of two habitats

b. areas with small habitat fragments exhibit especially pronounced edge effects

c. edge species will always have a habitat
OR
edge biodiversity increases

d. if patches of forest are too small the non-edge species cannot find a habitat

e. «then» overall non-edge biodiversity is lower

c. a. same richness as they have the same number of species/total of individuals

b. field 1 has more evenness as more even distribution of numbers among the species

Accept correct use 2 of Simpson diversity index.

Examiners report

a. [N/A]
b. [N/A]
c. [N/A]

Discuss the causes and consequences of eutrophication.

Markscheme

causes:

a. excess nutrients/nitrates/phosphates in an aquatic system

b. natural runoff from soil/erosion/weathering of rocks

c. runoff of fertilizers «from agricultural land/golf courses»

d. partially treated sewage/animal waste discharged into waterways

consequences: **[4 max]**

e. algal blooms

f. blocks light for photosynthetic organisms

g. dead organisms sink to bottom of water and decompose

h. decomposers/microorganisms increase BOD/use oxygen

i. oxygen/DO availability for other organisms decreases

j. decrease in biodiversity/disappearance of organisms

OWTTE

[Max 6 Marks]

Examiners report

[N/A]

Outline **three** issues arising from the release of pollutants into the environment.

Markscheme

a. reduction in biodiversity

b. biomagnification occurs

c. change in abiotic conditions

eg: loss of soil quality/loss of ozone layer

d. global warming

eg: methane, acid rain, climate change

e. community changes

eg: increase in pest species

f. health hazards/mutations

eg: animals choking on plastic, cancer, etc

g. other valid issue

eg: poisoning from toxins/pollutants

[Max 3 Marks]

Examiners report

[N/A]

Most reef-building corals contain photosynthetic algae, called *Zooxanthellae*, that live in their cells. Coral bleaching can occur as a result of human-induced changes leading to the *Zooxanthellae* being ejected from the coral.

a. State the type of interaction that occurs between *Zooxanthellae* and reef-building corals. [1]

b. State the trophic level of *Zooxanthellae*. [1]

c. When coral is bleached, certain organisms become more common in the ecosystem such as the cnidarian *Gorgonia*, the echinoderm *Diadema*, other algae and certain sponges. State the term that is used for organisms whose presence provides evidence of the existence of a particular environmental condition. [1]

d. A coat of algae builds up on coral reefs as a consequence of eutrophication. Explain the relationship between eutrophication and algal growth. [2]

e. Explain how an excessive growth of algae on coral reefs can be controlled by top-down factors. [2]

Markscheme

a. symbiosis/mutualism

b. producers

c. indicator species

d. a. eutrophication is nutrient enrichment of a body of water

b. example of nutrients *eg*: *nitrates*

c. «nutrients» serve as fertilizer for the algae «promoting growth»

e. a. top-down factors refer to predation/herbivory/trophic level above another one

b. which limit/control population growth

c. named example of a top-down predator *eg*: *parrotfish. Do not accept general names, like "fish"*.

Examiners report

a. [N/A]
b. [N/A]
c. [N/A]
d. [N/A]
e. [N/A]

Evaluate the use of indicator species in monitoring environmental changes.

Markscheme

indicator species sensitive to/need specific environmental conditions to survive;

monitor population size of indicator species over time;

biotic index can be calculated;

low overall score when abundance of tolerant species / lack of indicator species / *vice versa*;

represent summation of factors/overall assessment of environmental conditions;

time consuming / species not easy to identify (need keys) / species may not be present for other reasons such as season / another disadvantage;

methodology is simple / minimum equipment needed;

needs a reference study/guide to compare;

example of variable e.g. oxygen level / temperature / heavy metals / sulphur dioxide in air / other;

example of appropriate indicator species e.g. *Tubifex* to heavy metals / *Chironomis* to low oxygen levels / lichens to sulphur dioxide / other;

Examiners report

This question was very poorly answered by the majority of candidates with many not actually knowing what an indicator species was. The answers were very general, lacking in any detail. Some wrote about migration and changes in weather. Those that knew an indicator species did not link it with a specific environmental factor.

Explain, with examples, the use of specific indicator species and biotic indices to detect changes in the environment.

Markscheme

indicator species:

indicator species are sensitive to/need specific environmental conditions/have specific/limited range of tolerance;

their population growth/disappearance/reduction indicates specific changes in the environment;

example of indicator species and what it indicates; (*e.g. decrease in the population of stonefly larvae indicates increasing pollution levels/dissolved oxygen loss*)

Allow any other example.

biotic index:
compares the relative frequency of indicator species;
can be calculated for overall environmental assessment of an ecosystem;
multiply number of individuals of each indicator species by its pollution tolerance rating;
an abundance of intolerant species gives a high score / *vice versa*;
indicating an unpolluted environment / *vice versa*;
a change in the biotic index over time indicates a change in environmental conditions;
*Award **[4 max]** if only indicator species or biotic indices are addressed.*

Examiners report

Most candidates gained a variable number of marks for this question, mainly for stating factual information. Only a limited number of candidates clearly defined what indicator species and biotic indices are, and related to changes over time. Most could provide valid examples, but only a few could explain clearly the principle of calculating biotic indices. Many answers contained imprecise vocabulary.

---

a. State **two** bottom-up factors affecting algal blooms. [2]

1. . . . . .

2. . . . . .

b. Explain how top-down factors control algal blooms. [3]

Markscheme

a. minerals

OR

nutrients

OR

phosphorus

OR

nitrogen

*Award **[1]** to any two factors stated.*

Accept abiotic factors such as temperature, light, pH, CO_2 concentration.

b. a. the herbivores / «first» consumers regulate algal bloom

b. predators of the herbivores help regulate algal bloom/reduce herbivore abundance/OWTTE

c. overfishing/death of predators/decreased reproduction of predators decreases algal bloom as herbivore population increases/OWTTE

Accept vice versa for marking point c.

d. habitat degradation can decrease algal bloom

e. pathogens of algae will decrease algal bloom
OR
alien/invasive species may compete for habitat and affect algal bloom/OWTTE

Examiners report

a. [N/A]
b. [N/A]

---

a(i). Define *biomagnification*. [1]

a(ii). Outline a **named** example of biomagnification. [2]

Markscheme

a(i). biomagnification is a process in which chemical substances become more concentrated at each trophic level

a(ii) toxins/substances enter the body in water or food;

heavy metals are water soluble / synthetic organic compounds are fat soluble;

heavy metals bind to enzymes / synthetic organic compounds stored in fat;

no removal mechanism for heavy metals / synthetic organic compounds cannot be metabolized;

example of chemical/mercury (*e.g.* DDT/organophosphorus/ TBT/PCB);

example of affect on top carnivore in food chain (*e.g.* thin egg shells for birds of prey);

Award [1 max] if no named example given.

Examiners report

a(i). The definition of biomagnifications was mostly very well answered.

a(ii) Named examples of biomagnifications were often successfully given e.g. DDT or mercury. However, other than suggesting that these toxins enter the body in water or food, the reasons for the biomagnifications were not seen. Only very vague answers were seen. No details of exactly why an accumulation in any one step of a food chain was seen, e.g. accumulation in fat stores.

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a. Outline changes in species diversity during primary succession. [2]

b. Describe a method used to estimate the size of a mouse population. [3]

c. (i) Describe the environmental impact of a **named** invasive alien species. [2]

(ii) State an example of biological control of the invasive alien species named above.

Markscheme

a. few colonizing species establish themselves in harsh conditions/volcanic ash/ sand/areas devoided of life/bare rock;

e.g. moss/lichens/marram grass/bacteria;

more organic material accumulates/soil develops;

increasing species diversity;

b. capture-mark-release-recapture / OWTTE;

mice are trapped in a given area, counted, marked and released (without damage);

a second capture is made in the same area and marked and unmarked mice counted;

use of Lincoln index /

(*accept valid alternatives for equation*)
assumes marked mice randomly distributed / other valid comment on limitations;

c. (i) name of invasive alien species and impact

e.g.:

water hyacinth is an invasive plant with explosive growth that blocks waterways/kills other aquatic organisms

(ii) example of biological control organism *e.g.*: weevils/moths/fungus/mites have been used to control the water hyacinth growth *Do not award the mark if the example of the control does not correspond to the species named.*

Examiners report

a. Most candidates gained all the marks in part (a), although many answers demonstrated a poor understanding of primary succession and did not relate to an increase in species diversity.

b. The majority of candidates answered part (b) in terms of recapturing marked mice, but many answers missed out on a few details, mainly counting the mice; a limited number of candidates confused methods, mainly with quadrats or diversity indices and rare were the candidates commenting of methodological details or limitations of the method.

c. Part (c) was usually well answered, but some candidates lost marks because of imprecise organism name (for the invasive species and/or the control method), not stating the impact, or stating an unrelated control method with the named species; most candidates used textbook examples, but there were also valid regional examples and a certain number of plausible "creative" examples that were dismissed by examiners after some time wasted searching for their validity.

---

a. Outline the diversity of Eubacteria according to cell wall structure. [2]

b. State the role of *Rhizobium* and *Nitrobacter* in the nitrogen cycle. [2]

Rhizobium: .....

Nitrobacter: .....

d. Explain the use of bacteria in bioremediation. [2]

Markscheme

a. can be Gram-positive or Gram-negative;

Gram-negative have a thinner wall/less peptidoglycan/*converse*;

Gram-negative have an outer layer of lipopolysaccharide and protein;

b. *Rhizobium*: converts atmospheric nitrogen to ammonia / nitrogen fixation;

Nitrobacter: oxidizes nitrite into nitrate / nitrification;

d. bacteria remove contaminants from the environment;

by using them as energy sources;

(or) by converting them to a soluble/ harmless form;

example of bioremediation (*e.g. Pseudomonas* is used to clean up oil spills);

Examiners report

a. Most were able to get a mark for indicating that bacteria can be Gram-positive or Gram-negative. Many were able to obtain a second mark for indicating the different compositions of their cell walls.

b. Candidates tended to either get the roles of both bacteria in the nitrogen cycle correct or both wrong.

d. While many had a general idea of the use of bacteria in bioremediation, few were able to give an actual example.

---

a. Distinguish between *in situ* and *ex situ* conservation. [1]

b. The Atlantic cod is considered in many countries to be endangered due to overfishing. Describe two methods that could be used to estimate the cod population. [2]

d. Outline **one** reason for the extinction of a **named** animal species. [1]

Markscheme

a. *in situ* within the organism's natural environment whereas *ex situ* taken out of natural environment / *OWTTE*

b. a. record size of catches from fishing boats;

b. capture, tagging, releasing and recapturing fish / Lincoln index;

c. sample fishes with trawling nets;

d. estimate population with echo sounder/sonar/fish finder;

Award marks only for the first two methods if more than two written.

d. name of species and what caused it to become extinct (*both needed*)

The named species must be extinct and not endangered.

eg:

passenger pigeon (became extinct when) hunted as a source of food

Examiners report

a. Most candidates managed questions (a) to (d) relatively well.

b. Most candidates managed questions (a) to (d) relatively well.

Some candidates confused between methods to estimate the size of the population in (b) with methods to estimate the population structure, which was not answering the question; also some suggested quadrats, which is not appropriate for fish.

d. Most candidates managed questions (a) to (d) relatively well.

A few candidates confused extinct with endangered species in (d).

Eight sub-species of tigers existed in 1950, but three of these former sub-species have now become extinct. Discuss the role of active management techniques to prevent the extinction of the remaining tiger species.

Markscheme

*Award **[1]** for one argument for each of the following aspects:*

identification/monitoring of tiger populations;

creation of in situ/nature reserves;

provision of corridors between nature reserves;

hunting/poaching;

development of ecotourism;

impact on local economy;

ban on tiger products trade / development of synthetic alternatives;

increase of public awareness;

need for international cooperation/funds to implement measures;

ex situ/captive breeding programs;

extraction of DNA for gene bank;

Examiners report

Most candidates gained many if not all marks, but many answers were repetitive and not very clear.

---

b. Outline how habitat corridors can aid conservation of biodiversity in a nature reserve. [1]

c. Explain how living organisms can change the abiotic environment during primary succession. [3]

Markscheme

b. a. they allow species to travel between habitats / *OWTTE*;

b. outline of an example of a habitat corridor;

c. a. lichens secrete chemicals/acid which break down inorganic material/rock;

b. lichens/plants/litter change pH of the soil (which prevents/assists some species to establish);

c. organisms increase the mineral/organic/humus content of the soil when they decompose;

d. (organic matter and humus) can increase water retention;

e. plant roots can bind soil preventing erosion / break down soil particles;

Examiners report

b. There were mixed answers about habitat corridors. Many candidates apparently answered a previously asked question describing primary succession instead of focusing on the changes in the abiotic environment and the role of decomposition, resulting in generally poor answers.

c. Many candidates apparently answered a previously asked question describing primary succession instead of focusing on the changes in the abiotic environment and the role of decomposition, resulting in generally poor answers.

---

a(i). State **two** nitrogen-fixing bacteria. [1]

a(ii). Outline the conditions that favour denitrification. [2]

Markscheme

a(i). *Award [1] for any two of the following.*

Rhizobium / *Azotobacter* / Cyanobacteria / *Frankia*

a(ii). anaerobic conditions;

due to waterlogged soils;

Examiners report

a(i). This question was not very well answered by most candidates.

a(ii). This question was not very well answered by most candidates.

a. Earthworms are primary consumers that can be grown on household food waste such as fruit and salad leftovers. Outline their potential as an energy-containing food source for humans. [3]

b. State the units used in a pyramid of energy. [1]

Markscheme

a. a. much loss of energy / 10–20 % loss of energy;

b. low down food chain so efficient;

c. loss of energy through respiration/heat;

d. loss of energy through egestion;

e. less valuable as a food source than primary producers;

f. converts undigestible material into digestible materials;

b. kJ m^{-2} yr^{-1} / kilojoules per meter squared per year

Examiners report

a. Earthworms were recognized as primary consumers, many candidates could state the proportion of energy received and could indicate that the earthworms were using wastes to produce foods. The effects of UV radiation on living tissues were generally well understood.

b. Earthworms were recognized as primary consumers, many candidates could state the proportion of energy received and could indicate that the earthworms were using wastes to produce foods. The effects of UV radiation on living tissues were generally well understood.

Discuss the factors affecting population growth that can result in an exponential growth curve.

Markscheme

a. exponential growth occurs in ideal/unlimited environment

b. population growth determined by natality, mortality, immigration and emigration

c. natality / births / reproduction increases population
OR
number of reproducing individuals determine the rate of growth

d. as long as natality is higher than mortality

e. low mortality leads to exponential growth

f. absence of limiting factors will lead to exponential growth

g. «limiting factors» could be «competition for» resources/habitat / presence of predators/diseases

h. higher mortality and/or emigration compared to natality and/or immigration cause population to decrease/rate of growth to slow

i. graph with exponential curve/exponential part of sigmoid curve labelled

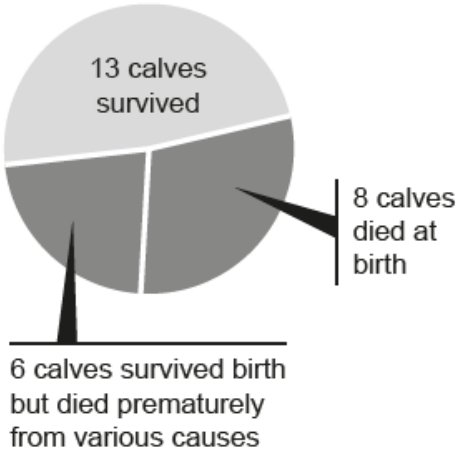
Allow annotations on a sigmoid population graph.

Examiners report

[N/A]

---

a. Zoos devote much effort to preserving and breeding elephants in captivity. Data for births resulting from artificial insemination in zoos in the United States from 1960 to 2012 are shown below. [1]



[Source: Association of Zoos and Aquariums, http://seattletimes.com]

54% of successful artificial inseminations have resulted in miscarriages, stillborn births or premature deaths.

Evaluate the success rate of breeding elephants by artificial insemination using these data.

b. Discuss **two** advantages of *ex situ* conservation measures. [2]

c. State the **two** components needed to calculate the biodiversity of an area. [2]

Markscheme

a. a. «not very successful as» less than half of the artificial inseminations have resulted in live births

b. there are no data for artificial insemination that did not result in pregnancy / no data for normal breeding success «in zoos»

Accept answers in the converse: «not very successful as» more than half do not result in live births

b. a. raise awareness / gain widespread public/political support for conservation actions

b. breed endangered species in captivity «for reintroduction»

c. education/research opportunities

d. lower maintenance/cost than *in situ* conservation

e. protect endangered species

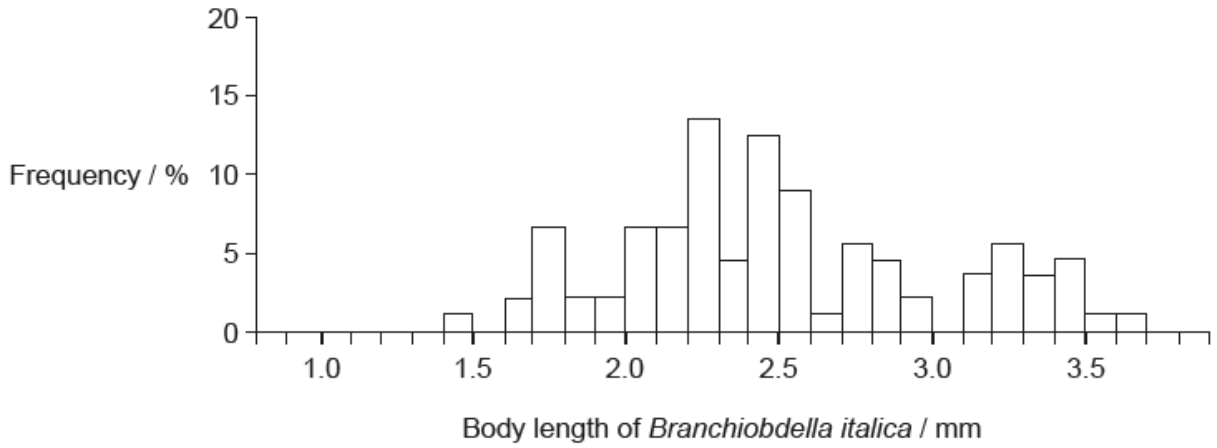
c. a. number of organisms of each species «present»

b. «total» number of species
OR
«total» number of organisms of all species found

Examiners report

a. [N/A]
b. [N/A]
c. [N/A]

The worm *Branchiobdella italica* lives on the external surface of the freshwater crayfish *Austropotamobius pallipes*. A study was carried out in a river in central Liguria, north-western Italy, of the range of sizes of *B. italica* found on adult *A. pallipes*.



[Source: M Mori, *et al.*, (2001), *Journal of Limnology*, 60(2), pages 208–210]

a. Describe the body length frequency of the *B. italica* worms collected in this study. [1]

b. The relationship between *A. pallipes* and *B. italica* is mutualistic. [1]

A. pallipes feeds on algae and another worm, *B. exodonta*, lives inside *A. pallipes* as a parasite. State the trophic level of *B. exodonta* in this food chain.

c. Distinguish between mutualism and parasitism, providing another example of mutualism and another example of parasitism. [2]

Markscheme

a. a. higher frequency of medium length worms

b. shows normal distribution

c. lower frequency at extremes

Allow correct numerical description of these points.

b. secondary consumer / third trophic level

c. a. in parasitism only one organism benefits whereas in mutualism both benefit

b. example for both parasitism ***AND*** mutualism

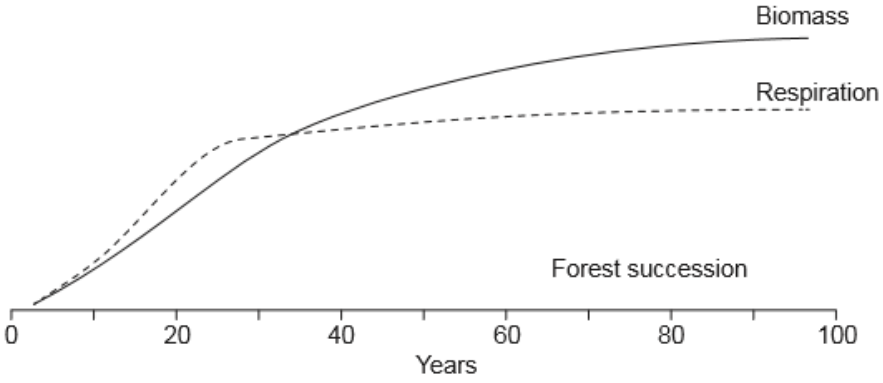
Do not allow B. italica or B. exodonta as examples.

*eg parasitic: human tapeworms **AND** mutualism: bacteria in human digestive tract*

Examiners report

a. [N/A]
b. [N/A]
c. [N/A]

The graph is a model showing biomass and respiration levels in a field where farming stops at time zero and the abandoned land develops into forest.



[Source: From "The Strategy of Ecosystem Development" by Eugene P. Odum. *Science*, 18 Apr 1969: Vol. 164, Issue 3877, pp. 262-270. Reprinted with permission from AAAS.]

a. Describe the change in biomass over the 100 year period. [2]

b. Outline the evidence from the graph that the area had plentiful rainfall. [2]

c. Explain the changes in biomass. [2]

d. Explain why biomass continues to increase after the respiration levels plateau. [2]

Markscheme

a. Increases

At a greater rate early on

Seems to plateau/levels off

b. Forest developed

Increase in biomass «over years» requires rainfall

Water is a limiting factor to photosynthesis

c. Initially there is low competition for sunlight/resources

Photosynthesis allows accumulation of biomass

Biomass rises as larger plants replace smaller plants

«In later stages» biomass increase limited due to competition for resources
OR
biomass stabilizes as climax community reached

d. Development of mature trees requires xylem/wood

Xylem/wood contributes to biomass but not respiration

Photosynthesis/production greater than respiration

Photosynthesis/production continues to accumulate biomass
OR
accumulated biomass remains/increases

Examiners report

a. Many candidates received the full 2 marks for seeing both the increase in biomass as well as the change in rate of increase as well.

b. Many candidates were able to score one mark for indicating that the increasing biomass was evidence for plentiful rainfall but seldom was a second point made. A few noted that a forest could not develop without rainfall or that water is a limiting factor for photosynthesis.

c. A few candidates realized that succession was occurring and the biomass increased as larger plants replaced smaller ones. Carrying capacity was sometimes mentioned when climax community is what they should have been referring to. Others seemed to have no idea as to why biomass was increasing.

d. Candidates did not seem to understand what was being asked in this question so marks for this were seldom seen.

Discuss the advantages of *in situ* conservation of endangered species, using examples.

Markscheme

in situ conservation is carried out in nature reserves/natural habitats;

named example of a species that is being conserved *in situ*;

in situ conservation reduces possibility that habitat disappears and the whole community is lost / may prevent the total number of species that become endangered from increasing;

allows species to live in an environment for which they are adapted / they are able to fit into their normal food chains;

threatened species in a reserve may be monitored for further deterioration in numbers / remedial steps can be taken;

offspring acquire skills from parents/peers around them / offspring acquire natural behaviour;

reserves and protected areas in various parts of the world can share experience on how to manage them successfully;

nature reserves are popular sites for the public to visit maintaining awareness/education/scientific study;

reserves are places to return endangered individuals from breeding programmes as they provide realistic conditions for re-adaptation / *OWTTE*;

Examiners report

This question was very poorly answered by the majority of candidates with many confusing *in situ* with *ex situ* conservation. Those that did understand the concept could not really "discuss" the advantages of it clearly and were vague in their responses; thus few received more than 3 marks.

Explain the causes and consequences of biomagnification with reference to a **named** example.

Markscheme

a. named example of chemical;

b. chemical absorbed by organism low in the food chain;

c. chemical not excreted/accumulates in body fat;

d. organism eaten by other organisms in higher trophic levels;

e. causing it to be much more concentrated at each trophic level;

f. substance accumulates in species at the highest trophic level;

g. may reach toxic levels;

h. named example of species at top of food chain;

i. harmful effect caused by the chemical;

*Award **[5 max]** if specific name of chemical is not given or chemical does not bioaccumulate.*

eg:
a. mercury;
b. absorbed by small fish;
c. (mercury) not excreted (by small fish) / accumulates in (small fish) tissues;
d. eaten by tuna;
e. (mercury) becomes more concentrated at each trophic level;
f. (mercury) accumulates in species at the highest trophic level;
g. may reach toxic levels;
h. humans may eat the tuna;
i. leads to brain damage / birth defects / mercury poisoning;

Examiners report

This question was relatively easy for the majority of candidates who used either DDT or mercury as example. Many answers nevertheless lacked detail needed for the "named example", and there were many other only partially correct statements. Candidates could describe the process in broad strokes, but failed to be able to explain it well in detail.

Discuss international measures that would promote the conservation of fish, including methods used to measure conservation of fish stocks.

Markscheme

measures to promote conservation: ***[3 max]***

reduce total allowable catch below maximum sustainable yield/MSY;

limit areas where fishing can take place;

decrease total net size;

increase mesh size to let immature fish through / set minimum landing sizes for fish;

reduce fishing effort;

reduce/stop subsidies for increasing size of fleet;

methods used to measure conservation: ***[3 max]***

monitor fish catches;

calculate the mass of fish that can be removed annually / maximum sustainable yield;

required knowledge of birth rate, growth rate of fish and mortality rates;

can be estimated by looking at age structure of landed fish;

can be estimated by catch per fishing effort;

Examiners report

The answers here were often mediocre.

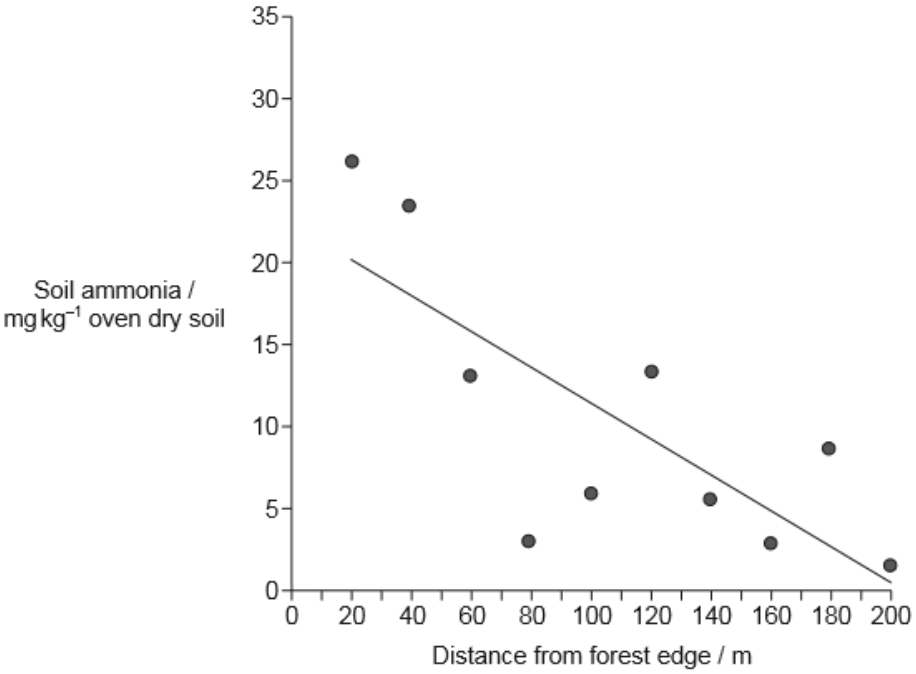
The most popular mark points seen were:

- Limiting areas where fishing can take place;
- Decrease total net size (including then the use of drag nets);
- Increasing mesh size to let immature fish through;

The methods to promote the conservation of fish stocks were acceptable, but methods used to measure conservation of stock were often poor. Some answers though did include required knowledge of age of landed fish as a mark point. Few could reliably suggest ways of monitoring catches; many did suggest capture-mark-recapture, but then went on to correctly criticise this as a method being restricted to e.g. lakes. Others wrote about electric-counting, which is limited to rivers.

The main problem seen here was the use of correct vocabulary concerning fishing and fishing efforts, maximum sustainable yields and so on.

Where high amounts of ammonium ions are present in agricultural areas, gaseous ammonia can be released into the atmosphere. This ammonia can dissolve and be carried across distances and then be deposited through precipitation. In a study of the effects of deposition of ammonium in a forest, soil samples were taken starting at the forest edge next to an open field and moving toward the centre of the forest.



[Source: "Spatial variations of nitrogen deposition and its effect on forest biochemical processes", M. A. Sutton *et al*. Crown Copyright, courtesy Forestry Commission, licensed under the Open Government Licence. http://www.forestry.gov.uk/fr/INFD-75PJ9E#sutton2001 (accessed May 2016).]

a. Outline the procedure that was most likely used by the researchers to decide where to take the samples. [2]

b. List **two** sources of the ammonium in the forest soils apart from deposition in rainfall. [2]

c. Suggest **one** reason for ammonium levels in the interior of the forest being lower than the soil ammonium close to the edge. [1]

Markscheme

a. Line transect

OR

a line is identified and individual walks the line

Decision on where to start and end the line/transect

Samples taken every 20m/at regular intervals

b. Activity of soil microorganisms/ammonification/nitrogen fixation

Urine/feces/other nitrogenous waste

Dead organisms

Fertilizers «on edge of forest»

c. Greater distance from an open field where they are applying fertilizer

More ammonium absorbed/recycled

Less ammonium in rain reaches soil/trapped in treetops

Examiners report

a. Identification of the procedure seemed like an easy question but in fact few candidates were correctly able to indicate that a transect was used and that using the graph as a guide, samples were probably taken at 20m intervals. Many tried to show how a random number generator would have been used instead.

b. Many were able to score 2 marks for listing sources of ammonium in the soil. However, some confused pesticides with fertilizers.

c. This was a discriminating question with only some able to suggest a reason for lower ammonium levels in the forest interior. The ‘forest edge’ seemed to lead some candidates incorrectly into a discussion of the edge effect.

. Discuss how international efforts can contribute to the conservation of fish stocks. [6]

c. Outline the biogeographical features of nature reserves that promote the conservation of diversity. [3]

Markscheme

. a. oceans are huge ecosystems with no borders / many important fishing grounds are in international waters;

b. fishing vessels often have a large geographical range / operate outside of national jurisdiction;

c. marine organisms migrate so need protection across their full range / breeding sites may be distant from feeding grounds so both need to be protected;

d. agree on maximum sustainable yields/quotas;

e. apply the precautionary principle in determining the level of exploitation;

f. agree on allowed fishing sites and exclusion zones;

g. agree on fishing seasons and moratoriums;

h. identify and agree on species that may be fished and those that may not;

i. determine and agree on which fishing methods are allowed and which are not/net and mesh size limitations;

c. a. nature reserve is a well defined/limited region with a protective framework/legislative protection;

b. large reserves promote biodiversity more effectively than small reserves;

c. size must be enough to have a well defined community of organisms;

d. edge effect is seen at or near the boundary between ecosystems;

e. leads to differences in population densities/biodiversity/levels of predation in central areas compared to edges;

f. habitat corridors allow organisms to move between parts of a fragmented ecosystem;

g. example of habitat corridors such as hedges/canals/drainage channels/tunnels/underpasses/overpasses;

Examiners report

. This was also a very popular option but not very high scoring in many cases.

Many were able to get 3 or more out of 6 marks, which made this Question 3 higher scoring than in some of the other options. The marks were usually for giving examples of agreed international conservation efforts such as maximum sustainable yields, but many candidates discussed pollution control and the monitoring of fish stocks rather than focusing specifically on conservation measures.

c. This was also a very popular option but not very high scoring in many cases.

This was poorly answered by most candidates as they did not seem to understand (or ignored) “biogeographical features”. Instead some talked about in situ and ex situ conservation

---

Discuss, using **three** examples, how alien species have impacted ecosystems.

Markscheme

a. the alien species can compete with existing species for resources / interspecific competition with native species;

b. appropriate example for competition with existing species;

c. alien species can be a predator of native species;

d. different appropriate example for predator of native species;

e. alien species can cause extinction of local species;

f. different appropriate example for causing extinction;

g. alien species can be deliberately added for biological control;

h. different appropriate example for biological control;

i. deliberate introduction of alien species for economic/other reasons;

j. different appropriate example for economic/other reasons;

Each impact must have a different example.

Examiners report

Although there were some very good answers, many candidates experienced some difficulty, partly due to poorly organized answers, repeated or vague examples and/or impacts.

---

a. Define the term *biomagnification*. [1]

b (i) Define the term *biomass*. [1]

c. Describe **one** technique used to estimate the population size of mice. [2]

Markscheme

a. Process by which chemical substances become more concentrated at each trophic level.

b (ii) total dry mass of organic matter in organisms/trophic level

c. (mice are) are captured marked and released (in first cycle);

(mice are) are recaptured and number of marked ones recorded (in second cycle);

population size

(*accept other symbols*)

Examiners report

a. Many correct definitions were given, but there were also many answers with missing elements.

b (ii) Many correct definitions were given, but there were also many answers with missing elements.

c. They could also describe a technique to estimate the population of mice, but some answers lacked important elements of the process, mentioned quadrats or used the whole population instead of a sample.

Discuss the role of *ex situ* conservation of endangered species.

Markscheme

a. named example *(e.g. zoo/botanic garden/seed bank/aquarium/laboratory)* / definition of *ex situ*;

Do not accept open parks e.g. Safari.

advantages: [3 max]

b. prevent extinction / help in conservation of species;

c. possible breeding;

d. reintroduction into the wild;

e. correct nutrition constantly;

f. veterinary care;

g. educational use / research use;

h. prevent poaching/picking rare flowers/damage to habitat by man;

disadvantages: [2 max]

i. difficulty in the reintroduction of the species to the wild;

j. increases inbreeding / restricted gene pool;

k. selection of organisms to be kept *ex situ*;

l. not their natural habitat / reduces evolution;

m. does not solve the cause/problem *e.g.* habitat loss;

Examiners report

A good number of candidates gave fairly complete answers. Many candidates did not discuss any disadvantages of *ex situ* conservation.

---

b. Define *indicator species.* [1]

c. Outline, with a **named** example, biological control of invasive species. [2]

Markscheme

b. species sensitive to certain environmental conditions / species used to monitor environmental change / species used to determine environmental conditions

c. name of species to be controlled;

method of biological control with species name of predator/parasite/pathogen;

e.g. rabbits (introduced into Australia);
controlled by release of myxoma virus / myxomatosis (from South America);
Allow any other verifiable example. Reject cane toads as a biological control agent and other unsuccessful cases.

Examiners report

b. Part (b) was well answered by most.

c. Many invalid answers were given, including cane toads. Although the purpose of their release in Australia may have been biological control, they are now better classified as an invasive species in their own right, rather than a biological control. Other answers were too vague to score marks. With topics such as the biological control of invasive species, teachers are encouraged to give their students a real and paradigmatic example, rather than atypical or dubious ones. Some candidates even suggested that rats had been introduced to New Zealand to control invasive birds.

Outline the consequences of the edge effect for small nature reserves.

Markscheme

edge effect is the contrast between different environments/from central area of reserve;

small reserves have more edge effect;

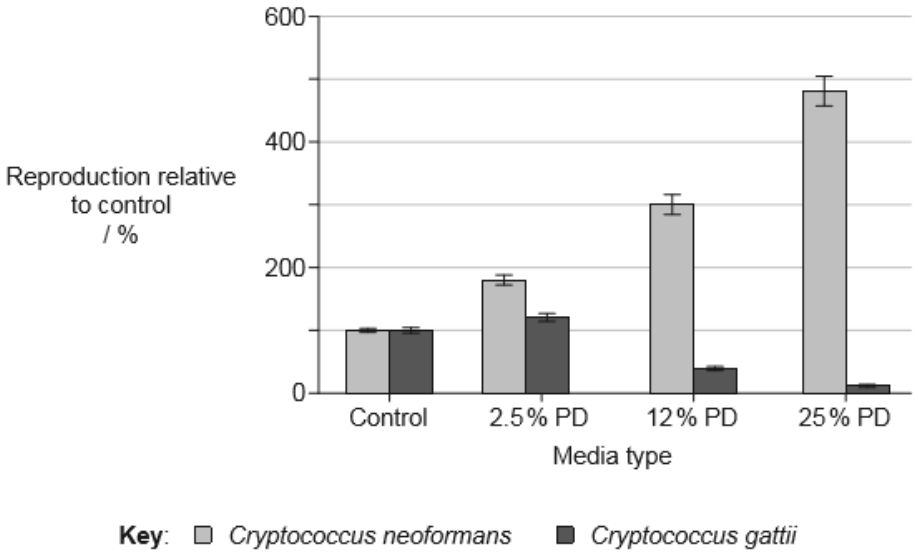
as fragmentation increases so does edge (effect);

example of edge effect (*e.g.* cowbirds that lay eggs in edge will increase);

Examiners report

Candidates struggled with this section on the consequences of the edge effect for small nature reserves. Most tended to talk about endangered species. Some were able to get a mark for an example of edge effect such as increase in cowbirds which lay their eggs in the edge or for the fact that small nature reserves have more edge effect.

Cryptococcus neoformans and the closely related species *Cryptococcus gattii* are human fungal pathogens. The reproduction of these yeast species on increasing concentrations of pigeon droppings (PD) was examined to determine whether they occupy the same or different ecological niches. The results for reproduction are expressed as a percentage relative to the control.



[Source: adapted from K. Nielsen et al. (2007), "*Cryptococcus neoformans* Mates on Pigeon Guano: Implications for the Realized Ecological Niche and Globalization". *Eukaryotic Cell*, vol. 6, pp. 949–959, DOI: 10.1128/EC.00097-07. Amended with permission from American Society for Microbiology]

Suggest how this experiment shows that pigeon droppings represent a realized ecological niche for *C. neoformans* and a fundamental (but not a realized) niche for *C. gattii*.

Markscheme

a. the realized niche is the actual while the fundamental niche is «all of» the potential

b. «shared» fundamental niche shown by equal reproduction on control

c. *C. neoformans* reproduces on PD indicating a realized ecological niche

d. competitive exclusion decreases realized niche of *C. gattii*

e. *C. gattii* reproduces poorly on PD representing a fundamental niche
OR
C. gattii reproduces poorly on PD so not a realized niche

Examiners report

[N/A]

---

a. Distinguish between the use of a quadrat and a transect in gathering field data. [2]

b (i) State the change in species diversity and the change in production during primary succession. [1]

Species diversity: .....
Production: .....

b (ii) State one difficulty in classifying organisms into trophic levels. [1]

Markscheme

a.

	Quadrat	*Transect*
a.	square frame	tape/string;
b.	used to estimate population size/density/cover/compare population sizes of two or more species	used to investigate distribution of plant or animal species/correlate distribution with abiotic variable;
c.	individuals within quadrat boundaries are recorded	samples taken at even intervals and individuals touching line are recorded;
d.	used in uniform habitat	used in habitat with gradient;

Accept any horizontal set of ideas, up to two sets.

b (i) *Species diversity:* rises

Production: rises

*Both needed for **[1]**.*

b (ii) an organism can occupy/feed at more than one trophic level

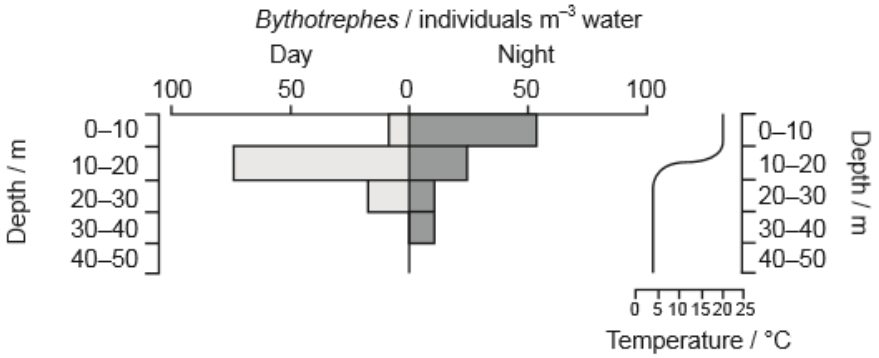
Examiners report

a. Candidates seemed to have very poor knowledge of the differences between a quadrat and transect and when each was used.

b (i) Both parts of this section were answered correctly by most candidates.

b (ii) Both parts of this section were answered correctly by most candidates.

During the 1980s, a tiny invasive crustacean *Bythotrephes cederstroemii* entered the eastern Great Lakes from Europe (probably via freshwater or mud in the ballast water of merchant ships) and eventually colonized Lake Michigan. *Bythotrephes* reproduces very quickly and eats common zooplankton, disrupting the food web by directly competing with small juvenile resident fish. *Bythotrephes* avoids predation by larger fish through the timing of its activities which have been investigated in offshore waters of Lake Michigan at various depths during the day and night.



[Source: Courtesy of Professor John T. Lehman, University of Michigan.]

a. State the depth range showing the most *Bythotrephes* during the night. [1]

b. Describe the distribution of *Bythotrephes* during the day. [2]

c. Deduce the responses of *Bythotrephes* to temperature and light. [2]

d. Explain the change in distribution of *Bythotrephes* between day and night in terms of its position in the lake food chain. [2]

Markscheme

a. 0–10 meters

b. a. *Bythotrephes* found at all depths down to 20–30 m/none below 30 m;

b. greatest number/density (of organisms) at 10–20 m;

c. least number/density (of organisms) at 0–10 m;

c. a. avoids/driven away by light (to colder water);

b. in absence of light attracted to warmer water;

c. can tolerate a wide range of temperature (*accept numbers in range of 4/5–20/25°C*);

d. a. zooplankton found in (warmer) surface water where small plants / algae/phytoplankton are found due to light;

b. as predator, *Bythotrephes* moves up to the surface to feed on zooplankton at night;

c. as prey, *Bythotrephes* moves to lower/darker depths during the day to avoid being (easily) seen by predators/fish;

Examiners report

a. Almost all candidates were able to get the 1 mark for reading the graph correctly.

b. This question also involved reading the graph correctly and most were able to get 1 mark. Many received a second mark as well.

c. The association between light, temperature and depth was problematic for many candidates. Many were able to get 1 mark usually for light avoidance.

d. There was poor reference made to the role of *Bythotrephes* as predator or prey. Many confused “position in food chain” for position in the lake in terms of depth.

Describe a **named** method for determining the size of fish populations and the challenges in conserving world fish stocks.

Markscheme

	name	brief description	limitations
	a.	b.	c.
example 1	echosounding;	bounce sonar off shoals of fish;	does not work at depths / need sample to identify fish;
example 2	capture–mark–recapture;	capture and mark fish, release, recapture and count to calculate population;	feasible in lakes but not open sea (due to migration);
example 3	collection of data on fish catches;	record numbers and age distribution of catches;	problems with sampling/ records/interpretations;

challenges:
d. maintain fish as an important food source for humans/other animals;
e. a sustainable yield means not overfishing an area/not causing a decline in the population/ not catching faster than the fish can replace themselves / OWTTE;
f. pollution threatens world fish stocks/habitat;
g. disagreements as to what is a sustainable population;
h. disagreements in the collection of data of population sizes;
i. requires international cooperation to define conservation measures/regulations/quotas;
j. difficult to reinforce/control regulations / monitor practices / *OWTTE*;
*Award **[4 max]** if only challenges addressed.*

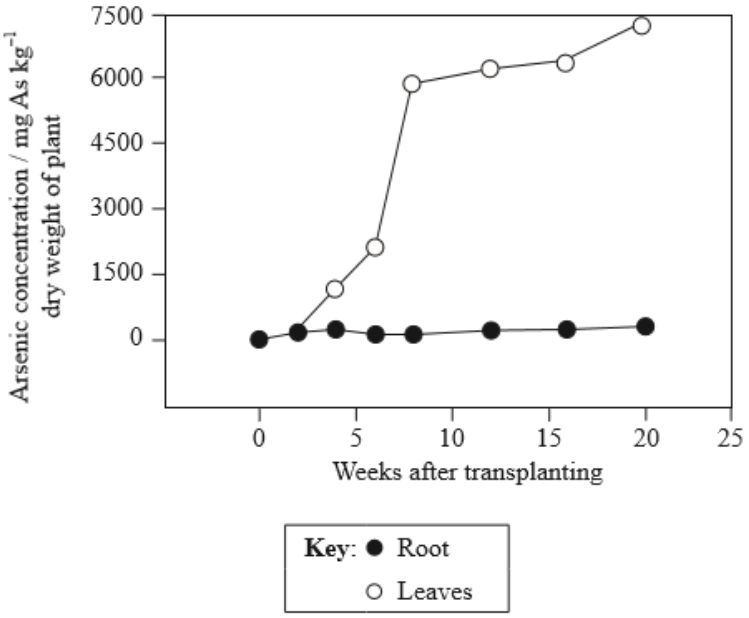
Named method could be any of the three examples given above but the description and limitation must be based on one named method only.

Examiners report

This question caused some difficulty as, although many candidates correctly named a method and described it, most could not mention limitations of the named method or even had difficulty describing it properly. The described challenges were often too vague and not focusing on conserving world fish stocks; many simply listed problems without going any further (e.g. net mesh size, fishing in breeding seasons, fish migration, etc.).

The element arsenic (As) is not needed for plant growth and development. The accumulation of arsenic in the Chinese brake fern (*Pteris vittata*) was studied. Young ferns with five or six leaves were transplanted to soil contaminated with arsenic and were grown for 20 weeks in a greenhouse.

The graph below shows the arsenic concentrations in leaves and roots of the Chinese brake fern during the 20 weeks after transplanting. Arsenic concentration is expressed as mg As kg^{-1} dry weight of plant.



[Source: C Tu, *et al.*, (2002), *Journal of Environmental Quality*, **31**, pages 1671–1675]

The table below shows the total amount of arsenic accumulated by the Chinese brake fern, expressed as a concentration in the plant tissue and as a percentage of the arsenic originally in the soil.

Time / weeks	Arsenic concentration in fern / mg As kg^{-1}	Percentage of original soil arsenic absorbed by fern
0	2	0.00
2	66	0.05
4	221	0.15
6	408	0.28
8	1300	0.88
12	5390	3.68
16	13 800	9.43
20	37 900	25.90

[Source: adapted from C Tu, *et al.*, (2002), *Journal of Environmental Quality*, **31**, pages 1671–1675]

a. Using the data in the graph, describe the accumulation of arsenic in the Chinese brake fern. [3]

b (i) Assuming the mean rate of arsenic accumulation over the first 20 weeks continued, calculate how long it would take to remove all the arsenic from the soil. [1]

b (ii) Using the data in the table, discuss the potential of using Chinese brake fern to remove arsenic from contaminated soil. [2]

c. Suggest **one** possible consequence of arsenic accumulation in plants for other organisms in the community. [1]

Markscheme

a. arsenic accumulates in leaves;

arsenic concentration (in leaves) increases rapidly in the first 7 weeks;

arsenic (in leaves) increases from 0 to approximately 6000 mg kg^{-1} at 7 weeks;

maximum arsenic level (in leaves) is about 7500 mg kg^{-1} at end of experiment / valid numerical example;

after week 7 arsenic concentration in plant increases more slowly/begins to plateau;

arsenic concentration in roots remains relatively unchanged throughout the experiment;

(*Accept range of 7 – 10 weeks in all of above points*)

b (i) 77 weeks (*Allow answers in range 70 – 80 weeks*)

b (ii) Chinese brake fern could be used to remove arsenic from soil;

after 20 weeks about 25 % of soil arsenic removed by fern;

arsenic concentration increases (rapidly) in fern (tissue) in 20 weeks;

eventually/longer periods may reach toxic levels for plant;

c. plants may become toxic for consumers;

arsenic may accumulate in the food chain / biomagnification;

Examiners report

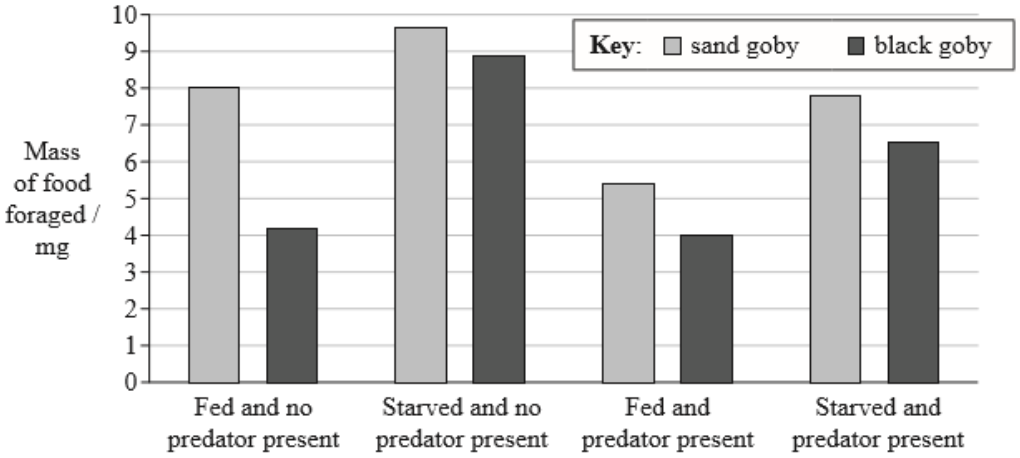
a. Almost all candidates correctly indicated that arsenic accumulates in the leaves and better candidates were able to expand on this and get two or three marks.

b (i) (i) While the mean rate of arsenic accumulation was thought to be a difficult concept by respondents on G2 forms, many candidates were able to get this correct.

b (ii) In (ii) most candidates indicated that the Chinese brake fern could be used to remove arsenic from contaminated soil but only a few received a second marking point.

c. The majority of candidates were able to get the mark here by either indicating that the plants would become toxic to consumers or that biomagnification may occur.

Investigators studied the behaviour of two species of small fish, the sand goby (*Pomatoschistus minutus*) and the black goby (*Gobius niger*), while they foraged for mud shrimps. The amount of food foraged by the gobies was measured after they had been fed or after they had been starved. The measurements were repeated when a predator of the gobies was introduced to the tank where they were feeding.



[Source: "Conflicting demands in gobies: When to eat, reproduce, and avoid predators" by Carin Magnhagen, *Marine & Freshwater Behaviour & Physiology*, Oct 1, 1993, vol. 23, issue 1–4, pp. 79–90.]

a. Calculate the decrease in mass of food foraged by fed sand gobies when a predator was introduced, giving the units. [1]

b. Compare the effect that starvation had on both species of goby when no predator was present. [2]

c (i) Describe the effect the predator had on the foraging of the gobies. [2]

c (ii) Suggest a reason for the effect of the predator. [1]

Markscheme

a. 2.6 mg (*units required*) (*accept answers in the range of 2.5 mg to 2.7 mg*)

No working required.

b. both foraged more after starvation;

black goby increased the amount of food foraged more than the sand goby;

c (i) a. predator present causes <u>both</u> to forage for less food;

b. fed black gobies showed little change in foraging (with predator present);

c. starved gobies foraged more than fed gobies (with predator present);

d. relative foraging remains similar between the two species / black goby always forages less than sand goby;

c (ii) a. gobies may feed on smaller mud shrimps when predator present;

b. gobies may hide rather than forage when predator present / gobies may feed less efficiently if they are watching out for predators;

c. predator may also eat shrimp so less for gobies;

d. if predator eats gobies the total mass of food foraged is less / *OWTTE*;

Examiners report

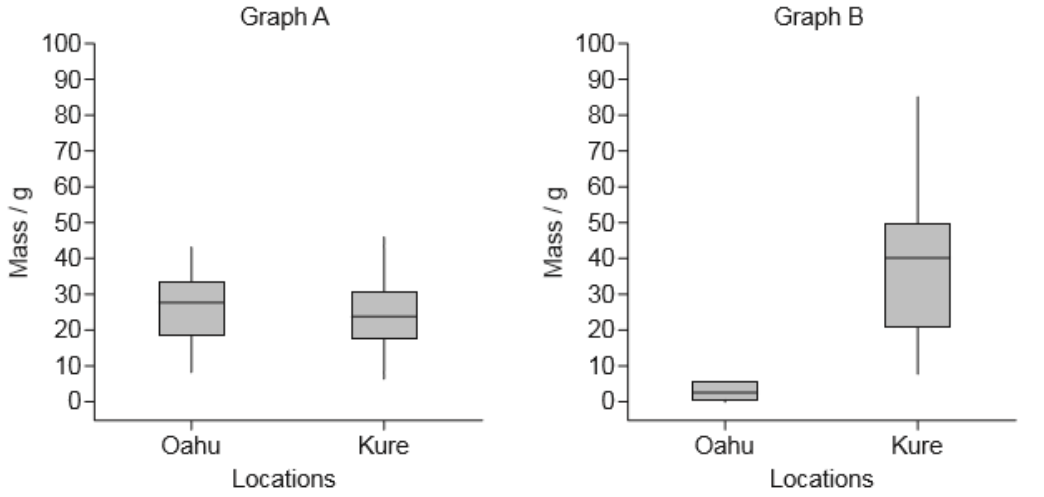
a. Generally well done, although some answers were a bit unclear.

b. Generally well done, although some answers were a bit unclear.

c (i) Generally well done, although some answers were a bit unclear.

c (ii) Generally well done, although some answers were a bit unclear.

The Laysan Albatross (*Phoebastria immutabilis*) sometimes ingests plastic. A bolus is a pellet made of material that the albatross cannot digest, so brings it back up from its stomach to its mouth and then ejects the indigestible matter. Graph A indicates the mass of indigestible natural material, such as bones and octopus beaks, in the bolus of birds at two different locations. Graph B indicates the mass of plastic in the bolus at both locations.



[Source: Young LC, Vanderlip C, Duffy DC, Afanasyev V, Shaffer SA (2009) Bringing Home the Trash: Do Colony-Based Differences in Foraging Distribution Lead to Increased Plastic Ingestion in Laysan Albatrosses? *PLoS ONE* 4(10): e7623. doi:10.1371/journal.pone.0007623]

a. Suggest **one** reason for the Laysan Albatross ingesting indigestible plastic. [1]

b. Suggest a reason for the difference in ingested plastic in the diets of the Laysan Albatross in the **two** locations. [2]

c. Outline the origin of microplastic debris in the marine environment. [2]

d. Using microplastics as an example, outline the concept of biomagnification. [2]

Markscheme

a. «Coloured object» mistaken for food

OR

skimming of ocean surface for food leads to plastic intake

b. Ocean currents concentrate plastic debris

Kure receives more debris than Oahu

More plastic available/more exposure to human populations/waste in the environment of Kure

c. «Macro» plastics blown/carried/washed from land sources into the ocean

Degraded over time

To form microplastic fragments

Substances already containing microplastics «*eg*: washing/cleansing products» get into water

d. Microplastic ingested by organisms at lower trophic levels

Accumulates in the tissues/guts of organisms

Becomes concentrated in the organs/tissues of organisms as moves through the food chain/at higher trophic levels

Examiners report

a. Most understood that plastic was being mistaken for food so were able awarded the mark.

b. Most were only able to score one mark for suggesting that perhaps Kure had more exposure to human populations and waste than Oahu (which is not in fact the real situation). Most candidates did not see the role of ocean movement and currents in distribution of floating plastics in waters around the two locations where the albatrosses feed.

c. Most answers about sources of microplastic debris were vague. However, many were able to get a mark for indication that plastics were carried from land sources to the ocean. A few knew that some washing products contain microplastics.

d. This question on biomagnification was surprisingly poorly answered, a few even writing about magnification using a microscope. Vague answers were given and few properly outlined the concept of biomagnification or seemed to know that substances accumulate in the tissues or gut of organisms.

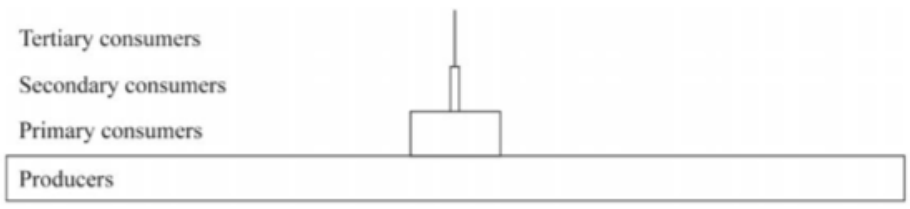
---

a. In a grassland ecosystem, the amount of energy captured by the photosynthetic organisms was 100 000 kJ m^{-2} yr^{-1}. Construct a pyramid of energy indicating the predicted energy levels for **four** trophic levels, including the producers. [3]

b. Define *biomass*. [1]

Markscheme

a.



Values: primary consumers: 10 000 kJ m^{-2} yr^{-1}, secondary consumers: 1000 kJ m^{-2} yr^{-1} and tertiary consumers: 100 kJ m^{-2} yr^{-1}
correct values; (*allow 20 % error*)
correct trophic level labels; (*do not accept trophic level 1, trophic level 2 etc.*)
drawing showing proper proportions; (*height of each step the same, each bar no more than one quarter of the one below*)

b. the dry mass / organic material (of a group) of organisms in a given area/habitat

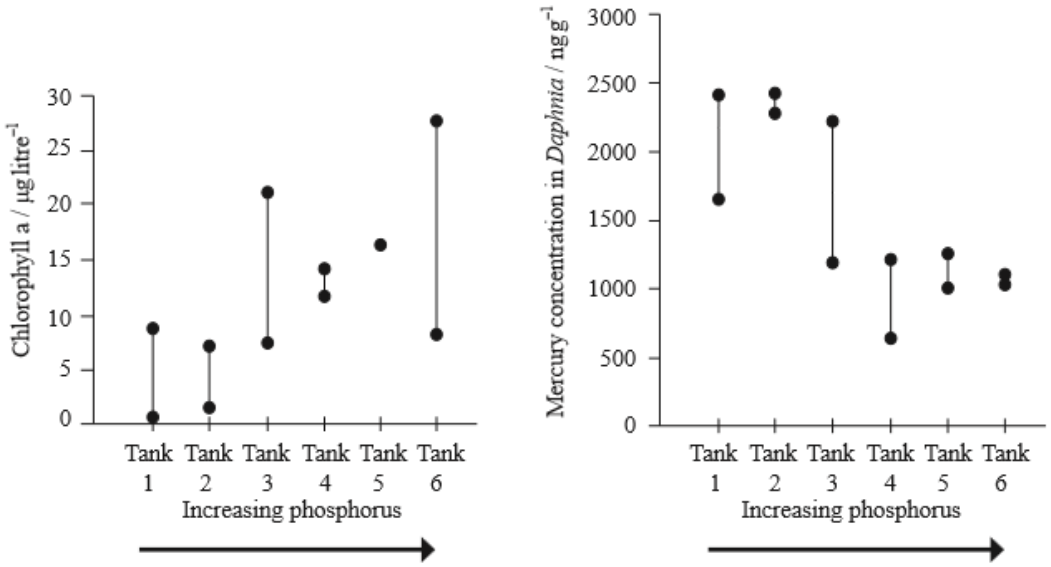
Examiners report

a. Most were able to correctly identify the trophic levels for one mark. Some were able to correctly give the predicted energy levels as roughly 10% of the previous level although some indicated that only 10% was used or lost so that 90% went on to the successive level. Few drew a good pyramid of energy diagram.

b. Again, the definition was not clear and concise in most cases.

Mercury is a toxic substance and its biomagnification in aquatic food chains is a global concern. A study tested the effects of inorganic phosphorus levels on both algal growth and mercury accumulation by *Daphnia mendotae* feeding on the algae which absorb mercury from the water. *Daphnia* may subsequently be eaten by fish.

Experiments were performed in six different tanks with increasing phosphorus concentrations. The same amount of mercury was added to each tank. The quantity of algae, determined by measuring the amount of chlorophyll a, and the accumulation of mercury by *Daphnia* was measured in each tank. Chlorophyll a and mercury levels were measured twice at each of the six different phosphorus concentrations.



[Source: adapted from Paul C. Pickhardt, Carol L. Folt, Celia Y. Chen, Bjoern Klaue and Joel D. Blum (2002) 'Algal blooms reduce the uptake of toxic methylmercury in freshwater food webs'. PNAS, 99, pp. 4419–4423. Figures 2A and 3C]

a (i) Deduce the tank in which the quantity of algae was highest. [1]

a (ii) Deduce the tank in which the level of mercury accumulation in *Daphnia* was lowest. [1]

b. Outline the relationship between phosphorus concentration in the water and the accumulation of mercury by *Daphnia*. [2]

c. Using the data, suggest reasons for the relationship between phosphorus concentration in the tanks and mercury concentration in *Daphnia*. [2]

Markscheme

a (i) (tank) 6

a (ii) tank) 4

b. increasing phosphorus decreases mercury accumulation by *Daphnia*;

increasing concentration of phosphorus above tank 4 has little effect;

highest levels of mercury accumulation recorded at low phosphorus concentrations;

c. increased phosphorus concentrations produce algal blooms/increased algae;

larger populations of algae result in smaller concentrations of mercury in the (individual) algae;

less mercury taken in/accumulated by *Daphnia* from their food;

Examiners report

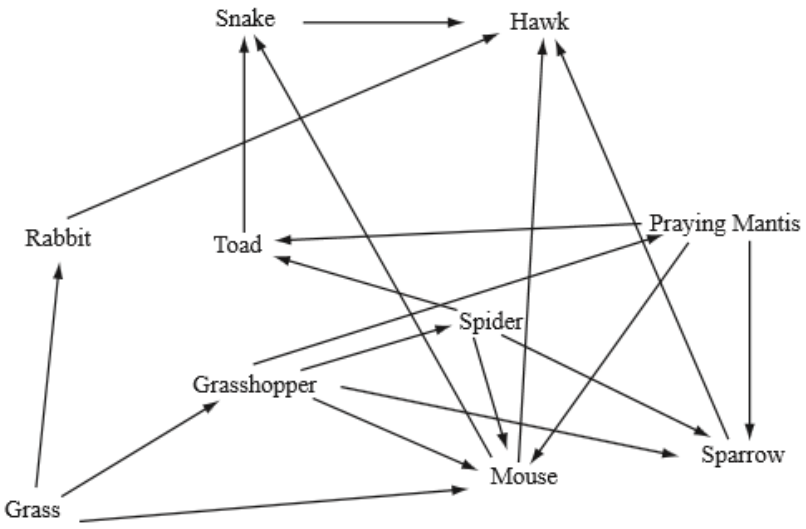
a (i). Almost all candidates correctly indicated that tank 6 had the highest quantity of algae.

a (ii). many incorrectly stated in (ii) that tank 6 had the lowest mercury accumulation in Daphnia. Tank 6 has the least difference between the two measurements of mercury accumulation but the lowest level was in tank 4.

b. While many candidates were able to get one mark for stating that increasing phosphorous decreases mercury accumulation in *Daphnia*, few were able to get a second mark in this outline question.

c. The better candidates were able to get two marks here by suggesting increased phosphorous concentrations led to algal blooms which absorbed the mercury and the result of this on mercury levels in *Daphnia.*

The following figure represents a terrestrial food web.



a. Identify the trophic level of the toad. [1]

b. Outline a method that could be used to estimate the population of rabbits in this environment. [4]

c. The Simpson diversity index is used to calculate the species richness in an ecosystem. [2]

Define the terms N and n in the formula above.

N =

n =

Markscheme

a. tertiary consumer / fourth trophic level

b. capture – mark – release – recapture method;

marked unit area;

apply a paint spot/ear tag/leg ring/radio transmitter to the captured rabbits;

sufficient time must elapse to allow mixing of population to occur;

second capture must be from same marked area;

calculate the Lincoln index / population size

n1=first capture, n2= second capture, n3= number marked in second capture;

c. N = total number of organisms of all species found;

n = number of individuals of a particular species/per species;

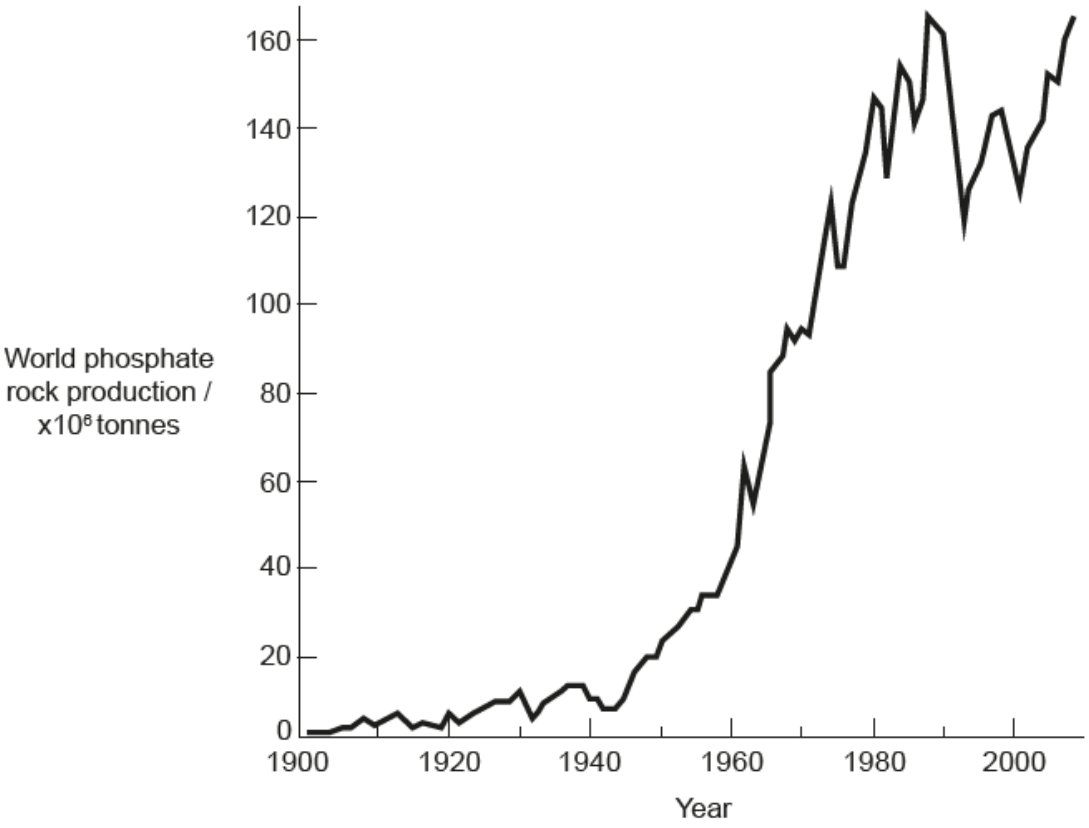
Examiners report

a. Many were able to correctly identify the trophic level as tertiary consumer. Candidates should not use unexplained symbols when answering questions.

b. Very few descriptions of the capture-mark-release-recapture technique were given. Several candidates mentioned the use of 1 m^2 quadrats. While they do give a marked unit area, they are not suitable for mobile species such as rabbits

c. Most candidates did not know what the N and n stood for in the formula for the Simpson diversity index.

The predominant source of phosphorus is rock containing phosphate (phosphate rock). The graph below shows the world production between 1900 and 2009.



[Source: From the US Geological Survey, http://minerals.usgs.gov/ds/2005/140/#phosphate), redrawn by the IB]

a. Some scientists estimate that available phosphorus reserves in the Earth will be completely depleted within approximately 100 years. Discuss the implications of these estimates. [2]

b. The percentage of phosphorus in an ecosystem that is recycled per year is in most cases very small, and far smaller than the percentage of nitrogen that is recycled. Suggest reasons for this difference. [2]

c. Nitrates (NO) are components of the nitrogen cycle. Outline the possible conversions of NO in the nitrogen cycle. [2]

Markscheme

a. a. production of fertilizers will decrease/price of fertilizers will rise

b. less food production / increase in cost of foods

c. development of alternative methods of agriculture

d. Phosphate needed by living organisms for nucleic acids/ATP so lack will affect growth negatively

b. a. largest store of phosphorus «in ecosystems» is in marine sediments and minerals/phosphate rock while nitrogen is in the atmosphere

b. main source of release of phosphorous is by weathering of rocks «very slow process»/ nitrogen is by bacterial action

c. high concentrations of nitrogen/low concentration of phosphorous «compounds» in living organism

d. phosphorus is not a very soluble mineral

c. a. assimilation by plants / conversion to amino acids

b. denitrification to nitrogen gas / reduction to nitrogen «N_2» by denitrifying bacteria

c. reduction of nitrates to nitrites

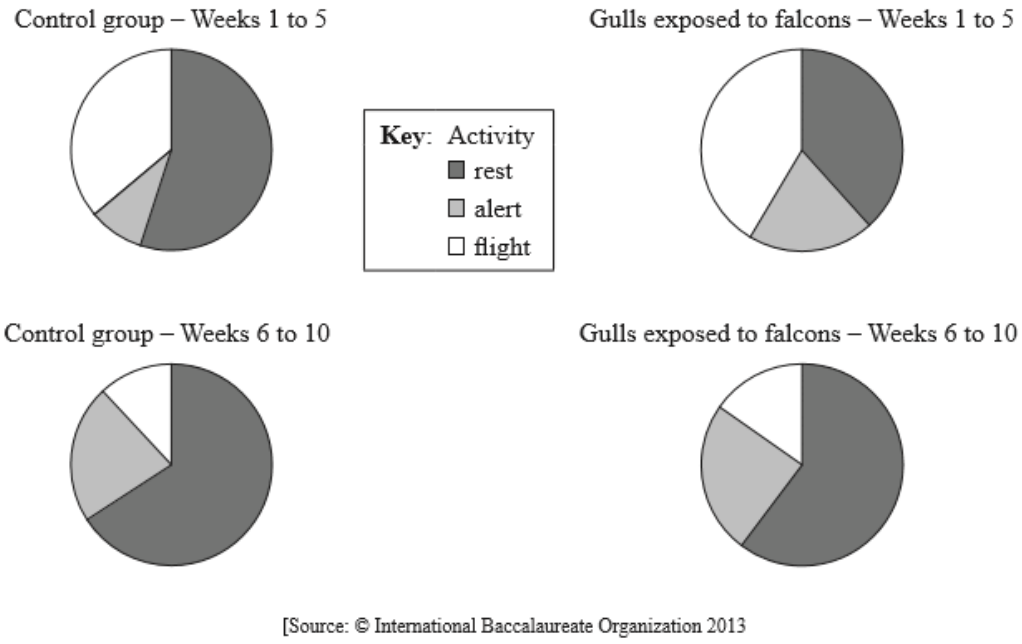
Examiners report

a. [N/A]
b. [N/A]
c. [N/A]

In 2009, the town council of Dumfries in Scotland tested a project to prevent lesser black-backed gulls (*Larus fuscus*) from nesting in the town where they were causing problems. They released trained falcons into the town centre for 10 hours each day during a 10-week period when the gulls normally lay their eggs. Although the falcons are predators of the gulls, they did not kill the gulls during the study. The behaviour of the gulls was observed and the percentage time spent on three activities was recorded. The results were compared to a control group not exposed to falcons in another part of town.

• **Rest**: sitting on their nests, standing or preening their feathers
• **Alert**: remaining on the ground but disturbed and visibly agitated
• **Flight**: flying regardless of the cause

The pie charts show the results of the project.



[Source: © International Baccalaureate Organization 2013

a. State which activity decreased in weeks 1 to 5 as a result of exposure to the falcons. [1]

b. Estimate the total percentage of time the gulls exposed to falcons spent flying and at rest in weeks 6 to 10. [1]

.....%

c. Compare the behaviour of the gulls exposed to falcons with the control group over the period of study. [3]

d. Predict, using the data in the pie charts for weeks 1 to 5 and weeks 6 to 10, if the use of falcons will succeed in causing a long-term reduction in the number of gull nests in problem areas. [2]

Markscheme

a. rest

b. 75 (%) (*accept answers in the range of 72 to 78 %*)

c. a. comparison for one of the behaviours (rest/alert/flight) between the control group and the falcon group for weeks 1 to 5;

b. comparison for one of the behaviours (rest/alert/flight) between the control group and the falcon group for weeks 6 to 10;

c. comparison for one of the behaviours (rest/alert/flight) between weeks 1 to 5 for the control group and weeks 6 to 10 for the falcon group / converse;

d. comparison between the proportions/differences of overall behaviours for the control group with those for the falcon group for weeks 1 to 5/weeks 6 to 10 / overall change in all groups over time;

*Award [**1 max**] for a correct comparison for each marking point. Do not award marks for a comparison between the control group only or the falcon group only.*

Please refer to the clarification document for further guidance.

d. a. falcon group has closer values (in all categories) to control in weeks 6 to 10;

b. falcon group has more rest in weeks 6 to 10 than in weeks 1 to 5 so indication for more nesting;

c. insignificant/no long-term effect as gulls seem to become accustomed to falcons / trend is likely to continue / *OWTTE*;

Examiners report

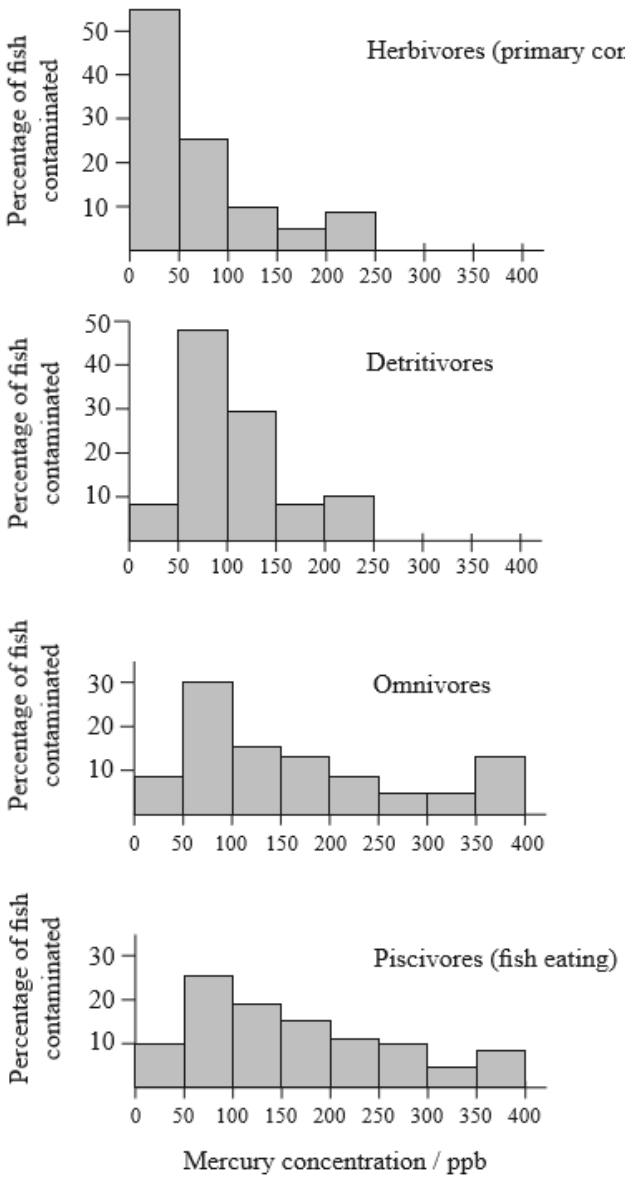
a. N/A

b. N/A

c. Most candidates did well, but some limited their comparisons or did not compare similar elements in (c).

d. Most figured out that the project would not succeed in the long term, but some had a certain difficulty to use the data properly to demonstrate it.

Indigenous human populations living along riverbanks in the Amazon basin often rely heavily on fish as a major part of their diet. The data shown below come from a study that was carried out to investigate levels of mercury contamination in the Rio Negro basin in Brazil. Mercury concentration was measured in fish belonging to four different trophic levels and is shown in parts per billion (ppb).



[Source: With kind permission from Springer Science+Business Media: *Archives of Environmental Contamination and Toxicology*, Mercury Biomagnification in a Tropical Black Water, Rio Negro, Brazil, 45, 2003, 235–246, A. C. Barbosa et al.]

a. State the trophic level of the fish that presents the least risk of mercury contamination for human consumers. [1]

b. Compare the levels of mercury found in herbivores (primary consumers) and detritivores. [2]

c. Explain the large range of mercury concentrations seen in the piscivores. [2]

Markscheme

a. herbivores (primary consumers)

b. a. same range of mercury concentrations/up to 200–250 (ppb);

b. levels above 50 (ppb) are lower/less common in herbivores than in detritivores / vice versa;

c. (0–) 50 (ppb) is most common in herbivores whereas (50–) 100 (ppb) is most common in detritivores;

c. a. piscivores feed at different trophic levels (within the food chain);

b. piscivores that feed on herbivores / detritivores will have lower levels of contamination;

c. piscivores that feed on carnivores/omnivores/top of food chain will have high levels;

Examiners report

a. This was also a very popular option but not very high scoring in many cases.

Almost all correctly identified the trophic level as herbivores (primary consumers) and thus were able to get this mark.

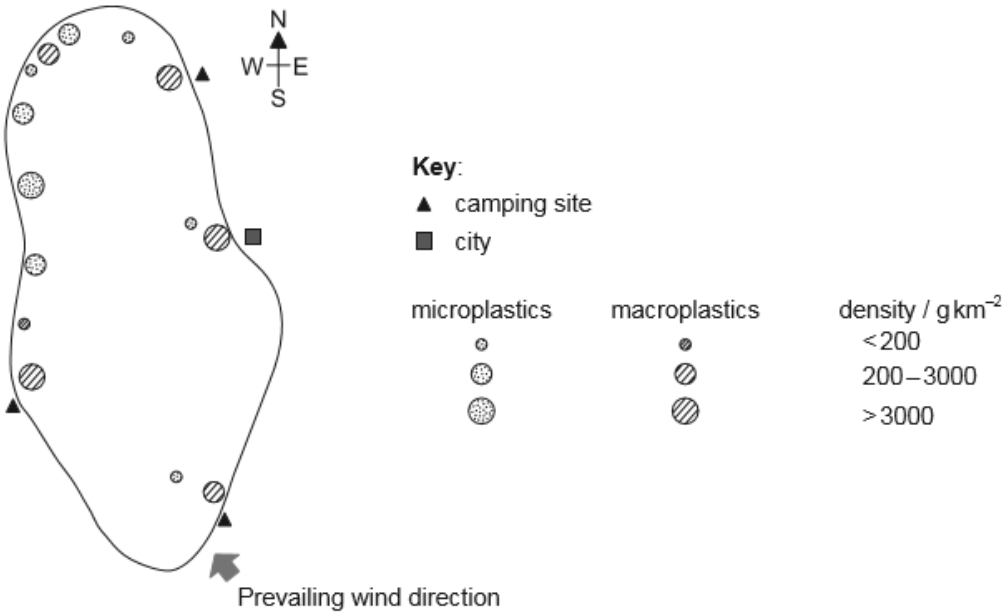
b. This was also a very popular option but not very high scoring in many cases.

Many were able to score 1 mark comparing levels of mercury in herbivores and detritivores with the better candidates scoring full marks.

c. This was also a very popular option but not very high scoring in many cases.

Many found this section difficult as they did not explain the large 'range' of mercury concentrations in piscivores but instead explained why there was a high level, which was not what the question asked. It was thus discriminating with only good candidates receiving the 2 marks.

The sketched map shows the density of microplastics and macroplastics found in a lake within a national park.



[Source: © International Baccalaureate Organization 2016]

a. Predict **one** example of macroplastic pollution that is likely to be found in this lake. [1]

b. State **two** possible effects on organisms of microplastic pollution. [2]

1. . . . . .

. . . . . .

2. . . . . .

. . . . . .

c. Outline the effect of wind on the distribution of plastic pollution in this lake. [2]

d. Suggest changes in the management of the national park that could reduce the amount of macroplastic pollution. [3]

Markscheme

a. plastic bottles

OR

fishing gear

OR

plastic bags

OR

plastic wrappers

*Award **[1]** for any source.*
Allow any other valid named source.

b. a. ingestion can reduce feeding

OR

false feeling of satiation

b. microplastics absorb toxins from water

c. filter feeders ingest the microplastics with the toxins

d. biomagnifications/bioaccumulation

c. a. microplastic density higher along the «north» western shore than the eastern shore

OR

wind blows plastics to opposite coast

OR

wind blows plastics away from their source/city/camping grounds

OR

wind increases degradation of macroplastics into microplastics

b. wind causes currents which moves the plastics

c. macroplastic pollution less affected by wind than microplastic pollution

d. a. improve city waste disposal

b. recycling programs
OR
develop community service teams to collect plastics «around the lake»/OWTTE

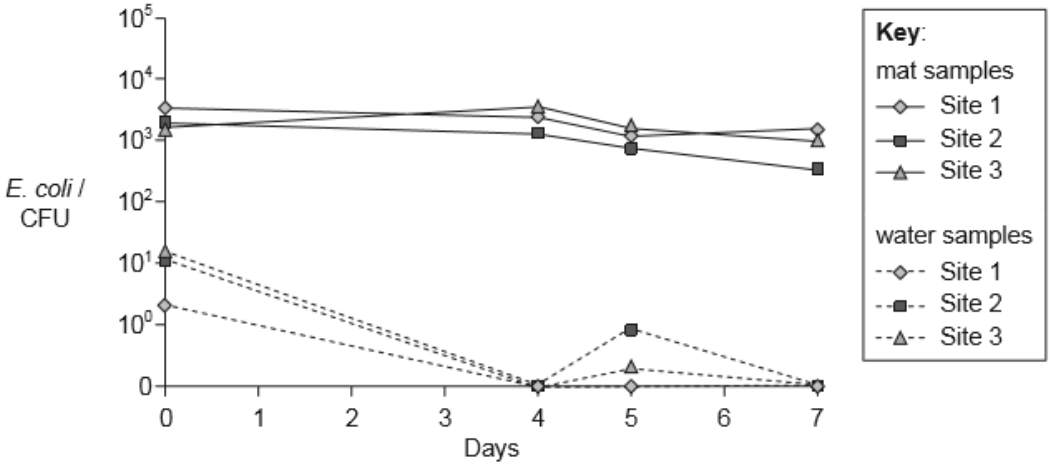
c. place litter containers/garbage cans close to camping sites

d. fines for those causing pollution
OR
pass littering laws

Examiners report

a. [N/A]
b. [N/A]
c. [N/A]
d. [N/A]

The filamentous green alga (*Cladophora*) forms mats along the shore of certain fresh water lakes. When the mats become stranded on beaches, they produce a bad odour from the action of decomposers. A study was undertaken on the abundance and persistence of fecal indicator bacterium *Escherichia coli* in the mats and in the water at three beach sites on one lake. The number of colonies (colony-forming unit or CFU) that grew from bacteria in a 100 gram sample of mat or water collected on day 0 at the three sites was measured on four days over an eight day period to test the survival of *E. coli.*



[Source: Adapted from O. Olapade *et al.* (2006) *Applied Environmental Microbiology*, **72** (3), pages 1932–1938. 'Microbial Communities and Fecal Indicator Bacteria Associated with Cladophora Mats on Beach Sites along Lake Michigan Shores'. Ola A. Olapade, Morgan M. Depas, Erika T. Jensen, and Sandra L. McLellan. Doi:10.1128/AEM.72.3.1932–1938.2006. Reproduced with permission from American Society for Microbiology.]

a. Identify the site with the lowest average CFU of *E. coli* in the water samples. [1]

b. Distinguish between the trends in the survival of *E. coli* on mat samples and in water samples over time. [2]

c. Scientists formerly related the population of *Cladophora* to changes in phosphorous levels in the lake. However, phosphorous quantities have decreased but *Cladophora* has recently increased along the shore. Suggest **two** reasons, other than phosphorous, for the change in population growth of *Cladophora* in the lake. [2]

d. Discuss the possible ecological relationships between *E. coli* and *Cladophora*. [2]

Markscheme

a. (site) 1

b. a. (CFU of) *E. coli* on mats remains higher/almost 10^2 more than in the water samples;

b. over time in mats the values do not change much while in water they decrease/disappear;

c. a. excess nitrogen from fertilizers as run-off from agricultural lands;

b. excess organic matter from sewage overflow;

c. change in temperature/global warming;

d. change in pH;

Do not accept a general statement of minerals or fertilizers in the water.

d. a. *Cladophora* provide a habitat for *E. coli* so more *E. coli*/CFUs (in mats);

b. *Cladophora* provide more food for *E. coli* so more *E. coli*/CFUs (in mats);

c. *Cladophora* in mats are dead and decomposed by *E. coli* /*Cladophora* in water are alive so not decomposed by *E. coli*;

Examiners report

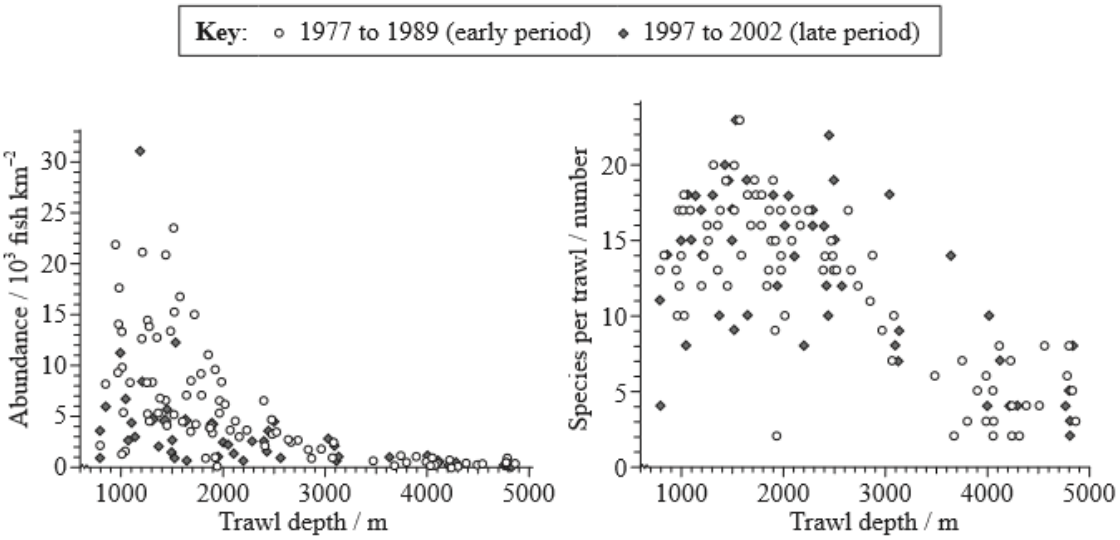
a. Most candidates were able to identify "site 1" and the trends in data, although some got lost in details for the latter.

b. The other parts of the question caused problems for most, showing that many candidates had not understood the relationship described in the stem, that the mats were formed of decomposing *Cladophora* and *E. coli*.

c. Suggestions were generally very vague and most candidates did not distinguish between conditions that would apply to a lake, such as changes in temperature and pH, and those in laboratory conditions, such as changing light intensity of CO_2 concentrations.

d. There were many wild guesses about the relationship between the two species, namely parasitism or mutualism without any justification for either.

Knowledge of deep-water fish is important for fisheries and marine reserve management. Scientists analysed data from scientific trawls made from 1977 to 1989 (early period) and from 1997 to 2002 (late period). These were at depths from 800 m to 4800 m in the Porcupine Seabight and Porcupine Abyssal Plain area southwest of Ireland. The graphs represent the abundance of fish and the number of species for each of these trawls.



[Source: D.M. Bailey, M.A. Collins, J.D.M. Gordon, A.F. Zuur and I.G. Priede, 'Long-term changes in deep-water fish populations in the northeast Atlantic: a deeper reaching effect of fisheries?' *Proceedings of the Royal Society B* (2009), 276 (1664), pp. 1965–1969. By permission of the Royal Society.]

a . State the depth at which the maximum number of species per trawl were caught. [1]

b (i) Compare the abundance of fish between the early period (1977 to 1989) and the late period (1997 to 2002). [2]

b (ii) Suggest **one** reason for the difference in the abundance of fish at depths down to 2000 m between the early period and the late period. [1]

c. Discuss the evidence in these data for a decline in the biodiversity of fish between the early period and the late period. [2]

d. State **two** types of interactions that are most likely to occur among deep-water fish. [1]

1. .....

2. .....

e. Outline the concept of maximum sustainable yield in the conservation of fish stocks. [2]

Markscheme

a . 1550 (m) (*accept answers in the range of 1450 (m) to 1650 (m)*)

b (i) both show decrease in abundance as depth increases;

both show similar/low abundance at depths greater than 3000 (m); (*accept values in range 2500 (m) to 3000 (m)*)

for depths less than 2500 (m) the abundance is (much) greater in the early period than in the late period; (*accept values in range 2000 (m) to 2500 (m)*)

the highest abundance occurs in the late period (although) this is isolated;

b (ii) overfishing / pollution / change in sea temperature / change in food sources

c. no evidence that there are fewer species;

difficult to compare as more trawls in the early period /early period of longer duration than late period;

diversity may have increased from (around) 2000 (m) to 4000 (m) / outliers for greater species diversity are all late period;

not enough details about time of year/duration of trawls; (*accept any other valid argument*)

Do not accept answers stating only "not enough data".

d. competition and predatory/predation *(both needed)*

e. is the maximum number of fishes of a species that can be caught/harvested without causing a population decline / still allowing a population to regenerate;

corresponds to the turning point of a population growth curve;

below that point yield is lower and population grows / above that point yield and population will decline;

used to determine fishing quotas;

difficulty in estimating populations;

Examiners report

a . Many candidates found interpretation of the graphical data about trawling challenging. Candidates frequently only gave enough to be awarded part credit. For (a) most candidates gave the correct answer.

b (i) Many candidates found interpretation of the graphical data about trawling challenging. Candidates frequently only gave enough to be awarded part credit. Most could compare the abundance values in (b) but many related to incorrect depth ranges.

b (ii) Many candidates found interpretation of the graphical data about trawling challenging. Candidates frequently only gave enough to be awarded part credit. Could not suggest one valid reason for the difference.

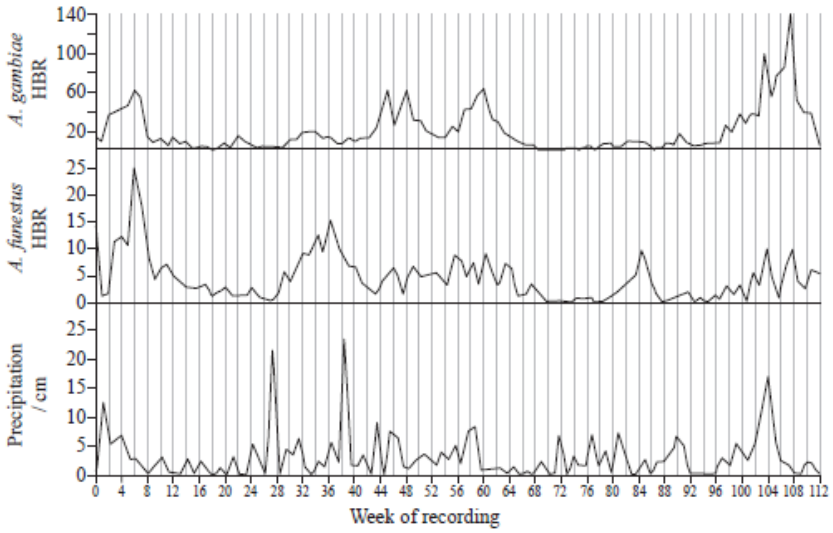
c. Many candidates found interpretation of the graphical data about trawling challenging. Candidates frequently only gave enough to be awarded part credit. Many candidates stated that there was no evidence for the decline in biodiversity, but very few could back up their statement using the data correctly, some overlooking that the data were showing fish abundance, or others restated the wording of the question.

d. Many candidates found interpretation of the graphical data about trawling challenging. Candidates frequently only gave enough to be awarded part credit. There was a mixture of answers for (d), many containing only one valid element.

e. Many candidates found interpretation of the graphical data about trawling challenging. Candidates frequently only gave enough to be awarded part credit. Most candidates could define the concept correctly in (e), but add difficulty to gain a second mark.

Many factors affect the distribution of animal species including weather patterns. The mosquito *Anopheles* is a carrier of malaria, a disease that kills one to two million people annually. The eggs of the mosquito are laid in water and they hatch out as larvae before turning into adult mosquitoes. A study was undertaken to look at the influence of weather patterns on the incidence of bites on children. Being bitten increases the risk of catching malaria.

The graphs show human biting rates (HBR) by *Anopheles gambiae* and *Anopheles funestus* and precipitation over the study period.



[J.A. Patz _et al._, 1998, "Predicting key malaria transmission factors, biting and entymological inoculation rates, using modelled soil moisture in Kenya", _Tropical Medicine & International Health_, 3, pp. 818-827, Figure 1 (adapted). Used with permission of John Wiley & Sons Inc.]

a. State the week number when the highest human biting rate (HBR) is found for *A. gambiae*. [1]

b. Calculate the difference in peak HBR for *A. gambiae* and *A. funestus* for week 6. [1]

c. Evaluate the effect of increased precipitation on HBR for both species. [3]

d. Suggest how predictions of global climate changes, such as predictions of precipitation patterns, could be used to help control malaria. [1]

e. Suggest another factor which might affect the ecological distribution of mosquitoes. [1]

f. Suggest a biological control that might be introduced to reduce HBR. [1]

Markscheme

a. (highest HBR for *Anopheles gambiae*/*A. gambiae* week) 107/108

b. 35 *(accept answers in the range of 34 to 37)*

c. a. both species show relationship between elevated precipitation and higher HBR (e.g. between week 0 and week 8 / week 100 and week 108);

b. there is a lag between the period of precipitation and the increase in HBR;

c. sometimes elevated precipitation does not lead to peaks of HBR (e.g. week 27);

d. precipitation has a greater effect on *Anopheles gambiae*/*A. gambiae*;

d. a. spraying insecticides just before rainy seasons;

b. draining swamps before (and after) rain;

c. providing (endangered) population with repellents/mosquito nets before rainy season;

e. temperature / breeding site / food supply / predators / other reasonable answer

Do not accept global warming.

f. a. using natural predators of mosquitoes;

b. using natural pathogens of mosquitoes;

c. introduction of sterile males;

d. setting traps baited with mosquito pheromones/hormones;

Examiners report

a. About half of the candidates could relate the peaks at different times. Most read the week well and calculated the difference in peaks well, but the evaluation of the effect of increased precipitation was poor.

b. About half of the candidates could relate the peaks at different times. Most read the week well and calculated the difference in peaks well, but the evaluation of the effect of increased precipitation was poor.

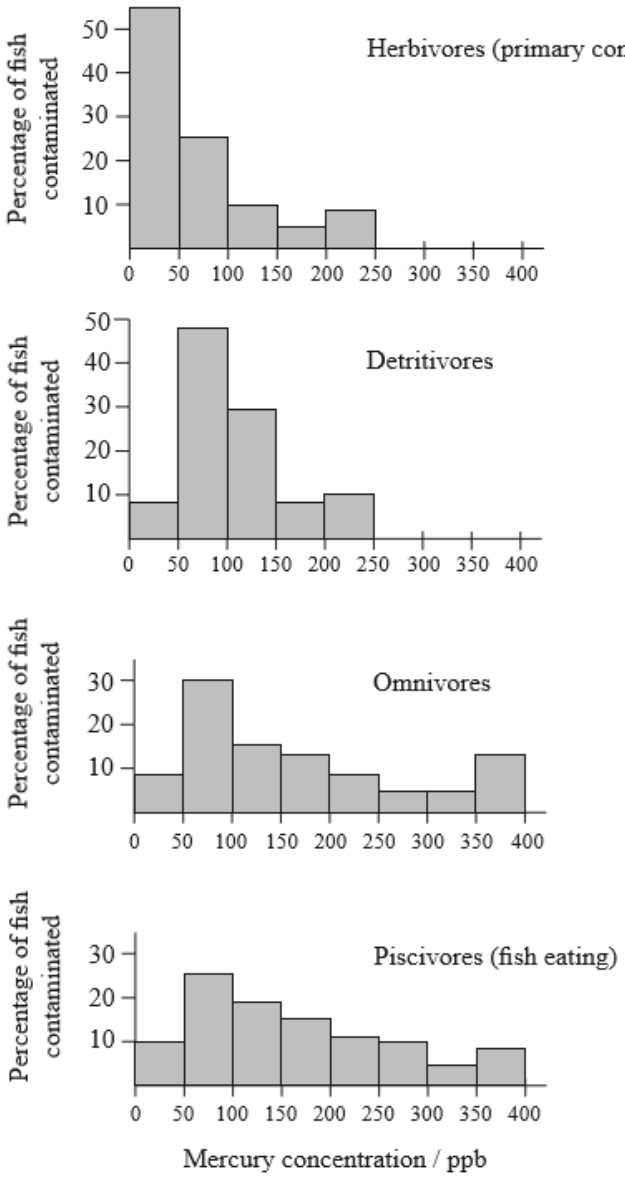
c. About half of the candidates could relate the peaks at different times. Most read the week well and calculated the difference in peaks well, but the evaluation of the effect of increased precipitation was poor.

d. About half of the candidates could relate the peaks at different times. Most read the week well and calculated the difference in peaks well, but the evaluation of the effect of increased precipitation was poor.

e. About half of the candidates could relate the peaks at different times. Most read the week well and calculated the difference in peaks well, but the evaluation of the effect of increased precipitation was poor.

f. About half of the candidates could relate the peaks at different times. Most read the week well and calculated the difference in peaks well, but the evaluation of the effect of increased precipitation was poor.

Indigenous human populations living along riverbanks in the Amazon basin often rely heavily on fish as a major part of their diet. The data shown below come from a study that was carried out to investigate levels of mercury contamination in the Rio Negro basin in Brazil. Mercury concentration was measured in fish belonging to four different trophic levels and is shown in parts per billion (ppb).



[Source: With kind permission from Springer Science+Business Media: *Archives of Environmental Contamination and Toxicology*, Mercury Biomagnification in a Tropical Black Water, Rio Negro, Brazil, 45, 2003, 235–246, A. C. Barbosa et al.]

Discuss how an understanding of biomagnification could help these human populations reduce their risk of mercury poisoning while maintaining their traditional diet.

Markscheme

a. (recognize that) some fish are more contaminated than others;

b. identify and eat fish that are close to the start of a food chain;

c. avoid eating piscivores/omnivores/highly polluted species;

d. eat only piscivores that feed close to the start of a food chain;

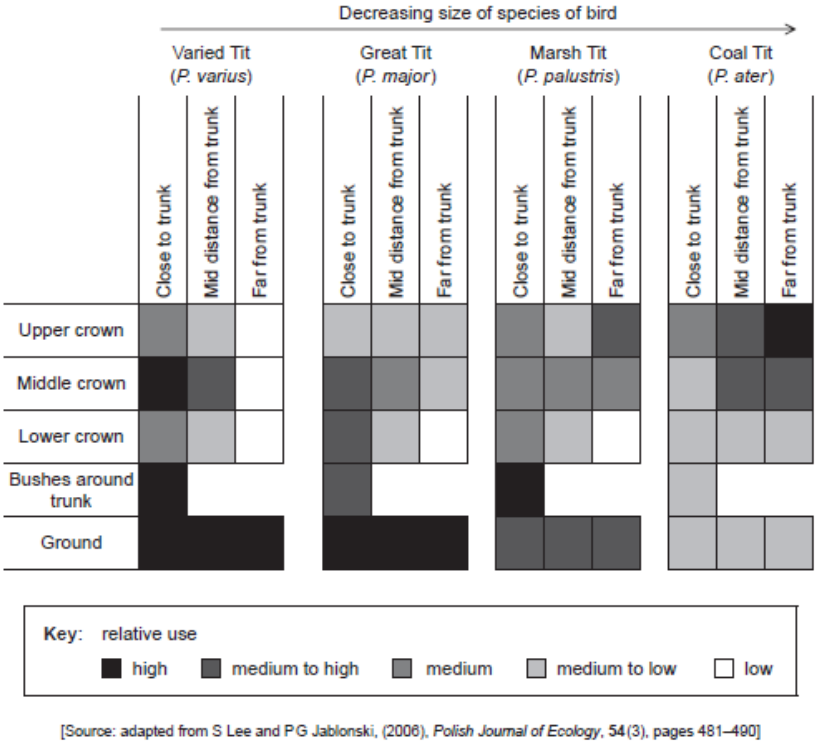
Examiners report

This was also a very popular option but not very high scoring in many cases.

Candidates often gave vague answers to this section and thus seldom were awarded more than 1 mark.

In South Korea, flocks of birds of the tit family (*Paridae*) forage together on trees for food. Researchers observed four species of *Paridae* to determine whether they shared the same habitat in the trees and whether their position on the tree depended on their size. The leafy part of the tree (crown) was divided into nine sections, three according to height from the ground and three according to the distance from the tree trunk. Observations were also made of birds foraging in the bushes surrounding the trunk and on the ground below the tree.

The chart shows the relative use of each section of the habitat by the birds.



[Source: adapted from S Lee and PG Jablonski, (2006), *Polish Journal of Ecology*, **54**(3), pages 481–490]

a. State the relative use of the habitat by the Great Tit in the upper crown of the tree close to the trunk. [1]

b. Identify the section of habitat used least by the birds. [1]

c. Compare how the Varied Tit and the Marsh Tit use the habitat in the upper crown of the tree. [2]

d. State how the distribution of birds changes with their size in the middle crown of the tree. [1]

e. Suggest **one** reason why few Varied Tits were found far from trunk. [1]

f. Discuss whether the results for the Varied Tit and Coal Tit indicate competitive exclusion. [2]

Markscheme

a. medium to low

b. lower crown, far from trunk

c.

	aspect	Varied Tit	Marsh Tit
a.	relative total use of upper crown to other habitats	less	more;
b.	use of close distance to trunk ***or*** use of mid distance to trunk	same;	
c.	highest use ***or*** use of far distance to trunk	closer to trunk less	far from trunk; more;
d.	selectivity of areas within upper crown	more concentrated in one section	all across three sections;

A table format is not required.

d. smaller birds make more use of the habitat further from the trunk / larger birds make more use of the habitat closer to the trunk

e. their food is close to the trunk / fewer predators close to trunk / too big for small outside branches

Accept any valid suggestion.

f. a. the competitive exclusion principle states that no two species can coexist if they occupy the same niche/compete for the same resources;

b. competitive exclusion is supported as there is little overlap between the two species in the habitat;

c. competitive exclusion is not supported as there is some overlap between the species;

d. we do not have enough information about the resources required by each species to say if competitive exclusion is occurring;

Examiners report

a. Some candidates simply did not read the questions with sufficient care and answered about sections of habitat that were not asked in the individual questions. Few candidates had difficulty stating the relative use for the Great Tit, but some did not address the two parts of the expected answer; some did not understand that the white spaces in the row of "bushes around trunk" were for lack of data, not "low" relative use. Most could compare the use of the habitat well although there was some difficulty in making clear, concise comparisons. Most could state how the distribution changes, but some in a very convoluted manner. Most candidates gave reasons as to food availability or the weakness of outer branches for heavier birds but some seemed to have understood the question the other way around. There were a considerable number of candidates who had a general understanding of competitive exclusion by realizing there is little overlap between the two species in the habitat, but only a few could define it correctly or provide opposite arguments.

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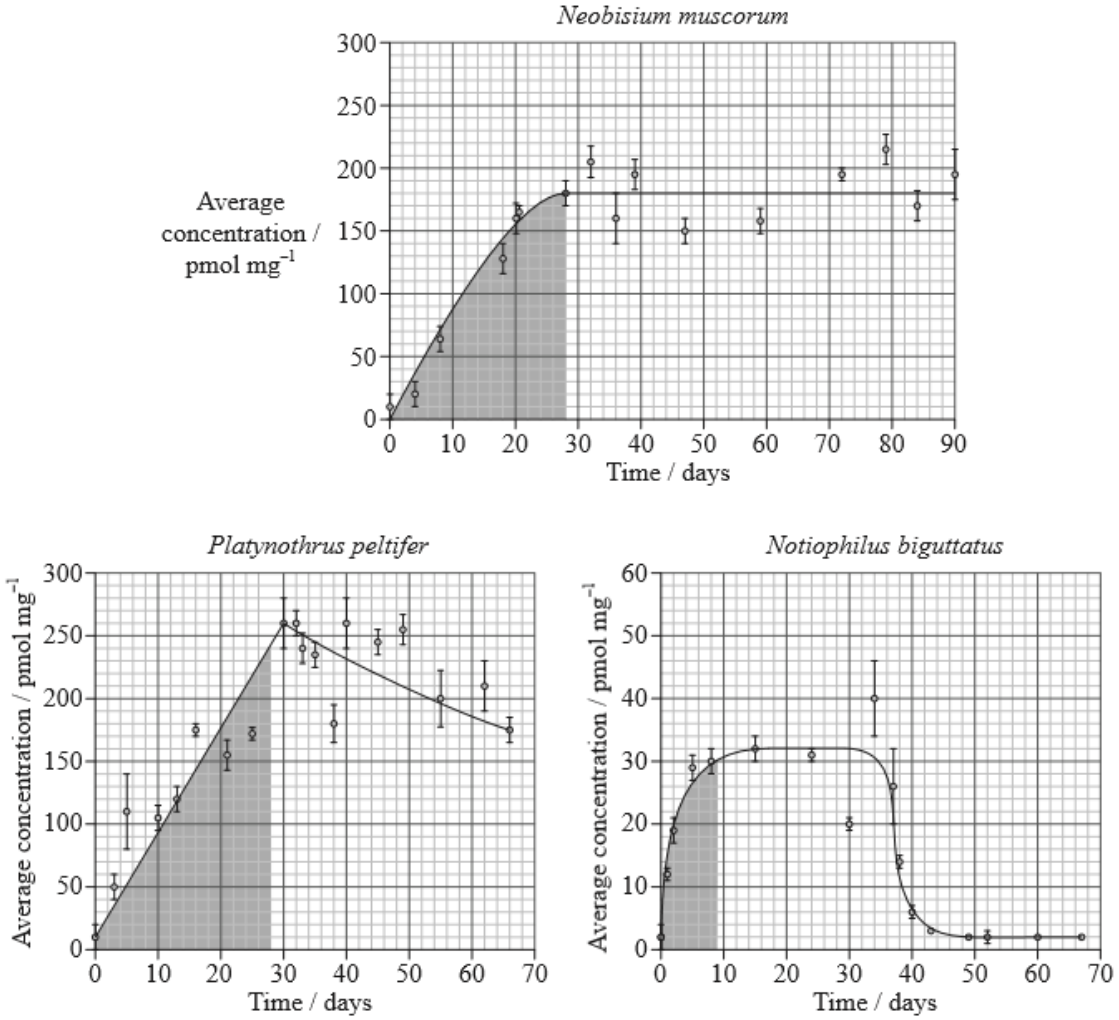
Cadmium is a heavy metal that can be toxic to many species. In a study, the concentration of cadmium was examined in the tissues of three soil arthropods, *Neobisium muscorum*, *Platynothrus peltifer* and *Notiophilus biguttatus*. The shaded area of each graph indicates the time that the organisms were exposed to cadmium in their environment, while the unshaded area indicates the time when cadmium was not present in their environment.



JANSSEN, M.P.M., BRUINS, A., DE VRIES, T.H., & VAN STRAALEN, N.M. (1991) Comparison of cadmium kinetics in four soil arthropod species. *Arch. Environ. Contam.* Toxicol., 20: 305-312

a. Identify the highest average concentration of cadmium found in *P. peltifer*. [1]

b. Determine, with a reason from the data, which species is unable to eliminate cadmium. [2]

c (i) State the species that accumulates the least cadmium. [1]

c (ii). Suggest, with observations from the data, a reason why the species stated in (c)(i) accumulates the least cadmium. [2]

d. Describe the possible effects of the presence of cadmium in food chains involving these arthropods. [2]

Markscheme

a. 260 pmol mg^{-1} (*accept answers in the range of 255 pmol mg^{-1} to 265 pmol mg^{-1}*)

b. *Neobisium muscorum*;

level of cadmium remains high / does not decrease (when cadmium is removed);

c (i). *Notiophilus biguttatus*

c (ii). can excrete/remove/eliminate cadmium (from its tissues);

faster reduction/removal / drops to lowest level after cadmium exposure;

cadmium levels stop rising sooner/rise slowing by day ten;

is less tolerant/dies when cadmium reaches a certain concentration;

exposed to cadmium for a shorter time/period;

d. cadmium accumulates along food chain / biomagnification / bioaccumulation;

heavy metals cause abnormal growth/behaviour/death/failure to reproduce;

Notiophilus biguttatus has less effect on the food chain (as it accumulates less);

cadmium harmful/lethal to organisms at/near the end of the food chain;

(death of arthropods) may change soil quality;

Examiners report

a. Parts (a) and (c) (i) were answered correctly by most candidates.

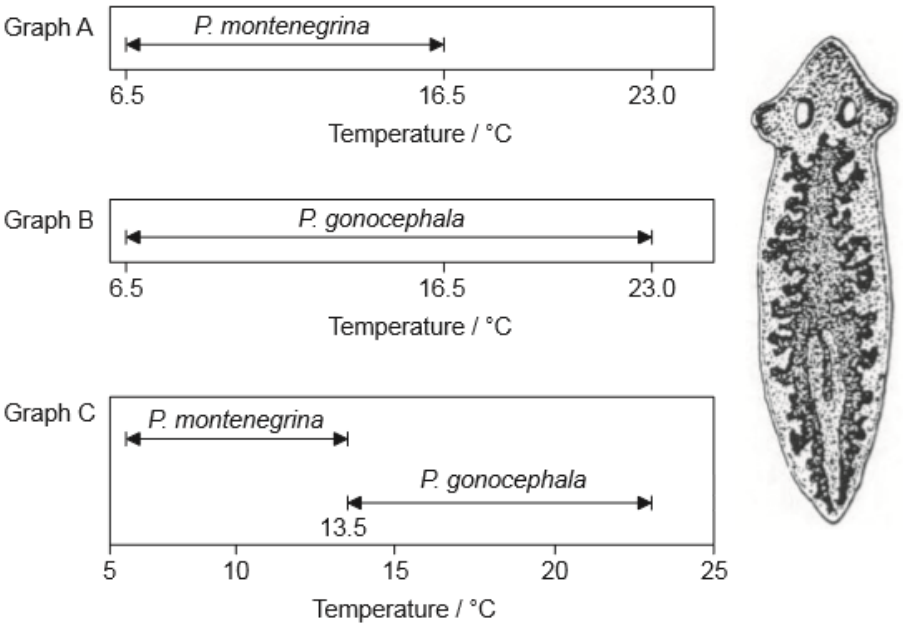
b. Most candidates answered (b) successfully.

c (i). Parts (a) and (c) (i) were answered correctly by most candidates. A few candidates abbreviated the genus names to an initial letter, which is not advised when there are two genera starting with the same initial.

c (ii). (c) (ii) proved more difficult. Where a question asks for reasons for something being least, among three species, it is necessary to give answers comparing the species, rather than just referring to the one that is least. For example, in this case it was better to say that *Noteophilus biguttatus* eliminates cadmium more rapidly than that it eliminates cadmium rapidly.

d. Part (d) was well answered by many candidates, who referred to biomagnification or bioaccumulation and then explained that animals at higher trophic levels would be most affected.

The figure shows the distribution of two species of freshwater flatworms, *Planaria gonocephala* and *Planaria montenegrina*, over a range of stream temperatures. Graph A and graph B show the distributions when each species is separate from the other. Graph C shows the distribution when they are found living together.



[Source: R. J. Putman (1994) *Community Ecology*, page 63. © Kluwer Academic Publishers Boston. Used with permission.]

a. Using graph A and graph B, compare and contrast the temperature ranges of the two species when they are found separately. [2]

b. Explain, with respect to the example of *P. montenegrina*, what is meant by realized niche. [2]

Markscheme

a. *P. gonocephala* is found over a greater range of temperatures (***Note**: do not accept just numbers (T) of ranges without comparing/contrasting clearly*).

P. gonocephala is found between 16.5 degrees and 23.0 degrees whereas *P. montenegrina* is not
OR
P. gonocephala is found at a higher temperature

Both are found in temperatures of 6.5 degrees to 16.5 degrees

Do not accept "both show a greater range" alone as this comes from graph C not A and B as the question asks.

b. Realized niche is that which organism actually occupies

Presence of another species/*P. gonocephala* narrows the niche

Limited by competition
OR
competitive exclusion

The realized niche is colder/smaller range in the presence of *P. gonocephala*

Examiners report

a. This question appeared to be fairly well understood but not always well answered. Some candidates simply listed the separate ranges without comparing them thus not getting the marks. As this was a ‘compare and contrast’ question, purely numerical descriptions do not score marks.

b. Again candidates often gave very poorly worded and confused answers and struggled to explain what a realized niche was. However, many were able to receive one mark as they understood that competition between species narrowed the niche.

---

a. State **one** example of a bacterium that forms aggregates. [1]

c. Outline the process of nitrogen fixation by a **named** free-living bacterium. [2]

d. The image shows part of a sewage treatment plant. [3]

[Source: http://purewatergazette.net]

Outline the role of bacteria in trickling filter bed treatment of sewage.

Markscheme

a. *Pseudomonas aeruginosa* / *Vibrio fischeri*

Accept other correct answers.

c. a. (atmospheric) nitrogen is converted to ammonia;

b. by *Azotobacter*;

Do not accept Rhizobium.

d. a. (saprotrophic) bacteria/biofilm fix on the surface of the rocks/material in the trickling filter;

b. bacteria decompose the sewage/organic matter as it runs over the filter bed;

c. bacteria break down organic matter aerobically;

d. the rocks increase the surface area for the decomposition of organic matter;

e. filter bed can treat high amounts of sewage quickly;

Examiners report

a. Many mentioned *Vibrio fischeri* or *Pseudomonas aeruginosa* as an example of bacteria forming aggregates, but some gave far too vague categories, such as methanogenic bacteria.

c. Most could state halophiles and *Azotobacter*, although there was some confusion with *Rhizobium*.

d. Many knew only that bacteria fix on the rocks, but did not give enough detail for more, showing poor understanding of the treatment of sewage.

Distinguish between tropical rainforest and taiga in terms of nutrient stores, nutrient flows and climate. Gersmehl diagrams can be used to support your answer.

Markscheme

Conditions		Tropical rain forest	Taiga
Nutrient stores	*Biomass (B)*	a. high levels «in biomass»	low levels ✓
	Litter (L)	b. low amounts of nutrient storage in litter	high amounts ✓
	Soil (S)	c. low amounts of nutrient storage in soil	low amounts ✓
Nutrient flows	*Transfer*	d. higher rates «S→B» «L→S» ***OR*** lower rates «B→L»	lower rates «S→B» «L→S» ***OR*** higher rates «B→L» ✓
	Leaching/run-off/ weathering	e. higher rates «not as high as other flows»	low rate ✓
Climate	*Temperature*	f. higher annual mean ***OR*** higher/warmer	lower average annual ***OR*** lower/colder ✓
		g. average annual temperature greater than 24 °C *«allow between 22°C and 26°C »*	–10 °C ***or*** –5 °C to 5 °C ✓
	Precipitation	h. high amounts of rainfall ***OR*** wet/wetter	much less rainfall ***OR*** dry/dryer ✓
		i. greater than 200 or 250 cm of rainfall annually	20–75 cm annually ✓

Examiners report

[N/A]

In 1988 a fire destroyed large portions of forest in Yellowstone National Park, USA. Photograph A was taken soon after the fire and photograph B one year later. The photographs are of the same area.

Photograph A

[Source: http://commons.wikimedia.org/wiki/File:Grass_growing_after_fire.jpg, created by National Park service employee.]

Photograph B

[Source: http://commons.wikimedia.org/wiki/File:Flowers_Yellowstone_1989.jpg, created by National Park service employee.]

a. Identify, with a reason, the type of succession that has taken place. [1]

c. Outline a method that could be used to sample the plant population shown in photograph B. [2]

d. Yellowstone National Park was the first national park in the world and is a designated biosphere reserve site. Outline the biogeographical features of nature reserves that promote conservation of diversity. [3]

Markscheme

a. secondary succession as some plants/organic components were present before fire

c. describe method for ensuring random placement of quadrats in a grid; (*do not accept transect*)

different species present in quadrat identified and counted;

used to estimate species density/frequency/abundance/cover;

d. *size*:

large nature reserves usually promote conservation better than small ones;

large areas needed for far-ranging animals (e.g. grizzly bear);

larger areas have proportionally smaller perimeters/less affected by edges;

edge effect:
ecology of edges of ecosystems is different from central areas due to edge effects;
fragmentation (of forests) leads to increase in edges which will favour some species over others;

habitat corridor:
habitat/movement/wildlife corridors allow organisms to move between different parts of fragmented habitat;

*To award **[3]** responses must refer to size, edge effect and habitat corridor.*

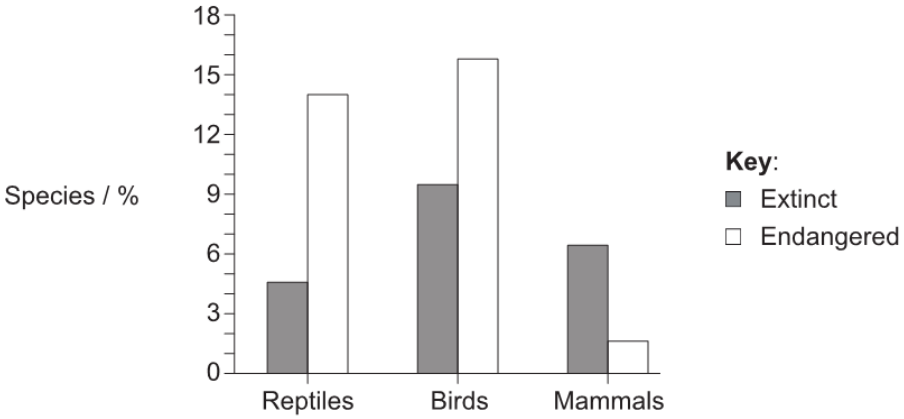
Examiners report

a. A good number of answers compared the two photos and made no reference to "before the fire", which was not strictly needed.

c. Similarly here, a question that could produce an essay for the answer. Answers generally referred to the fact that a single large herbivore appeared to be better for plant community due to higher and abundance. The rest of the answer tended to lack the clarity for the other marking points. Also some candidates took the question to mean a single plant species/population (understandably) therefore not evaluating what would happen when multiple large herbivores are present.

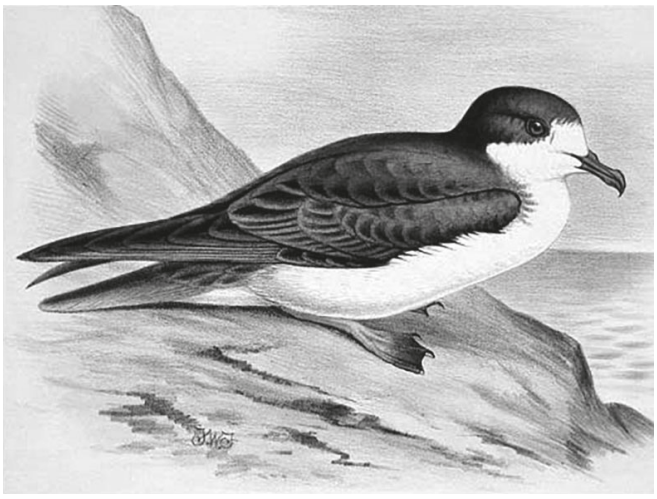
d. There were some very good answers including examples of all 3 requirements but most candidates wrote vaguely about pollution and avoiding humans. Some answers about natural reserves were also too vague, about "good nutrition and absence of predators".

To assess the impact of introduced cats (*Felis silvestris*) that prey on native species, a study was carried out on 120 islands around the world. The graph shows the impact of *F. silvestris* on reptiles, birds and mammals.



[Source: A global review of the impacts of invasive cats on island endangered vertebrates, F. M. Medina et al. (2011) Global Change Biology, 17, pp. 3503–3510. Reproduced with permission from John Wiley and Sons.]

The ‘Ua‘u petrel (*Pterodroma sandwichensis*) is considered to be an indicator species in the Hawaiian Islands.



[Source: https://commons.wikimedia.org/wiki/File:Oestrelata_phaeopygia_AvesHawaiienses00Wils_0382.jpg]

a.i. Identify how the pattern in mammals is different from reptiles and birds. [1]

a.ii. Describe how invasive species such as *F. silvestris* can have a significant impact on native species. [2]

a.iii. Suggest a method to limit the impact of *F. silvestris* on native species. [1]

b.i. State the role of an indicator species. [1]

b.ii. Identify possible approaches to maintain the population of *P. sandwichensis*. [2]

Markscheme

a.i. a. more extinct than endangered «in mammals as opposed to reptiles and birds»

b. total percentage extinct plus endangered mammals lower than reptiles and birds

[Max 1 Mark]

a.ii. a. cats/invasive species compete with native species for food/habitat/resources

OWTTE

b. invasive species/cats may reduce/endanger native populations

c. invasive species/cats may change the structure/balance of the food web/chain

[Max 2 Marks]

a.iii. a. control population/sterilization «of cats»/culling/hunting

b. keep household cats indoors

[Max 1 Mark]

b.i. a. early warning system

b. provide information on environmental conditions/ecosystem

OWTTE

[Max 1 Mark]

b.ii. a. ex-situ/zoos/captive breeding

b. control predators

c. in-situ/management of natural reserves/breeding habitats/parks/resources/clean-up pollution

d. education

OR

government legislation

Accept any other valid answer

[Max 2 Marks]

Examiners report

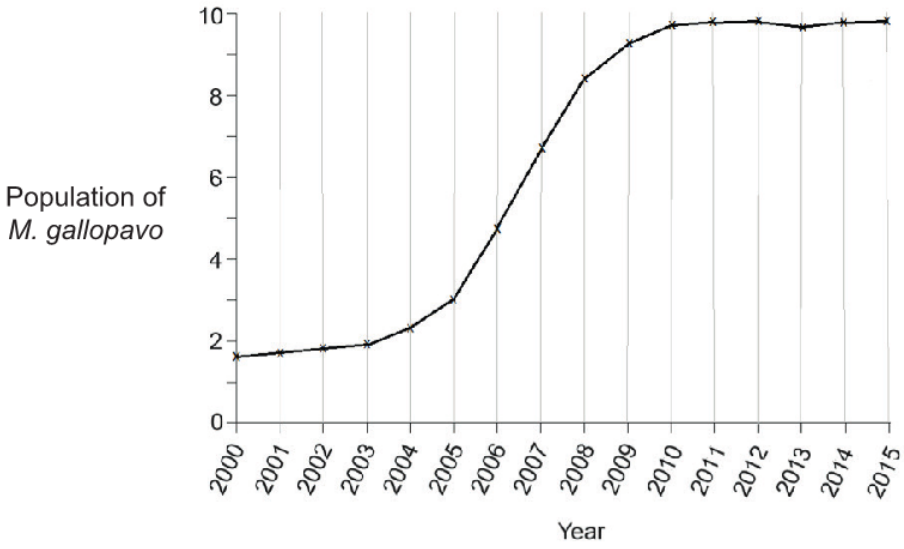
a.i. [N/A]
a.ii. [N/A]
a.iii. [N/A]
b.i. [N/A]

b.ii. [N/A]

Wild turkeys (*Meleagris gallopavo*) once inhabited most forested areas of North America. As an important food source for early European settlers, the population of *M. gallopavo* seriously decreased. Due to recent conservation efforts, population numbers are increasing.

[Source: https://commons.wikimedia.org/wiki/File:A_wild_turkey_in_Middleboro,_Massachusetts.jpg] (https://commons.wikimedia.org/wiki/File:A_wild_turkey_in_Middleboro,_Massachusetts.jpg])

The curve shows a population of M. gallopavo from 2000 to 2015 in Ohio in the mid-western USA.



a.i. State the range of years when exponential growth of the *M. gallopavo* population occurred. [1]

a.ii. Suggest factors that could account for the growth curve of the *M. gallopavo* population. [2]

b. State how the population of *M. gallopavo* may have been determined. [1]

c. Hunting of *M. gallopavo* is currently regulated. Predict what would happen if the hunting regulations were removed. [2]

Markscheme

a.i. 2000–2008

a.ii. a. natality ***AND*** mortality

b. immigration ***AND*** emigration

c. resources/abiotic conditions/carrying capacity

d. predation/hunting

[Max 2 Marks]

b. capture–mark–release–recapture/Lincoln/Peterson method

c. a. population would decrease/may become extinct

b. open realized niche for other organisms

OWTTE

c. food web may change

d. less intraspecific competition

[Max 2 Marks]

Examiners report

a.i. [N/A]
a.ii. [N/A]
b. [N/A]
c. [N/A]