OXFORD IB PREPARED

# ENVIRONMENTAL SYSTEMS & SOCIETIES

# ANSWERS

IB PREPARED

IB DIPLOMA PROGRAMME

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# IB Prepared environmental systems and societies

**Answers to *test yourself* questions**

Here are the answers to the *test yourself* questions from *IB Prepared Environmental Systems and Societies.*

For direct access, click on the unit title below.

## Unit 1: Foundations of environmental systems and societies

**1.1** Rainforests should be conserved and not be overexploited; rainforests have an economic value to humans as they may contain food, medicines, and materials for human use; ecotourism can also provide income; tropical rainforests have an intrinsic value and the biodiversity there has a right to exist free from human exploitation; rainforests provide life support functions for water cycles; they lock up carbon in plants that would otherwise be in the atmosphere; they are home to many indigenous peoples; because the soil is poor and thin the regeneration rate of rainforests is slow if they are cleared; rainforests provide spiritual, cultural, and religious value to local communities; it is important for humans to act as stewards for rainforests so that they can be enjoyed by future generations.

**1.2** Anthropocentrism is people-centred while technocentrism is technology-centred. Anthropocentrism: people can manage the environment in a sustainable manner; policies can be used to manage use of natural resources and restrict environmental damage; economic and educational tools can be used to encourage sustainable behaviour; problems are solved via community participation.

Technocentrism: trust in science and technology to provide solutions to environmental problems; seeks for scientific analyses of issues; technological evaluations and solutions need to be limited to experts, thereby excluding the wider community.

**1.3** A particular worldview that shapes the way an individual or group of people perceive and evaluate environmental issues.

**1.4** Self-reliant soft ecologists: social; conservation biologists: environment; bankers: economic.

**1.5** Self-reliant soft ecologist: e.g. community cooperative set up to sell local produce and share production costs to increase profits. Conservation biologist: e.g. preserving standing forest to generate revenue through ecotourism. Banker: e.g. investing in renewable technologies to meet energy needs in the future.

**1.6** Negative feedback: Feedback that tends to counteract any deviation from an equilibrium and promote stability; e.g. increased global temperatures cause more evaporation, leading to increased cloud cover that reduces input of solar radiation, thus decreasing temperatures.

Positive feedback: Feedback that increases change away from an equilibrium; e.g. increased global temperatures cause melting and shrinking of ice sheets, reducing albedo and thus further increasing global temperatures.

**1.7** A tipping point is a degree of change within a system that will destabilize it, causing it to adopt a new equilibrium.

**1.8** Social: reduced tourism; reduced storm protection; reduced food availability through fishing. Ecological: reduced biodiversity; reduced carbon fixation by coral structures.

**1.9** Natural capital is the sum of a natural resource in a given environment; natural income is the growth of that capital over time; for resource exploitation to be sustainable, it must not reduce the potential for future exploitation, hence the capital remains and it will have the potential to provide the same income in the future; if harvest is greater than natural income, natural capital is reduced and so there is a reduction in capital that will reduce the potential for future income.

**1.10** The regulating services that mountains, moorlands, and heaths provide include climate regulation, flood regulation, wildfire regulation, water quality regulation, and erosion control.

**1.11** The cultural services associated with urban ecosystems are likely to include recreation and tourism, aesthetic values, cultural heritage, spiritual values, education, sense of place, and health benefits.

**1.12** Soil formation, photosynthesis, and nutrient and water cycling.

**1.13** EIAs are time-consuming so may effectively prevent valuable development or not be completed in time to prevent development. A wide variety of skills are needed to collect appropriate data, which implies extensive education. There may be conflicts of interest as developers pay for the EIA, which may bias findings. The EIA allows the local community an input into the development of their area. Monitoring post development is often not completed so usefulness is limited. The recommendations of an EIA may not be followed. In some countries corruption may influence decisions rather than EIA.

**1.14** Technocentric approach: emphasizes technological solutions to environmental problems; can reduce footprints by increasing the biocapacity, e.g. using hydroponics or intensive agriculture; enables people to maintain their lifestyles while they are reducing their footprints; is more likely to be popular and therefore adopted; can increase efficiency of energy use, e.g. through halogen light bulbs whereas an ecocentric approach requires individual self-imposed restraint on resource use, which is less likely to be successful because people are too selfish or ignorant of the potential importance.

Ecocentric approach: emphasizes minimum disturbance of natural processes; emphasizes need for sustainability; encourages individual responsibility for reducing the resources they use/ can reduce waste, e.g. growing own food would reduce food miles; is community-based/ people feel part of the process; can be simple and therefore cheap, e.g. composting, so is possible even in LEDCs; involves education and therefore leads to changes in EVSs; whereas technocentric approaches require political will and more capital and often give rise to further increases in ecological footprint.

**1.15** Technological development may decrease the EF through the use of agricultural technologies for irrigation, fertilizers, and pesticides to increase productivity technology for hydroponic agriculture requiring fewer resources, thereby increasing energy efficiency and reducing $CO_2$ waste. Alternative energy sources (e.g. wind, solar, etc.) also reduce $CO_2$ waste.

Technological development may increase the EF through fossil fuel-dependent technology, thereby increasing $CO_2$ waste in production; technological development will lead to increasing demands for resources used in manufacture of technology; pollution produced by the manufacture of technology will require more waste assimilation; this will reduce limits to population growth, thereby increasing demand for resources and waste assimilation; this in turn will promote rapid turnover of technologies, encouraging a consumer market that increases the rate of resource consumption.

**1.16** Rich countries can have a “throwaway” society and so generate a large amount of waste/pollution; some LEDCs accept the waste of other countries for recycling; e.g. Bangladesh accepts many old ships for recycling; often the polluters would rather follow step three (i.e. clean up pollution and restore damaged systems), when caught, than the other steps, as this may <u>seem</u> cheaper; capitalist societies often consider the economic profit over the environmental damage of pollution: often they would rather treat the symptoms (effects) of pollution rather than address the causes of pollution.

## Unit 2: Ecosystems and ecology

**2.1** **(a)** As the population of prey increases, more food is available for predators; this leads to an increase of the predator population; this leads to an increase in predation, so prey population decreases; this in turn leads to cyclical changes around a stable equilibrium; this is a negative feedback mechanism.

**(b)** There may be excessive predation by the predator population so the prey species declines; this would occur if the predator is a non-native species; predator populations may continue to grow unregulated by a given prey species if they feed on other prey species as well, leading to the long-term decline of the given prey species; if an environmental change causes decline of other prey species, predators with a choice of prey may focus predation more heavily on remaining species, leading to their long-term decline; if the prey species does not have time to reproduce then prey numbers will decline.

**2.2** Similarities: both can be population interactions; in both two individuals are involved (includes both inter- and intra-specific); both can lead to a stable equilibrium in populations; both limit population size; at least one species is negatively affected in both.

Differences: predation negatively affects one species whereas competition (usually) negatively affects both competitors; in predation, one species (predators) depends on the other, whereas in competition neither is dependent on the other; competition reduces available resources for both species; competition can involve competing for habitat, not just food; the species involved in predation represent two different trophic levels, whereas competition may represent the same trophic level.

**2.3** Biotic factors are living components of the environment which influence an organism or ecosystem; abiotic factors are non-living factors which influence an organism or ecosystem. Abiotic examples include rainfall, temperature, sunlight; biotic examples include predators, which eat prey.

**2.4** Ecosystems are open systems, i.e. both matter and energy are exchanged; matter is cycled, but not energy; ecosystems contain inputs, outputs, and stores; inputs and outputs can be of energy and matter to and from e.g. producers, consumers, decomposers, water, and soil storage; energy enters an ecosystem as light, is transferred in matter, e.g. food web, and leaves as heat.

**2.5** The first law is the law of conservation of energy, whereby in transformations energy is conserved and not created or destroyed; the first law is demonstrated in that all chemical energy comes from light energy and is converted by photosynthesis, but no new energy is “created”; energy entering producers is equal to energy stored and then energy dissipated as heat. The second law states that in any transformation there is a dissipation of energy; this is demonstrated in that while some energy is stored as chemical energy in producers, there is a net dissipation of energy which is lost as heat through respiration to the environment; the efficiency of photosynthesis and subsequent conversions is much less than 100%; often only 10% is passed on, and 90% lost before the next trophic level; producers maintain order through the continuous input of solar energy.

**2.6** The example of a food chain should be from an ecosystem you have studied, possibly on a field trip. You need appropriate names of organisms and arrows showing the direction of energy transfer (if arrows point in the wrong direction, you will not receive any marks). Appropriate names could be species with common names or scientific names or broader groups of organisms, e.g. oak tree, water snail. General terms, e.g. plant, fish, bird are not acceptable. Food chains must have four or more named organisms (i.e. at least three links). Food chains must start with a producer.

**2.7** Pyramid of biomass; pyramid of productivity.

**2.8** Strengths include the idea that they are a simple method of giving an overview and that they are good for comparing changes in the number of individuals over time or season. Weaknesses include: all organisms are included regardless of their size; numbers can be too great to represent accurately; there is the question of where to put animals that feed at more than one trophic level (e.g. omnivores).

**2.9** Pyramid of numbers: displays the numbers of individuals at each trophic level of a food chain; they may differ greatly in shape and may be inverted (depending on e.g. size of organisms and time of year); represents storages; represents quantities present at a given moment/snapshot in time.

Pyramid of productivity: represents the flow of energy at each level; measured in units of $g/m^2/yr$ or $J/m^2/yr$; tends always to be pyramid-shaped and cannot be inverted; represents flows rather than storages; represents rates/changes over a period of time.

**2.10** Data required: (rate of) food eaten minus faecal loss; rate of food absorption/gross secondary production; rate of respiration; measurements must be per unit area, per unit time; can be calculated using biomass/ at time $t + 1$ minus biomass at time $t$.

**2.11** Energy enters (most) ecosystems from the Sun (energy enters some ecosystems from e.g. geothermal vents); plants convert this energy into new biomass; plants use photosynthesis to convert light energy into chemical energy; energy is transferred from the autotrophs to consumers by consumption; energy is lost as heat in respiration as it is transferred along a food chain; this illustrates the second law of thermodynamics; only about 10% of the available energy in one trophic level is passed onto the next/higher trophic level; chemical energy is transferred to decomposers via waste and the death of organisms.

**2.12** **(a)** $\left(\frac{630}{4200}\right) \times 100 = 15\%$

**(b)** $\left(\frac{5}{25}\right) \times 100 = 20\%$

**2.13** **(a)** combustion; **(b)** respiration; **(c)** consumption; **(d)** photosynthesis.

**2.14** X: nitrogen fixation; nitrification; Y: denitrification; Z: nitrification.

**2.15** Named biome: e.g. deserts. Deserts are located around 30° N & S of the equator; this is an area where dry air descends, limiting the rainfall in these regions; deserts are also associated with rain-shadows formed from mountains or cold ocean currents, limiting rainfall; their location ensures that deserts receive relatively high levels of insolation; due to lack of moisture and cloud formation and the high insolation, deserts are subject to relatively high diurnal temperature fluctuations; due to lack of water, deserts have low relative productivity; lack of primary production leads to nutrient-poor soils; this leads to a very simple ecosystem structure with short food chains.

**2.16** Succession is the (orderly) process of change over time in a community; changes in the community of organisms frequently cause changes in the physical environment that allow another community to become established and replace the former through competition; zonation is the arrangement of communities into zones over distance due to a change in an environmental factor. An example of succession is the change over time in a forest community from a pioneer community of lichens and mosses to a climax community of mature trees and shrubs. An example of zonation is the arrangement of communities in bands on a mountain from tropical rainforest at the bottom to alpine communities.

**2.17** Pioneer communities are at the start of a succession whereas climax communities are at the end. Other differences:

| Pioneer community | Climax community |
|---|---|
| The first seral stage of a succession | The final seral stage of a succession |
| *r*-strategists are abundant | *K*-strategists are abundant |
| Simple in structure with low diversity | Complex in structure with high diversity |
| Species can tolerate harsh conditions such as strong light and low nutrient levels | Characteristics of climax community are determined by climate and soil |
| e.g. community of lichens covering bare rock | e.g. community of trees and shrubs |

**2.18** Ecosystem stability refers to the resilience of the system and its tendency to avoid tipping points and maintain stability; a complex ecosystem, with the variety of nutrient and energy pathways it provides, contributes to its stability; habitat diversity is associated with high levels of species diversity which in turn are associated with high levels of genetic diversity; high levels of habitat, species, and genetic diversity are intrinsically linked with ecosystem stability; during the initial stages of colonization, biodiversity increases greatly but then stabilizes; a climax community is more diverse and thus more stable than the earlier stages of succession; during earlier stages of succession, the communities can become diverted due to human interference, when the system has less resilience; an ecosystem's capacity to survive change may depend on diversity and resilience; a climax community in a tundra biome, with simple nutrient and energy pathways, may be less resilient than a climax community (with complex nutrient and energy pathways) in a tropical rainforest.

**2.19** Some features can change with season, gender, age, and genetic variety; keys often require detailed and specialized knowledge of anatomical parts, etc.; judgment is subjective and it is easy to make a mistake; it can be difficult to distinguish between similar species; only already discovered species can be identified; it only applies to physical features, not all attributes (such as differences in vision).

**2.20**

$$\frac{(60\times 50)}{15}=200$$

**2.21 (a)**

| Species | Stream A | | Stream B | |
|---|---|---|---|---|
| | ***n*** | ***n* − 1** | ***n*** | ***n* − 1** |
| Mayfly nymph | 4 | 4(3) = 12 | 0 | 0(−1) = 0 |
| Caddis fly larva | 30 | 30(29) = 870 | 0 | 0(−1) = 0 |
| Freshwater shrimp | 70 | 70(69) = 4,830 | 1 | 1(0) = 0 |
| Water louse | 34 | 34(33) = 1,122 | 4 | 4(3) = 12 |
| Bloodworm | 10 | 10(9) = 90 | 45 | 45(44) = 1,980 |
| Sludgeworm | 2 | 2(1) = 1 | 100 | 100(99) = 9,900 |
| **$\sum n(n-1)$** | | **6,925** | | **11,892** |
| **Simpson diversity index** | **3.23** | | **1.88** | |

For stream A:

$$N=4+30+70+34+10+2=150;\ N(N-1)=150(149)=22{,}350$$

$$D=\frac{22{,}350}{6{,}925}=3.23$$

For stream B:

$N = 0+0+1+4+45+100 = 150; N(N-1) = 150(149) = 22,350$

$D = \frac{22,350}{11,892} = 1.88$

**(b)** The Simpson diversity index is higher in stream A compared to stream B; there is greater evenness/similarity between species counts in stream A compared to stream B; all species are found in stream A whereas mayfly nymph and caddis fly larva are not found in stream B.

**(c)** Stream B may be polluted, leading to a reduced diversity index; certain species may be able to survive in stream B but not in stream A, leading to the dominance of one species (sludgeworm); stream A may be an older/more complex environment, leading to a greater number of niches and increased diversity; stream B may be a simpler ecosystem with fewer niches and deceased diversity.

**2.22** Answers should include a named ecosystem, e.g. an Alpine Pine Forest in the Swiss Alps.

Reference to establishing a baseline study and repetition: make a baseline study before human activity begins and repeat at regular intervals over time after the human activity or at different distances from human activity.

Methods to record changes due to human activities: use an appropriate biotic sampling method, e.g. randomized quadrats, water samples, kick samples, mark-release-recapture (Lincoln Index), and so on, to establish abundance of species; use the Simpson diversity index to assess the community; use a relevant and standardized sampling method of measuring abiotic data e.g. light meter, anemometer, thermometer, pH meter, Secchi disk, and so on.

## Unit 3: Biodiversity and conservation

**3.1** Biodiversity is a broad concept encompassing the total diversity of living systems, which includes the diversity of species, habitat diversity, and genetic diversity.

Transects, quadrats, or other sampling methods are used to collect data on number and abundance of species; the Simpson diversity index, or another diversity index, can be used to calculate species diversity; then values are extrapolated for larger areas.

**3.2** Rainforests may contain food, medicines, and other materials for human use; rainforests have an intrinsic value; they have a life support function for water cycles, as carbon sinks, and as an oxygen provider; they contain high biodiversity; they have aesthetic value; they can attract tourists who can bring income to the area; they may be the home for indigenous people; their regeneration rate is slow; they may have spiritual, cultural, or religious value to local communities; stewardship value of having rainforests for future generations.

**3.3** Adaptive radiation of species, e.g. Galápagos finches; variation in species within the fossil record, with some species surviving and others going extinct; fossils show a chronological (time) sequence in which characteristics appearing and developing in complexity; similarities and differences in DNA structure between species.

**3.4** Natural selection is survival of the fittest, where the best adapted survive; survivors will pass on favourable, inheritable traits to their offspring; populations of a species may become isolated from one another; isolation may lead to speciation and greater species diversity; with natural selection populations will adapt over time to their different environments; the change will occur up to a point when they can no longer interbreed, and so new species are formed; adaptive radiation through natural selection in newly formed and diverse habitats can increase species and genetic diversity in a population.

**3.5** The outer crust of the Earth is divided into many plates that move over the molten part of the mantle (magma)—the plates move apart, slide against each other, or collide; magma can be released through plate movement, causing new land to form; as plates move populations become isolated; plate activity results in the creation of new habitats; island populations are separated from each other, allowing speciation; populations become separated by mountain uplift or other physical barriers; the uplift creates new habitats, promoting biodiversity; adaptation to new habitats occurs; isolation can lead to behavioural differences, leading to reproductive isolation; in addition, collision of plates allows convergence of land masses, producing a mixing of genetic pools, promoting new ecological links and possibly hybridization. Examples of plate tectonics movement leading to speciation—plate activity can create new islands, usually through volcanic activity; this can lead to adaptations to fill new habitats; e.g. Galápagos finches have undergone speciation to fill many of the niches on the volcanic islands and they now are very different from the mainland original finch.

**3.6** Natural selection leads to survival of the fittest, leading to adaptation of populations to new environmental conditions; isolation occurs when members of a population are prevented from interbreeding due to geographical barriers, e.g. mountain formations, continental drift, and island formation; isolation occurs when members of a population are prevented from interbreeding due to reproductive barriers, e.g. behavioural, ecological or anatomical differences; the isolated groups within the population may then be subject to different selective pressures and natural selection occurs; this means that the separate groups evolve increasingly different characteristics and become unable to reproduce fertile offspring between them; in this way natural selection can lead to speciation.

**3.7** Fossil record extinctions occurred over relatively long timescales, over thousands to hundreds of thousands of years; present-day extinctions are occurring over relatively short timescales, from decades to hundreds of years; extinctions within historic times are largely attributable to human causes, e.g. overhunting, habitat loss, pollution, and climate change; past mass extinctions are linked to natural causes, e.g. meteorite impact, extreme volcanic activity and changes in atmospheric composition; give a named example or time of a mass extinction, e.g. K-T boundary, Triassic, Permian, Devonian and Ordovician; give an example of a present-day organism that has gone extinct due to human causes, e.g. passenger pigeon.

**3.8** An alien species that has increased rapidly in number, having a negative effect on the environment and on native species.

**3.9** Some occur naturally, for example climate change has allowed mosquitoes to breed in parts of southern Europe (and the southern UK as they did in the early 20th century); others may be escaped pets, such as the parakeets of south-west London; some are deliberately introduced by humans for a food supply, for hunting, for potential medical or commercial reasons, and for aesthetic purposes.

**3.10** The impacts are very varied. In some cases they can lead to the decline of native (indigenous) species, e.g. the decline of red squirrels relative to grey squirrels; likewise many forestry plantations prefer quick-growing coniferous trees at the expense of slower-growing native deciduous trees as they derive a faster economic return. Another impact is the introduction of disease, such as the crayfish plague introduced by the invasive signal crayfish that attacks the white-clawed crayfish. Yet another impact is the cost of tackling invasive species—estimated to cost the UK £1.7 billion per year. Alien species altogether are estimated to consume 3,300 million cubic metres of water, which amounts to 7% of South Africa's annual run-off. Invading alien plants destroy the productive potential of land, contributing to poverty, unemployment, and social problems. After habitat destruction by humans, the introduction of invasive species is the second biggest potential cause of species extinction in the world.

**3.11** For example: red-clawed signal crayfish (*Pacifastacus leniusculus*), a large, aggressive American species which has wiped out almost 95% of the native UK white-clawed species (*Austropotamobius pallipes*) since it was introduced to the country in the late 1970s; human activity has led to an increase in numbers of crown of thorns starfish which eat coral reefs, leading to extensive damage (e.g. Great Barrier Reef).

**3.12** It is difficult and expensive to manage invasive species. To preserve the white-clawed crayfish the South West Crayfish Project is trying to:

- increase awareness about how disease can be transmitted and the problems facing native crayfish
- introduce a breeding programme and release crayfish back into the wild
- move "at risk" populations to safe areas.

In South Africa, for example, a lightly infested hectare of land could cost about R100 (£9) to clear, whereas the same land, left for 15 years, would cost 40 times as much to clear. Thames Water is paying up to £1 million a year to keep pipes and filters clean and clear from alien species such as zebra mussels.

**3.13** Example for modern agribusiness in temperate grasslands of Prairies, USA.

Explanation: monoculture leads to loss of species diversity; pesticides can kill all insect species, not just the pests being targeted; crops reduce species diversity as natural grasses are outcompeted; selective herbicides remove broad leaf species in cereal crops.

Example for cyanide fishing in tropical waters off the Philippines.

Explanation: reefs are biological hotspots, cyanide kills many species directly; cyanide kills coral polyps which form the base of the food chain and therefore other species are lost as they lose their food source.

**3.14** Example: Amur tiger.

Ecological factors: as a top carnivore, the tiger requires a large ecosystem so that it can find sufficient food; as a mammal with a relatively low reproduction rate, its population growth is slow.

Human activities: direct hunting by humans leads to reduction in the population; fragmentation of habitat through human land use leads to lack of gene flow and inbreeding, leading to low genetic diversity; loss of habitat and prey species through pollution, hunting, and habitat disturbance leads to increased competition for resources.

Conservation difficulties: tiger habitat may cross national boundaries, making cooperative management and international protection agreements difficult; protection may be undermined by corruption and an illegal market demand for tiger parts; low employment may promote poaching, limiting the effectiveness of enforcement and protection.

**3.15** A named extinct species, e.g. Sumatran rhinoceros in Borneo; white Rhino in Uganda.

Low species numbers could lead to non-viable population; habitat degradation, fragmentation, and loss, e.g. through logging, could lead to loss of food and shelter; increased competition due to human interference, e.g. invasive species or environmental change; pollution can degrade the habitat, e.g. greenhouse gases and global warming could reduce habitat range in Arctic regions for polar bears; pollutants can bioaccumulate, e.g. some pesticides can biomagnify up the food chain, especially affecting successful breeding of species high in the food chain.

Interventions to improve conservation status: e.g. legislation to stop or reduce hunting; international agreements to control trade in endangered species, e.g. CITES; policing and enforcement of legislation, e.g. hunting ban; community involvement, education, and general awareness could improve the value placed on the species; captive breeding and re-introduction programmes could increase numbers; setting up a protected area to conserve habitats.

**3.16** Without economic valuation, services provided may be ignored by decision makers; valuation allows for a comparative measure, e.g. value against income generated from building roads through woodlands; it may be difficult or impossible to objectively quantify intrinsic value; ideologically, there is a need to move away from economic value and be guided by intrinsic value in nature; organisms have rights like humans and no price is attached to human life.

**3.17** When problems cross borders (e.g. smuggling endangered species), international cooperation is vital; many issues are global and so require a global response; international agreements highlight issues involved in conservation and development across the globe; they can help motivate governments to take action and honour their commitments.

**3.18** The snow leopard is a flagship species and as such likely to attract public attention; it could be a keystone species; the species faces a variety of different threats; threats may be increasing, due to climate change and overhunting.

**3.19** Anthropocentric: humans must sustainably manage the ecosystem; their approach is practical, e.g. raising awareness and support in local communities.

Technocentric: they believe that technological developments can provide solutions to environmental problems, e.g. GPS tracking to monitor leopards; their approach is optimistic about the role humans can play in improving the situation; scientific research is encouraged in order to form policies and understand leopard depletion.

**3.20** Advantages of CITES: It is supported by many countries (178); it lists many species (ca. 35,000); it bans international trade in many products and species under Appendix I (i.e. species under threat of extinction); it regulates trade in Appendix II species to ensure sustainable use; it has proven to be successful for many species; many countries have signed up to it: it has only 14 member states fewer than the United Nations.

Disadvantages of CITES: Enforcement is difficult; fines are relatively small and may not deter poaching and smuggling; support by some countries is limited and ineffectual; despite the agreement illegal hunting still occurs, e.g. poaching of elephants in Africa.

**3.21** Strengths: attaching intrinsic value to species that have no economic value can prevent them being overlooked in decision making and prevent collapse of ecosystems and loss of biodiversity; recognition of intrinsic value is likely to promote ecosystem conservation, so preserving whole habitats and many species; public perception of intrinsic value is often crucial to the success of conservation efforts; some argue that all species have rights and their intrinsic value needs to be considered; a wide variety of ecosystems can be conserved as each species has intrinsic value rather than just charismatic species; educating people with respect to intrinsic value will encourage people to respect even species considered as pests, which would help in conservation efforts.

Weaknesses: Decisions usually have an economic aspect and intrinsic value has no economic value; intrinsic value is not recognized by some value systems, causing conflicts in decision making; intrinsic value given to a species may vary according to different EVSs; environmental NGOs may hinder economically important projects (e.g. construction of buildings) on the ground of species' intrinsic value; applying the ideals associated with intrinsic value may overlook significant human needs (e.g. where human rights may be overlooked).

**3.22** The Convention on International Trade in Endangered Species of Wild Flora and Fauna (CITES); captive breeding and reintroduction programmes; zoos.

**3.23** Uses high-profile species that catch the public attention both nationally and internationally (e.g. the tiger in India); however, it may be less successful in saving non-charismatic species (e.g. the endemic Madagascan cockroach); with *in situ* conservation, saving a named species means that its habitat will also be protected, which benefits other organisms in the same habitat; however, a species can be artificially preserved in a zoo (*ex situ* conservation) whilst its natural habitat is destroyed (e.g. giant panda); the species-based approach may lead to conservation efforts focusing on less-endangered animals but ones that attract public to zoos.

**3.24** Trade in souvenirs (e.g. body parts); habitat loss; fashion (e.g. furs); exotic pet trade; traditional medicine; competition with invasive species; bush meat; overhunting; pollution; agricultural growth.

**3.25**

| | **Advantage** | **Disadvantage** |
|---|---|---|
| Protected areas | Can conserve whole ecosystems<br>Allow research and education<br>Preserve many habitats and species<br>Prevent hunting and other disturbance from humans<br>Allow *in situ* conservation | Can be very expensive<br>Difficult to manage<br>Subject to outside forces that are difficult to control<br>Difficult to establish in first place due to political issues/vested interests |
| Zoos | Allow controlled breeding and maintenance of genetic diversity<br>Allow research<br>Allow for education<br>Effective protection for individuals and species | Have historically preferred popular animals not necessarily those most at risk<br>Problem of reintroducing zoo animals to wild<br>*Ex situ* conservation and so do not preserve native habitat of animals |

**3.26** Species-based conservation: focuses on vulnerable species and raising their profile; attracts attention and therefore funding for conservation; can be very successful in saving keystone species; can successfully preserve a species in zoos and botanic gardens, e.g. golden lion tamarin; CITES addresses cross-border issues and can prevent illegal trade, thereby protecting species; but if habitat is not preserved it is difficult to preserve species; high cost due to enforcing trade restrictions at border crossings and maintenance costs in zoos.

Protected areas: protect the whole ecosystem and therefore complex species interrelationships so long-term survival is more likely; preservation of diversity is more likely with a holistic approach as diversity can be species, habitat, and genetic; visiting an intact ecosystem enables it to be studied to increase understanding of its functions; there may be species that have not been discovered yet; protected areas can become islands and therefore lose biodiversity due to their size and shape; require sufficient funding to ensure that they are not disturbed; visiting protected areas as an ecotourist raises awareness and profits are recycled back into biodiversity programmes.

## Unit 4: Water and aquatic food production systems and societies

**4.1** 2.5%.

**4.2** Ice sheets and glaciers 68.7%, groundwater 30.1%.

**4.3** The hydrological cycle is an open system as it receives energy and matter from outside of its boundaries in the form of insolation and precipitation.

**4.4** Storages include vegetation, soils, bedrock, river channels, and lakes. Flows include throughflow, stem flow, infiltration, percolation, and base flow.

**4.5** Infiltration is the process by which water soaks into or is absorbed by the soil. Throughflow refers to water flowing through the soil in natural pipes and percolines (lines of concentrated water flow between soil horizons).

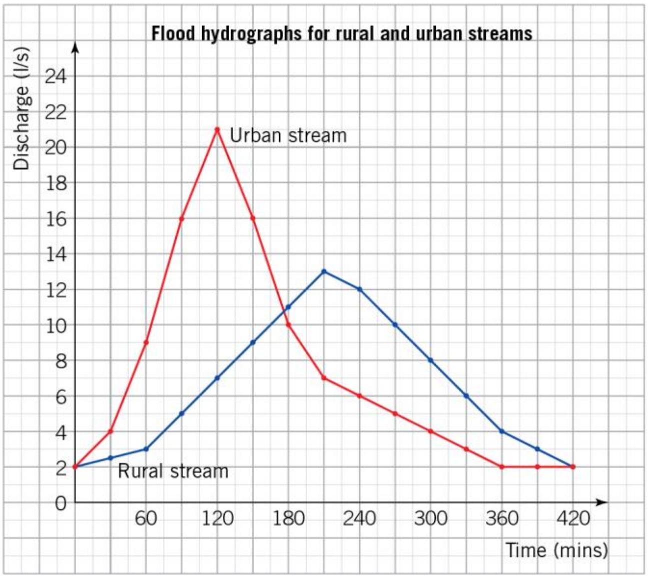
**4.6** Aquifers are permeable rocks, such as sandstone and limestone, and they can store large volumes of water.

**4.7** Agriculture/irrigation, which accounts for 8% of freshwater runoff.

**4.8** Agriculture can lead to a decline in infiltration and an increase in overland flow due to compaction of the soil by machines and/or animals; cultivation of steep slopes; removal of natural vegetation, allowing higher rates of wind erosion and overland flow.

**4.9** Deforestation can lead to reduced infiltration and increased overland flow due to reduced interception rates of mature forests, increased raindrop impact causing soil compaction which leads to reduced infiltration and increased overland runoff.

**4.10**




**4.11** **(a)** 13 l/sec at 210 minutes; **(b)** 21 l/sec at 120 minutes.

**4.12** The rising and recessional limbs for the urban hydrograph are steeper than those for the rural one.

**4.13** The urban areas have more impermeable sources (pavements, roads, buildings, roofs) and a higher drainage density (gutters, drains, sewers as well as any streams/rivers) so less water gets into the soil. It gets to rivers and streams quicker than in rural areas.

**4.14** The Gulf Stream/North Atlantic Drift is an example of a warm current; the Labrador Current is an example of a cold current.

**4.15** Ocean currents are important as they transfer energy and nutrients around the world. They influence climate in coastal areas.

**4.16** 27%.

**4.17** 844 million.

**4.18** **(i)** 47% **(ii)** 37%.

**4.19** Physical water scarcity occurs when water consumption exceeds 60% of the usable supply, whereas economic water scarcity occurs when there are sufficient water supplies but additional funding is required to pay for storage (e.g. dams) and transport (e.g. pipes and canals).

**4.20** Water stress is expected to increase in some areas due to a combination of increased population, improvements in standards of living, change in diet and global climate change.

**4.21** In 1945 the majority are in the northern hemisphere; the USA has most dams; there are a large number of dams in Europe/Japan/India; there are relatively few dams in most of South America/Africa/Oceania. By 2005, there are more large dams in all parts of the world; there are major increases in the number of large dams in China/India; there are many large dams around the coast of South America.

**4.22** Water harvesting refers to the capturing and channelling of a greater proportion of rainfall into the soil, and keeping it in the root zone. In contrast, desalination refers to the removal of salts and minerals from seawater making it usable for human consumption and irrigation.

**4.23** It will receive a share of the energy; it will control flooding, increase the amount of water for irrigation, and increase agricultural output.

**4.24** Egypt fears that it will receive less water and so have less potential for HEP and for irrigation.

**4.25** Fishing and aquaculture mainly harvest from the top of the food chain (high up the food chain) whereas agriculture mainly harvests from the lower trophic levels (producers and herbivores).

**4.26** Shallow oceans, coastal margins, and coasts with upwelling currents are generally more productive/have more nutrients and so are more productive.

**4.27** The proportion of overfished marine stocks increased from around 10% in 1975 to over 30% in 2015.

**4.28** Aquaculture showed very low rates of growth from 1950 to 1975 (about 1 to 5 million tonnes (mt)); it then began to rise steadily to about 10 mt by 1985. Thereafter, it increased rapidly to about 80 mt by 2015.

**4.29** The mayfly nymphs are abundant upstream of the source of pollution, but their numbers reduce significantly at the site where the pollutants enter the stream. With increased distance downstream, the mayfly nymphs begin to recover.

**4.30** The mayfly nymphs require clean and well-oxygenated streams. At the source of pollution there is an increase in tubifex worms, increased biochemical oxygen demand and reduced oxygen availability. Hence the mayfly population is reduced. However, downstream, as the effluent has been broken down or consumed, the tubifex population decreases, there is less BOD, and oxygen availability increases. Hence the mayfly population can increase.

**4.31** Eutrophication leads to the nutrient enrichment of water bodies. The increased nutrients lead to algal blooms, oxygen starvation and, eventually, a decline in species diversity.

**4.32** Two ways of dealing with eutrophication are to avoid using nitrate fertilizers in areas close to streams, and using bales of barley straw to prevent the growth of green algae.

## Unit 5: Soil systems and terrestrial food production systems and societies

**5.1** The soil has a mineral-organic layer at the surface, consisting of vegetation, litter and soil particles. Beneath is a light-brown soil with some roots present. There is a very clear division between the soil and the bedrock.

**5.2** An E horizon is an eluvial horizon which has material taken away (leached). A B horizon is a deposited/illuvial horizon in which materials are deposited.

**5.3** Field capacity is the maximum amount of water that a soil can hold.

Soil moisture deficit occurs when the loss of water by plant uptake and evaporation exceeds the amount of water entering a soil through precipitation.

**5.4** The podzol has very clear horizons. There is some vegetation at the surface and then underneath is a very dark mineral organic horizon. Beneath this is a lighter leached (eluvial) horizon and then a darker deposited (illuvial) horizon at the base of the soil. The horizons are clearly differentiated. In contrast, the brown earth varies from a darker brown at the surface to a lighter brown further down. There are no clear horizons, just a merging from top to bottom.

**5.5** Leaching refers to the downward movement of materials in a soil, carried by percolating water. In contrast, waterlogging can be top-down (too much rain saturating a soil) or bottom-up (rising groundwater). Waterlogging leads to oxygen deficiency in a soil.

**5.6** Salinization refers to the accumulation of saline salts in a soil, usually at the surface, and these are toxic to most plants.

**5.7** Nutrients get into soil either from the weathering of rocks or dissolved in rainwater. Nutrients from rocks are taken into the soil—some may be leached away but some are taken up by plants and pass through the food chain. When organisms die, the nutrients that they contain are released from the litter back into the soil through degradation and mineralization. Some nutrients may be removed from the litter by runoff.

**5.8** Loam soils are mixed soils.

**5.9** Loam soils contain varying proportions of sand, silt and, clay. They retain some moisture and allow some water to infiltrate; they have some nutrients present and some air too. They support a high primary productivity.

**5.10** **(a)** A silt loam **(b)** A sandy clay loam.

**5.11** **(a)** Using a large amount of money/machinery per unit area **(b)** producing food for consumption by the farmer and their family **(c)** producing crops for export, not for home consumption – the produce may not even be edible, e.g. tobacco, flowers.

**5.12** The countries most dependent on agriculture are generally poor as agricultural exports do not earn much currency, their agriculture is often subsistence, and they lack capital for investment in agriculture. Often TNCs control some of the higher-quality productive land.

**5.13** The largest producers have very large populations (e.g. China and India), advanced technology (e.g. the USA), a favourable climate and soils for agriculture (e.g. Indonesia), and a large area of land for farming.

**5.14** Fertilizers help to increase crop yield and indirectly livestock yields, by making the soil more fertile/productive. Pesticides control weeds, insects, fungi, and other small organisms that may damage crops and reduce yields.

**5.15** Pesticides may accumulate in the food chain (bioaccumulation) and may become more concentrated higher up in the food chain (biomagnification). They can also have an impact on human health—an estimated 70,000 agricultural workers die every year due to pesticide poisoning.

Antibiotic-resistant bacteria may develop in animals' guts. These bacteria can spread into the environment and may infect animals sold for human consumption. Each year around the world there are some 1.2 million cases of food poisoning due to salmonella, resulting in nearly 20,000 hospital cases and about 400 deaths.

**5.16** Inequalities in food production occur at two scales—the international and the intra-national. At the international scale, food production is greater in areas with an adequate water supply and favourable land. At the intra-national level (within a country) production of and access to food are influenced by poverty, accessibility, infrastructure, and conflict.

**5.17** In some MEDCs governments provide subsidies for their farmers. Subsidies encourage farmers to produce more food. Many LEDCs cannot afford to pay their farmers subsidies. MEDCs may also charge import tariffs. This makes it more expensive to import food from overseas. Multi-government organizations, such as the EU, have provided guaranteed prices and guaranteed markets to encourage food production. These have been modified to reduce over-production and harm to the environment.

**5.18** The farms/allotments on the edge of Shanghai are a form of intensive, sedentary, arable, subsistence farming. The farm by the Three Gorges reservoir appears to be arable, intensive, and sedentary.

**5.19** The walkers on the mountain have compacted the soil, making it impermeable and causing water to flow overland and erode the soil. They have also degraded the vegetation to the point that it is absent from the footpath. Thus there is nothing to hold the soil together.

**5.20** In time, the walkers will move away from the centre of the path towards the edge, where there are fewer rocks but more vegetation cover. This may cause the cycle of footpath erosion to start all over again.

**5.21** Overgrazing occurs when there are too many animals on the land, grazing on the vegetation and compacting the soil. Over-cultivation is the process of growing too many crops on the land and not allowing the soil to recover its fertility.

**5.22** Irrigation is the artificial adding of water to the soil to make crops grow. In hot areas, evaporation and capillary action may draw the water back up towards the soil's surface. If the soil contains soluble salts, these too may be drawn up to the surface, but left behind when the water evaporates, leading to the development of a saline crust near the surface. This is known as salinization.

**5.23** Contour ploughing involves ploughing around a hill (along the contours) rather than up and down a hill. This reduces the downslope movement of water as it gets trapped in the plough furrows. Cover crops help to bind the soil. They also protect it from rain-splash erosion.

**5.24** The check dams traps water and soil following a flood. These produce good conditions for upslope farming behind the check dam. Water and/or soil can be taken from the reservoir following a flood and applied to the land locally, thereby improving soil quality and providing water for crops.

## Unit 6: Atmospheric systems and societies

**6.1** Incoming solar radiation (insolation).

**6.2** Outgoing terrestrial radiation and reflected solar radiation.

**6.3** Flows in the Earth's climate system include the flow of energy from the Sun to the Earth, the flow of energy from the Earth into the atmosphere, and flows of energy through ocean currents and wind.

**6.4** Ice and fog.

**6.5** Humans may influence the Earth's climate system through emissions of dust, $CO_2$, water, sulfur dioxide, leading to changes in temperature and rainfall, etc.

**6.6** Cambrian, Ordovician, Silurian, Devonian, Jurassic, and Cretaceous.

**6.7** Polluted air contains more particles than clean air (e.g. ash, soot, sulfur dioxide) and therefore provides many more sites for water to bind to. The droplets formed tend to be smaller than natural droplets, which means that polluted clouds contain many much smaller water droplets than naturally occurring clouds. Many small water droplets reflect more sunlight than fewer larger droplets, so polluted clouds reflect far more light back into space, thus preventing the Sun's heat from getting through to the Earth's surface.

**6.8** The amount of incoming radiation that is reflected by a surface.

**6.9** Cumulonimbus clouds and stratocumulus clouds are very thick and tall—some can be up to 10 km in height—and so they reflect a large amount of insolation. They only appear dark because light cannot pass through and they contain a lot of moisture.

**6.10** The greenhouse effect is the process by which certain gases (greenhouse gases) allow short-wave radiation from the Sun to pass through the atmosphere but trap an increasing proportion of outgoing long-wave radiation from the Earth. This radiation leads to a warming of the atmosphere.

**6.11** Stratospheric ozone shields the Earth from harmful radiation that would otherwise destroy most life on the planet.

**6.12** It is a thinning of the ozone layer in the stratosphere.

**6.13** CFCs were in fridges, aerosols, air conditioners, fire extinguishers, and pesticides.

**6.14** UV radiation damages marine phytoplankton; it causes reduced rates of photosynthesis; organisms that live at the surface of the water during their early life stages are also affected. These include phytoplankton and fish eggs and larvae; UV radiation can cause genetic mutations in DNA. Recent studies of the effects of UV radiation on phytoplankton show a range of impacts. There are also negative impacts on reproduction. It can cause cancer in living tissue.

**6.15** HFCs and hydrocarbon refrigerants have largely replaced CFCs in fridges. Alternatives to aerosols can be used, e.g. using soap instead of shaving foam. The use of methyl bromide was phased out in the USA and Europe in 2005.

**6.16** The Montreal Protocol led to the phasing out of some 98% of the ozone-depleting substances (ODSs) contained in nearly 100 hazardous chemicals worldwide by 1986.

**6.17** Primary pollutants are the emissions that are active when emitted, e.g. nitrogen monoxide, whereas secondary pollutants are pollutants that arise from the physical or chemical change of primary pollutants, e.g. nitrogen monoxide reacting with oxygen to form nitrogen dioxide.

**6.18** A temperature inversion is an atmospheric situation in which cold air is found at low altitudes and warm air at higher altitudes, inverting the normal pattern of a decrease in temperature with increasing altitude.

**6.19** It is possible to alter human activity to deal with photochemical smog, e.g. increased walking or cycling rather than using a car. It is possible to control the release of pollutants, e.g. car sharing, or increased use of public transport. It is possible to have more clean-up and restoration, e.g. reforestation, new green spaces, conservation areas to sequester carbon.

**6.20** Wet deposition refers to acid rain and acid snow whereas dry deposition refers to the fallout of particulates of sulfur and nitrogen.

**6.21** Sulfur and nitrogen oxides.

**6.22** Copper.

**6.23** Coniferous trees experience thinning of the crown, decreased resistance to drought, disease and frost; there is increased shedding of leaves and needles; there is increased loss of nutrients from leaves, e.g. calcium and magnesium, and damage to the root hairs.

**6.24** Use alternatives to coal; develop international agreements to reduce pollution.

**6.25** Use of catalytic convertors and scrubbers to reduce nitrogen and $SO_2$ from vehicles and coal-burning power stations.

## Unit 7: Climate change and energy production

**7.1** Non-renewable energy resources can only be used once, e.g. oil and coal, whereas renewable resources can be used many times, e.g. HEP and tidal.

**7.2** Figure 7.1.1 shows a nodding donkey which is used to extract oil.

**7.3** Oil is predicted to increase from around 200 TJ to about 225TJ. Gas is predicted to increase from around 150 TJ to about 190 TJ.

**7.4** Natural gas (40 TJ)

**7.5** Hydroelectric power and nuclear power.

**7.6** Biofuel can be cheap to produce and may be sustainable. However, it has high production costs and it releases greenhouse gases.

**7.7** Peat burning is a relatively inefficient form of energy and it releases a large volume of greenhouse gases.

**7.8** The use of fossil fuels is projected to increase as there is a large supply of fossil fuels (at least in the short term), countries have the infrastructure to develop and use these resources, and the companies producing them are keen to continue making profits.

**7.9** Two methods of energy conservation include greater use of public transport and carpooling (sharing).

**7.10** Zero carbon emissions can be achieved by using electric vehicles which derive their energy from renewable sources.

**7.11** The community living in the settlement shown could benefit from increased agricultural productivity (higher temperatures mean it is warmer and has a longer growing season) but could also be affected by increased flooding if the glacier were to melt.

**7.12** **(a)** Absolute increase 80 ppm (75–85 ppm is an acceptable answer); **(b)** relative increase c. 25% (20–27% is an acceptable answer).

**7.13** Between 1880 and about 1940, global temperatures were below the long-term average for 1880–2018. Briefly in the 1940s they went above average, and then fluctuated above and below average until the mid-1970s. Since then, temperatures have always been above the long-term average, and they peaked around 2016 at about 1°C above the long-term average.

**7.14** The average temperature rise is predicted to rise slowly at first and then more rapidly after 2040, reaching 4°C above the 2000 level by 2100. In contrast, the worst-case scenario has more rapid growth, and for longer, and is predicted to be 6°C above the 2000 level by 2100.

**7.15** 5,235 (floods, storms, extreme temperatures, wildfire, and drought).

**7.16** Some floods may not be related to weather, i.e. dam bursts due to structural failure, earthquake-lakes, some fires could be due to arson, etc.

**7.17** There are likely to be many deaths due to drought. Drought may lead to famine, malnutrition, hunger – these are usually the recorded causes of death rather than drought.

**7.18** Sea level is predicted to rise by between 40 cm (average prediction) and 80 cm (worst-case scenario) by 2100 compared with 2000.

**7.19** Negative feedback is self-regulating and returns to the original starting point. Positive feedback leads to increasing deviation away from the original starting point.

**7.20** **(a)** A technocentrist would claim that people have the technology and know-how to solve the problems associated with global warming. **(b)** An anthropocentrist would stress the need for people to manage global warming, e.g. through taxes, environmental regulation, and legislation. **(c)** An ecocentrist would argue that nature is more important than humans and that we should reduce greenhouse gas emissions, no matter what the cost (economically).

**7.21** It is a form of adaptation as it is dealing with rising tidal/sea levels in the Thames estuary.

**7.22** Increased reflectivity (albedo) will reflect more solar radiation, therefore the Earth will heat up less (from outgoing long-wave radiation).

**7.23** Afforestation will increase the storage of carbon, therefore less gets into the atmosphere and so global warming will be reduced.

**7.24** Increased ocean fertilization occurs due to runoff of fertilizers and detergents into the oceans, which leads to increased nitrate and phosphate in the waters. These increase the amount of carbon-absorbing plankton, so atmospheric increases are reduced and global warming is slowed down.

**7.25** The Kyoto Protocol is an example of mitigation as it is trying to reduce the emissions of $CO_2$.

**7.26** 2.5°C–4.5°C.

**7.27** **(a)** Sea walls and **(b)** irrigation or desalinization.

**7.28** Rich countries have the financial resources to build facilities, e.g. sea walls and desalinization plants, whereas low-income countries do not.

**7.29** There may not be sufficient water resources; there might not be the resources to develop water resources; there may not be the political resolve/ technical ability.

**7.30** There are a number of reasons: **(a)** deforestation to make land available for agriculture, settlement, transport, industry, etc.; **(b)** climate change is leading to less rainfall, increased temperatures and more fires; **(c)** corruption in some countries releases forest areas for development purposes.

## Unit 8: Human systems and resource use

**8.1** CBR c. 19.1‰; CDR c. 4.7‰

**8.2** NIR 1.44%. Doubling time 48.6 years.

**8.3** **(a)** 118 years **(b)** 37 years **(c)** 13 years and **(d)** 12 years.

**8.4** 3.5 billion.

**8.5** Over time the proportion of elderly people increases; the proportion of young people declines; there are changes in the age of the adult population—in 1950 it was mainly young adults and the proportion decreased steadily with age, but by 2020 there are two bulges, one around 20–24-year-olds and one around 40–44-year-olds.

**8.6** In stage 5 of the DTM there is an increased number of elderly people, i.e. it is an aging society. Hence the death rate increases. The country is at a high level of development. Most young women are educated and have careers—they may not wish to have children or they may decide to have fewer children. The cost of raising children and home ownership has become very expensive in MEDCs and so many young people believe that they are unable to undertake the burden of having children—thus the birth rate falls.

**8.7** **(a)** MDG 4 Reduce child mortality and MDG 5 Improve maternal health; **(b)** SDG 3 Ensure healthy lives and promote well-being for all at all ages.

**8.8** China's one-child policy was an anti-natalist policy. As a result, China's population growth slowed, and by 2015 it had an aging population and a declining workforce. To meet the shortfall in the workforce (which would be worse some 20 years later) the government introduced a pro-natalist policy to encourage more people to have more children.

**8.9** "Ecological services" refers to the range of goods and services that ecosystems provide for humanity. For example, they can provide food, water, flood control, climate regulation, raw materials, building materials, protection against ultraviolet radiation, etc.

**8.10** Non-renewable resources can take millions of years to be "renewed".

**8.11** **(a)** Wood fuels, fossil fuels, and electricity; **(b)** Water, fossil fuels, and wood fuels.

**8.12** Carbon storage (sequestration) may decline in the short term as trees are felled – it might increase in the long term with afforestation.

**8.13** Services provided by woodlands include: primary productivity; climate regulation; flood regulation; and recreation/relaxation.

**8.14** Some of the value provided by ecosystems (natural capital) may be spiritual, aesthetic, intrinsic, and ethical. These are important values but are impossible to quantify and may vary from person to person and across societies.

**8.15** **(a)** Cultural factors may promote nuclear power as it does not produce greenhouse gases when operating; **(b)** however, nuclear power is associated with radiation and there have been nuclear disasters such as Fukushima–Daiichi in Japan.

**8.16** The use of uranium may decline in future if nuclear fusion is commercially developed. Fusion is based on hydrogen atoms and so there would be less need for uranium.

**8.17** It is most likely from an MEDC/NIC since the waste material is electronic and electrical and most people in LEDCs do not throw away as many electrical/electronic goods.

**8.18** **(a)** The largest component of waste in LEDCs and NICs is organic/biomass waste whereas in MEDCs it is paper and card. **(b)** All three types of country have as their lowest disposal metals and glass, although both are higher in MEDCs.

**8.19** The highest rates, over 2.5 kg per person per year, are in MEDCs such as the USA, Norway, New Zealand, and Ireland. Sri Lanka is an exception, being an NIC. There are high rates (above 2 kg per person per year) in MEDCs and NICs. In contrast, the lowest rates (0.00–0.49 kg per person per year) are in LEDCs, especially in sub-Saharan Africa and south Asia.

**8.20** Rates are likely to increase in urban areas because of the movement to urban areas to work and to improve standards of living. As people's disposable income increases, they spend proportionately more on food, packaging, consumer goods, and this in turn generates more waste. Urban dwellers are generally richer than rural dwellers.

**8.21** Some batteries contain lithium, lead, cadmium, and/or mercury which can leak into aquatic ecosystems and groundwater. Production, transport, and distribution of batteries use fossil fuels, thereby contributing to global warming.

**8.22** It will most likely relocate to poor countries in west Africa and Asia. There may be some illegal recycling in China (possibly as the result of the import of second-hand electronic goods).

**8.23** **(a)** Controlling the release of pollutants may be the easiest to achieve as long as there is the political will to achieve it. **(b)** Reclamation/restoration is most likely to be the most expensive.

**8.24** It may be difficult to reach everyone as not everyone has access to TV/radio/internet; there are many who are illiterate; some people are very poor and cannot afford to make changes; there are also powerful interest groups who make short-term profits through environmental destruction, e.g. fossil fuel companies.

**8.25** There is an inverse relationship between ecological footprint and carrying capacity. Areas with a large ecological footprint require a big area to support a given population rather than the population that a given area can sustainably support (carrying capacity). The same area could support more people who had a small ecological footprint.

**8.26** Ecological footprints are measured in global hectares (gha).

**8.27** The total ecological footprint has increased nearly three-fold, from around 7 million gha to over 20 million gha. The largest increase has been in carbon, from around 3 million gha to around 12 million gha (a four-fold increase) and cropland from 1.5 million gha to about 4 million gha (more than doubled). The smallest increases have been in built land and fishing grounds.

**8.28** The largest ecological footprints (>7 gha) are found in the USA, Canada, Netherlands, Mongolia, and the UAE. There are large ecological footprints (>5.25 gha) in Russia, Scandinavia, oil-rich countries, and Australia. In contrast, the smallest ecological footprints (<1.75 gha) are found in sub-Saharan Africa and south Asia.

**8.29** There are major differences between them. The largest contribution to the USA's ecological footprint is carbon. This accounts for nearly 70% of the US footprint. Carbon accounts for less than 25% of the ecological footprint in Bangladesh. Cropland accounts for the largest contribution of the ecological footprint in Bangladesh, at just over 50%. In the USA cropland only accounts for 15% of the ecological footprint. Forests and fishing make up a similar contribution to the ecological footprints of USA and Bangladesh.

**8.30** The Limits to Growth model suggests that food output and population grow exponentially until the rapidly diminishing resource base forces a slowdown in industrial growth. Because of delays in the system, both population and pollution continue to increase for some time after the peak of industrialization. There is an inverse relationship between population and resources. Population increases exponentially until around 2000, whereas the decline in resources is slow initially and then increases rapidly (negative exponential). Population growth is finally halted by a rise in the death rate due to decreased food production.

# IB Prepared environmental systems and societies

## Answers to practice exam papers

Here are the answers to the practice exam papers from *IB Prepared Environmental Systems and Societies.*

For direct access, click on the paper below.

## Paper 1:

## Paper 2:

## Paper 1

### Suggested mark scheme for paper 1

**1.** 1 mark for each valid point up to a maximum of 2 marks.

The reasons include the influence of the North Atlantic Drift/warm ocean current/ prevailing winds blowing over warm water. Gulf Stream is an acceptable answer [1]; and the presence of mountains/rainshadow effect/relief rainfall [1].

**2.** Physical landscape, e.g. mountains/lakes/forests [1]; and cultural landscapes, e.g. castles/houses/heritage attractions [1].

**3.**

| Fish species | *n* | (*n* − 1) | *n*(*n* − 1) |
|---|---|---|---|
| Perch<br>*Perca fluviatilis* | 331 | 330 | 109,230 |
| Brown trout<br>*Salmo trutta* | 179 | 178 | 31,862 |
| Rudd<br>*Scardinius erythrophthalmus* | 50 | 49 | 2,450 |
| Eel<br>*Anguilla anguilla* | 27 | 26 | 702 |
| Killarney shad<br>*Alosa fallax killarnensis* | 36 | 35 | 1,260 |
| Flounder<br>*Platichthys* | 19 | 18 | 342 |
| Tench<br>*Tinca tinca* | 6 | 5 | 30 |
| Salmon<br>*Salmo salar* | 4 | 3 | 12 |
| Arctic char<br>*Salvelinus alpinus* | 1 | 0 | 0 |
| | **$N = \Sigma n = 653$** | | **$\Sigma n(n-1) =$ 145,888** |

$$\text{Simpson diversity index} = \frac{N(N-1)}{\sum n(n-1)} = \frac{425\,756}{145\,888} = 2.92$$

**4.** 1 mark for each valid point up to a maximum of 2 marks, e.g.

The index is higher than that of 2008 but lower than that of 2011 [1]. Answers showing an incorrect value for the Simpson diversity index but a correct interpretation of how the calculated value differs from those of 2008 and 2014 may still receive credit.

This may be due to altered environmental conditions in the lake, e.g. over time it has become more polluted, making survival for some species difficult [1]; water temperatures may have changed, making the environment too hostile for some species [1]; the pH of the water may have altered/ an increase in turbidity/decrease in oxygen may affect some species’ ability to feed/survive [1].

Other valid reasons can receive a mark.

**5.** 1 mark for each valid point up to a maximum of 3 marks, e.g.

The area infested with rhododendron in 1989 is along the south-west side of Lough Leane/near Shehy Mountain and along the higher slopes of Torc Mountain/along the main road southwards [1]; there is a thin strip of land infested with rhododendron along the southern edge of Lough Leane [1].

By 2014, the heavily infested area of Shehy Mountain remains largely unchanged/expanded slightly [1]; the area around Torc Mountain appears to be more infested/now stretches further northwards to Muckross Lake [1].

A maximum of 2 marks can be given if only one year is described or two separate descriptions are given without any comparison.

**6.** 1 mark for each valid statement up to a maximum of 2, e.g.

There is a much greater range of types of organisms/17 types of organisms in native woodland [1].

No species is dominant in native woodland whereas spiders/harvestmen, then beetles dominate in rhododendron stands [1].

Other possibilities include: harvestmen are the dominant species/ beetles account for c. 25% of the composition of species/ flies account for c. 20% of the species composition in rhododendron-infested areas [1]/ spiders are the most common invertebrate/ true flies and millipedes are the next most frequent invertebrates in native woodland [1].

**7. (a)** 1 mark for each valid evaluative statement, up to a maximum of 5, e.g.

In the past, mature plants were ripped out of the soil using horses and chains. This was hard work and took a long time to complete [1].

Stem injection involves making an incision into the plant and treating it with herbicide [1]. It is quite cost-effective and works best on individual plants rather than those occurring in dense stands [1]. However, some herbicides may drift into surrounding areas and may be toxic to other plants [1].

Cutting back plants and treating the cut stem with herbicide works well on larger stands of rhododendron [1]. It is not always possible to cut stems close to the surface, as blades may be broken by rocks/ the herbicide may be ineffective if applied during rainy days/ the build-up of dead rhododendron may pose a fire risk [1].

Despite over 50 years of treatment, the rhododendron problem has not gone away, therefore it is possible to conclude that none of the methods used is very effective [1].

**(b)** Natural capital is the income derived from natural resources [1].

**(c)** Ecosystem services are the resources and processes that are provided by ecosystems that benefit humanity [1]; regulating services, e.g. climate regulation or flood control/ supporting services, e.g. nutrient cycling
or soil formation/ cultural services, e.g. health benefits, tourism or recreation [1].

**(d)** €274 million/year [1].

**8. (a)** An invasive species is a species not native to the area that has been introduced/has moved into an area [1].

**(b) (i)** Red deer are found in four main parts of the country – the south-west, the east, north-west and the west [1]. Sika deer are also found in the south-west and the east [1] but in a larger area in both locations [1]. There are far fewer sika in the west than red deer/ the area in the north-west is south-east of the main area of red deer [1].
A maximum of 2 marks can be given if two separate descriptions are offered without any comparison.

**(ii)** 353.2% (350–355% is acceptable) [1].

**(iii)** The 1976 Wildlife Act gave increased protection to all species of deer [1]; the lack of any natural predators allowed deer populations to increase [1].

**(c)** Carrying capacity is the maximum size of a population/species that can be maintained by an environment [1].

**(d)** 46 deer [1] in 8.5 ha = 5.4/ha [1].

**(e)** The density of sika deer on Inisfallen of 5.4/ha (or 540/100 ha) is much greater/more than ten times the recommended carrying capacity for sika deer (50/100ha) [1].

Students would not be doubly penalized if the answer to (d) is inaccurate – the answer to (d) should be compared with the value of 50/100 ha (or 0.5/ha).

**(f)** Give 1 mark for each valid point up to a maximum of 3 marks, e.g. detrimental effects on ecosystems, habitats and vegetation/ on Inisfallan the deer have stripped the bark from the trees in their search for food/largely consumed the ground vegetation/ the native forest/woodland has been unable to regenerate due to grazing/browsing by the deer [1]; conflict with commercial land-uses, e.g. agriculture and forestry [1]; increased risk of deer being involved in motor vehicle collisions with potential for human and deer fatalities and injuries [1]; increased risk of disease transmission [1]; over-population/population exceeding the carrying capacity may lead to starvation, e.g. among the sika deer as food supply is limited [1].

# Paper 2

## Suggested mark scheme for paper 2

### Section A

**1. (a)** The total fertility rate (TRF) is the average number of births per thousand women of child-bearing age. It is the number of children that a woman will have over her lifetime, if the fertility rates in that country remained unchanged [1].

**(b)** Niger [1]

**(c)** Singapore [1]

**(d)** Range = 6.62 – 0.82 = 5.8 [1]

**(e)** Bangladesh c. $4000 ($3600–$4000 is acceptable), France c. $40 000 ($36 000–$40 000 is acceptable) [1].

Difference is $36 000 ($34 000–$38 000 is acceptable) [1].

**(f)** There is a negative/inverse correlation/relationship [1]/ i.e. as GDP increases TFR decreases [1]. 1 mark for any further development or use of supporting examples, e.g. Somalia/Niger have low GDP but high TFRs, whereas Singapore/Hong Kong/Qatar have high GDP and a low TFR/ or identification of anomalies, e.g. North Korea and Qatar have similar TFRs but very different GDP/person [1].

**(g)** A log-log graph is appropriate because the range of values for TRF and GDP is so great [1]/ it would be difficult to show low values, especially for GDP [1]/ Somalia has a GDP of c. $400/person whereas Qatar and Singapore are well over 100 times greater [1] so showing them on the same graph would be difficult [1]. The use of logarithmic scales makes it possible to show differences in small values as well as differences in large values [1]/ it shows variations in low TFR much more clearly than a normal scale would show (while at the same time showing large values) [1].

**2. (a)** There is a long-term increase in the pH of water/ an increase from around 4.6 (4.5–4.7 is acceptable) in 1993 to around 5.6 (5.5–5.7 is acceptable) in 2007 [1]/ there are also seasonal changes—highs and lows within the same year [1]/ more extreme acid conditions were experienced in the earlier years, e.g. 1993 and 1994 [1]/ greater extremes of less acidic conditions were experienced in 2002–4 [1].

**(b)** It decreases from c. 4.6 (4.5–4.7 is acceptable) to 5.6 (5.5–5.7 is acceptable) [1] a change of 1.0 (0.8–1.2 is acceptable) [1].

**(c)** 1 mark for each valid reason, up to a maximum of 3 marks, e.g.

Acidification could be reduced due to a decline in coal burning power stations [1]/ fewer heavy industries, e.g. iron and steel [1]/ less domestic burning of coal [1]/ water may have been treated [1]/ powdered lime may have been added to it so it becomes less acidic [1]/ an increase in the use of renewable energy sources [1]/ more government schemes such as clean air acts to reduce emissions of sulphur/coal burning and to promote the use of clean(er) forms of energy [1].

**3. (a) (i)** Carbon stored below ground (soil and biomass) [1]

**(ii)** Carbon absorption by photosynthesis [1]

**(b)** Before deforestation 180 tCha, after 43 tCha [1], so a decline of 137 tonnes of carbon per hectare/ a decline of 76.11% (75–77% is acceptable) [1].

**(c)** Respiration has decreased by 72% (71–73% is acceptable) [1].

**(d)** The increase in atmospheric carbon occurs because less is taken up in photosynthesis [1]; there is an increase in atmospheric carbon due to burning of vegetation/decay of cut vegetation/soil erosion [1]; there is still some input from respiration putting carbon into the atmosphere [1].

## Section B Essays

**4. (a)** 1 mark for each term correctly described, up to a maximum of 4 marks, e.g.

Urbanization leads to an increase in the amount of impermeable surface [1], which can lead to increased amounts of surface runoff [1]. Building over the soil means there is less chance for water to infiltrate into the soil [1]. Urbanization may also reduce vegetation cover, so there is less interception of water and more surface runoff [1].

**(b)** 1 mark for each valid explanation, up to a maximum of 7 marks, e.g.

Water supplies can be increased through the creation of reservoirs using earthen or concrete dams [1]/ canals and artificial channels may be used to redistribute water from areas with a plentiful supply to an area with a shortage of water [1)/ desalination can be used to create freshwater from seawater – this is very expensive, however [1]/ aquifers can be recharged by pumping water into the ground [1]/ rainwater harvesting schemes ranging from simple butts to large-scale areas covered with concrete to collect water [1]/ water conservation may be used, e.g. covering reservoirs with plastic or filling them with gravel to reduce evaporation [1]/ water can be recycled/reused for alternative purposes [1].

**(c)** The following guidelines show what needs to be included in student answers. All five of these bullet points should be covered.

Answers may include:

- **understanding concepts and terminology** of anthropocentric/technocentric/ecocentric value systems, pollution management strategies, eutrophication, acidification, DDT, heavy metals, tropospheric ozone, waste disposal
- **breadth in addressing and linking** pollution management strategies with relevant EVSs, e.g. ecocentric with altering human activity, less materialistic lifestyle, greater self-sufficiency; anthropocentric with controlling release of pollutants, environmental regulation, use of taxes and legislation; technocentric with clean-up and restoration of damaged systems, technological developments to provide solutions to environmental problems
- **examples** of pollution management strategies, e.g. altering the use of nitrates in agriculture; reduction in use of fossil fuels; reduced emissions of $SO_2$ and NOx; reducing electronic waste and the use of landfill and incineration; clean-up technologies such as liming of acidified lakes, removal of algae, greening of urban environments
- **balanced analysis** of the way in which different pollution management strategies (altering human activity, controlling the release of pollutants and clean-up and restoration of damaged systems can be related to different environmental value systems, namely ecocentrism, anthropocentrism, and technocentrism
- **a conclusion that is consistent with, and supported by, analysis and examples given**, e.g. 'There are many types of pollution management strategies. However, anthropocentric value systems are particularly valuable in achieving a wider global effort to tackle pollution. Technological solutions are often limited to rich countries and ecocentric solutions tend to be small-scale and very localized.

  NB This is only an example of a possible conclusion. Students' conclusions do not have to agree.

There is a mark band on page 10 for you to refer to.

**5. (a)** 1 mark for each valid reason, up to a maximum of 4 marks, e.g.

Capture fisheries are also known as wild fisheries [1]/ they are a modern form of hunting and gathering in which the resource—wild fish—is produced free of charge [1]. Aquaculture is the farming of aquatic organisms [1], plants as well as animals/ both in coastal and inland areas [1]./ It involves intervention in the rearing process to enhance production [1].

**(b)** 1 mark for each valid environmental impact and a further mark for development/use of examples, up to a maximum of 7 marks

Food inequalities may exist as some farmers may be able to afford inputs that can increase their yields [1]. For example, food production may increase with mechanization, as more work can be done in a shorter amount of time [1]/ greater use of fertilizers enables greater plant growth [1]/ increased use of fossil fuels allows machines to operate [1]/ selective breeding enables higher yielding varieties of plants and/or animals to grow [1]/ increased irrigation water allows plants and animals to grow in dry areas [1]/ greater use of pest control eliminates competing species [1]/ greater use of antibiotics increases resistance to disease [1]/ government subsidies may encourage farmers to produce more food [1]/ electrification may allow greater storage of farm products [1]/ improved transport systems may get more farm products to markets [1].

**(c)** The following guidelines show what needs to be included in student answers. All five of the following bullet points should be covered.

Answers may include:

- **understanding concepts and terminology of** sustainability of food production systems, organic production, meat consumption, food labels, food miles, eutrophication, soil degradation, soil conservation, food wastage, biodiversity loss, habitat loss
- **breadth in addressing and linking** food production systems to more sustainable forms of food production, e.g. organic farming, no-tillage farming, precision agriculture, drip irrigation, soil conservation, locally produced food, vertical farming, in vitro farming, pollution management systems to reduce the problem of eutrophication
- **examples** of soil conservation, e.g. Dust Bowl/Great Plains; terracing in south-east Asia; zero tillage, wind breaks, the use of leguminous plants to improve soil fertility, crop rotation, fallow land and wind breaks; 'magic stones'/diguettes in Burkina Faso/Sahel to reduce soil erosion and trap rainwater; drip irrigation, organic fertilizers, etc
- **balanced analysis** of the ways in which food production systems can become more sustainable and an examination of the difficulties of adopting these measures, e.g. cost, knowledge, and understanding, availability of infrastructure
- **a conclusion that is consistent with, and supported by, analysis and examples given**, e.g. it is possible to make food production systems more sustainable. However, some methods, e.g. organic farming, may not be as productive, thereby limiting the uptake of sustainable methods. Some methods (e.g. in vitro farming and precision agriculture) may be expensive and only widely available in MEDCs.

  NB This is only an example of a possible conclusion. Students' conclusions do not have to agree.

There is a mark band on page 10 for you to refer to.

**6. (a)** 1 mark for each valid point, up to a maximum of 4 marks:

The greenhouse effect is a natural process in which incoming solar radiation (insolation)/short-wave radiation passes through the Earth's atmosphere [1] and heats up the ground/Earth [1]. The Earth emits long-wave radiation [1]. Greenhouse gases, such as water vapour, carbon dioxide and methane trap a proportion of the outgoing long-wave radiation [1]. This heats up the Earth's atmosphere [1].

**(b)** 1 mark for each valid point/reason, up to a maximum of 7 marks, e.g.

Both positive feedback and negative feedback are associated with global climate change.

<u>Positive feedback</u>

Melting of the polar ice caps results in less ice and lowers planetary albedo [1].

Since ice is more reflective than water in this respect, less ice means less reflection [1]. Lowering albedo increases the amount of solar energy absorbed at the Earth's surface and leads to an increase in temperature, i.e. a positive feedback mechanism [1]. Increased temperature leads to increased thawing of permafrost [1]/ this releases methane from the permafrost [1]/ methane is a greenhouse gas, so the increase in greenhouse gases increases temperature – an example of positive feedback [1].

<u>Negative feedback</u>

Increased evaporation in tropical latitudes due to higher levels of precipitation [1] will lead to increased snowfall on the polar ice caps [1], reducing the mean global temperature [1]. Increase in carbon dioxide in the atmosphere leads to increased plant growth by allowing increased levels of photosynthesis [1]. Increased plant biomass and productivity would reduce atmospheric concentrations of carbon dioxide [1].

If only positive or negative feedback is covered the answer can only score a maximum of 5 marks.

**(c)** The following guidelines show what needs to be included in student answers. All five of the following bullet points should be covered.

Answers may include:

- **understanding concepts and terminology** of energy security, fossil fuels, renewable energy, nuclear power, fracking, biofuels, global warming/climate change, acidification, tropospheric ozone
- **breadth in addressing and linking** energy security, fossil fuels, renewable energy, nuclear power, fracking, biofuels, global warming/climate change, acidification, tropospheric ozone, MEDCs, LEDCs, newly industrializing countries
- **examples** from any part of the world—likely to include MEDCs such as the USA, NICs/emerging/developing nations such as China, poor countries such as Haiti/Zimbabwe; events such as Fukushima-Daichi, Deepwater Horizon
- **balanced analysis** to show that some energy forms lead to increased environmental damage but some countries are trying to develop environmentally friendly forms of energy
- **a conclusion that is consistent with, and supported by, analysis and examples given**, e.g. although there are many attempts to achieve energy security that does not harm the world's environment, in many cases countries are continuing to use environmentally damaging forms of energy because they are cheap/abundant/the technology is available.

  NB This is only an example of a possible conclusion. Students' conclusions do not have to agree.

There is a mark band on page 10 for you to refer to.

**7. (a)** 1 mark for each valid point/use of examples, up to a maximum of 4 marks, e.g.

The value of a resource changes over time [1].

For example, oil in the Middle Ages was used to treat open wounds [1]/ oil in the 20th century was used as a fuel/a raw material for plastic [1].

Uranium has existed for millions of years but has only been used widely as a resource since the middle of the 20th century [1]/ nuclear fission splits uranium atoms to release energy [1]/ as a result of safety issues (e.g. Fukushima) nuclear energy has become less attractive as a source of energy in some countries [1].

**(b)** 1 mark for each valid explanation, e.g.

In soils, acidification may lead to the leaching of iron and aluminium (when the pH is 4.5 or lower) [1].

The impact of acid deposition on water (lakes and rivers) causes an impoverished species structure [1]/ increased levels of dissolved metals such as cadmium, copper, aluminium, zinc and lead [1].

Acid rain breaks down lipids in the foliage and damages membranes, which can lead to plant death. Sulfur dioxide interferes with the process of photosynthesis [1]. When soil pH is below 4.2, aluminium is released—this damages root systems and decreases tree growth, as well as increasing development of abnormal cells and premature loss of needles [1]. The low pH of soil and the presence of metals may cause damage to root hairs (used by the tree to absorb nutrients) [1]. The tree loses vitality, growth is retarded, there is an inability to cope with stress (such as frost, drought and pests); the tree becomes susceptible to injury [1]. Extreme pH values cause most damage to plants [1].

No more than 4 marks can be given if only one category is considered, a maximum of 6 marks if only two are considered.

**(c)** The following guidelines show what needs to be included in student answers. All five of the following bullet points should be covered.

Answers may include:

- **understanding concepts and terminology** of solid domestic waste, waste management schemes, landfill, incineration, recycling, re-use, reduce, remove, non-biodegradable pollution (plastic, e-waste, batteries)
- **breadth in addressing and linking** different viewpoints regarding solid domestic waste, waste management schemes, landfill, incineration, recycling, reuse, reduction, removal, non-biodegradable pollution (plastic, e-waste, batteries), relocation of waste, especially the export of e-waste
- **examples** such as e-waste in China/Ghana, plastic waste in the oceans (Great Pacific Garbage Patch), Laogang, Shanghai landfill
- **balanced analysis** showing that some forms of waste management do not harm the environment, e.g. removal/reduction whereas others are more damaging, e.g. recycling of e-waste and plastics
- **a conclusion that is consistent with, and supported by, analysis and examples given**, e.g. Although there are some forms of waste management that are not environmentally damaging, such as reduction and removal, many of the others, including recycling and incineration, can be quite damaging, especially in poor countries that import waste from rich countries.

  NB This is only an example of a possible conclusion. Students' conclusions do not have to agree.

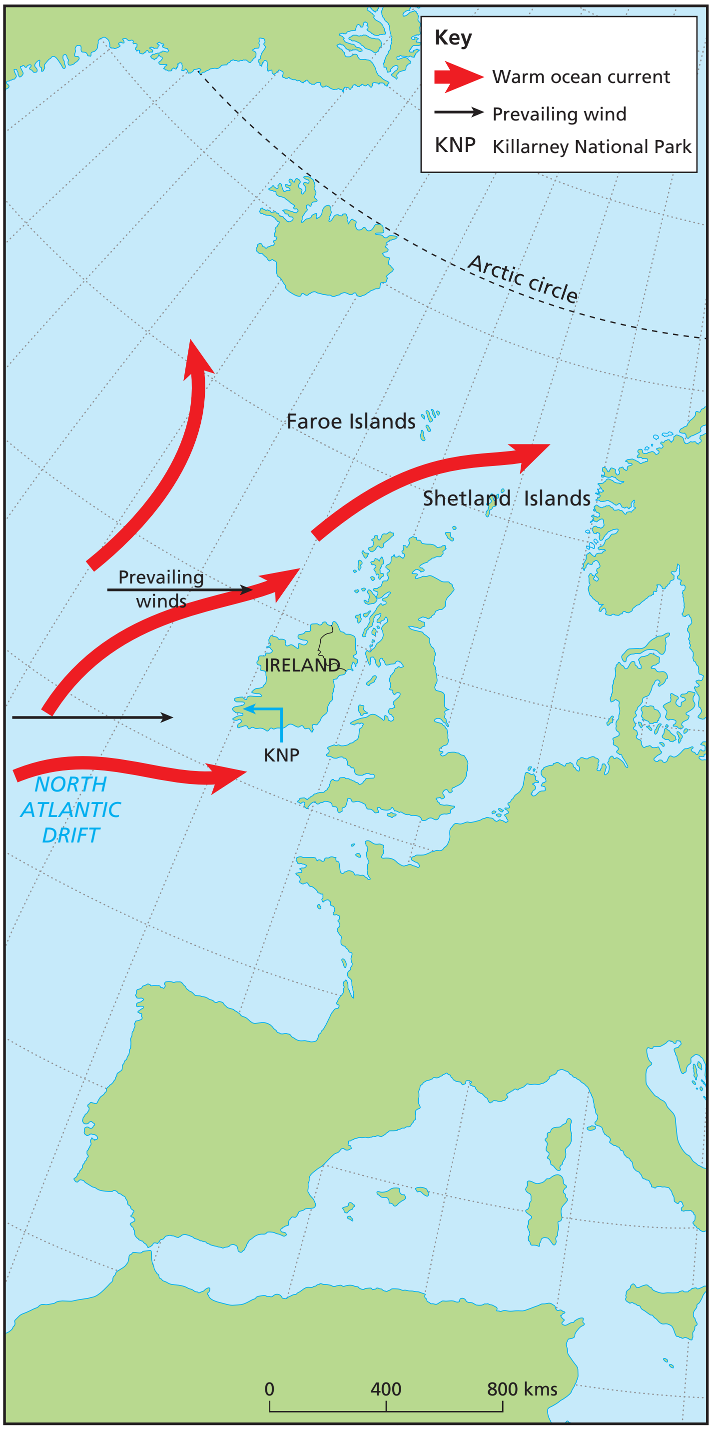
There is a mark band on page 10 for you to refer to.

## Section B, part (c) mark bands

<table>
<tr><th>Marks</th><th>Level descriptor</th></tr>
<tr><td>0</td><td>The response does not reach a standard described by the descriptors below and is not relevant to the question.</td></tr>
<tr><td>1–3</td><td>The response contains:<ul><li>minimal evidence of knowledge and understanding of ESS issues or concepts</li><li>fragmented knowledge statements poorly linked to the context of the question</li><li>some appropriate use of ESS terminology</li><li>no examples where required, or examples with insufficient explanation/relevance</li><li>superficial analysis that amounts to no more than a list of facts/ideas</li><li>judgments/conclusions that are vague or not supported by evidence/argument.</li></ul></td></tr>
<tr><td>4–6</td><td>The response contains:<ul><li>some evidence of sound knowledge and understanding of ESS issues and concepts</li><li>knowledge statements effectively linked to the context of the question</li><li>largely appropriate use of ESS terminology</li><li>some use of relevant examples where required, but with limited explanation</li><li>clear analysis that shows a degree of balance</li><li>some clear judgments/conclusions, supported by limited evidence/arguments.</li></ul></td></tr>
<tr><td>7–9</td><td>The response contains:<ul><li>substantial evidence of sound knowledge and understanding of ESS issues and concepts</li><li>a wide breadth of knowledge statements effectively linked with each other, and to the context of the question</li><li>consistently appropriate and precise use of ESS terminology</li><li>effective use of pertinent, well-explained examples, where required, showing some originality</li><li>thorough, well-balanced, insightful analysis</li><li>explicit judgments/conclusions that are well supported by evidence/arguments and that include some critical reflection.</li></ul></td></tr>
</table>

# PAPER 1: RESOURCE BOOKLET

The scenery of the Killarney area, including the National Park, is world-renowned. It is a major attraction and the area is one of the most visited tourist venues in Ireland. Over a million visitors travel to Kerry each year, bringing an estimated £160 million to the area. Of these the majority visit Killarney, a town with a resident population of 14,000 and over 4,000 tourist rooms! Under legislation in Ireland, where conflict arises between the need for tourism and the need for conservation, the protection of the natural heritage takes precedence over other considerations.




▲ **Figure 1** The location of Ireland and Killarney National Park, Ireland


▲ **Figure 2** The main features of Killarney National Park

Source: Adapted from *Killarney National Park Management Plan, 1990*, The Office for Public Works

Limestone rocks by
Muckross Lake

Boat on Lough Leane

Dinis Bridge

Upper lake from Ladies View

Ross Castle

Lough Leane (Lower lake)

Muckross House – the main
cultural attraction

Busy street scene from
Killarney

Visitors admiring the view of
the Lakes

▲ **Figure 3** Pictures of Killarney National Park

**Table 1** Result of a survey of fish populations in Lough Leane in 2014

| Fish species | *n* | (*n* – 1) | *n*(*n* – 1) |
|---|---|---|---|
| Perch *Perca fluviatilis* | 331 | 330 | 109,230 |
| Brown trout *Salmo trutta* | 179 | 178 | 31,862 |
| Rudd *Scardinius erythrophthalmus* | 50 | 49 | 2,450 |
| Eel *Anguilla anguilla* | 27 | 26 | 702 |
| Killarney shad *Alosa fallax killarnensis* | 36 | 35 | 1,260 |
| Flounder *Platichthys* | 19 | 18 | 342 |
| Tench *Tinca tinca* | 6 | 5 | 30 |
| Salmon *Salmo salar* | 4 | 3 | 12 |
| Arctic char *Salvelinus alpinus* | 1 | 0 | 0 |
| | $\sum$ | | $\sum =$ |

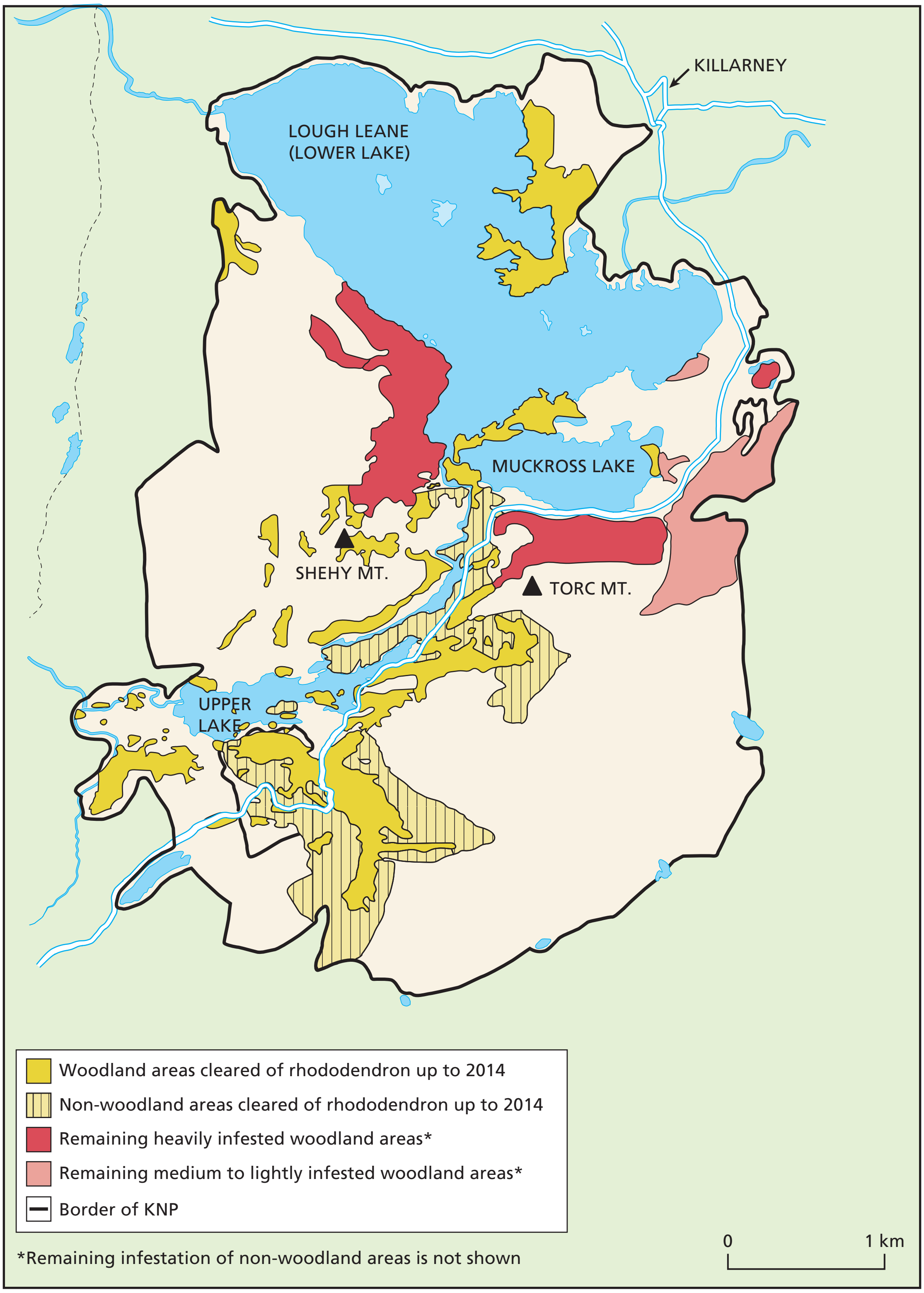
Source: http://wfdfish.ie/wp-content/uploads/2011/11/Leane_report_2014.pdf

## Factfile 1: Invasive species: the rhododendron

- The shrub, *rhododendron pontium*, is a native of Spain, Portugal, and around the Black Sea.
- It was introduced into the British Isles in 1763, and was widely used as a decorative plant and as a cover for game.
- It was planted in the Muckross and Kenmare Estates in the 19th century, and now affects almost 40% of Killarney National Park's area.
- It grows vigorously on the acid soil, and thrives in the mild, ice-free, damp environment of Killarney.
- The plant can survive fire and frost.
- In some woodlands it has replaced the holly understorey and shaded out the ground cover.
- It does not get grazed as its leaves are toxic.
- Efforts to eradicate rhododendron have been in place since the 1960s.

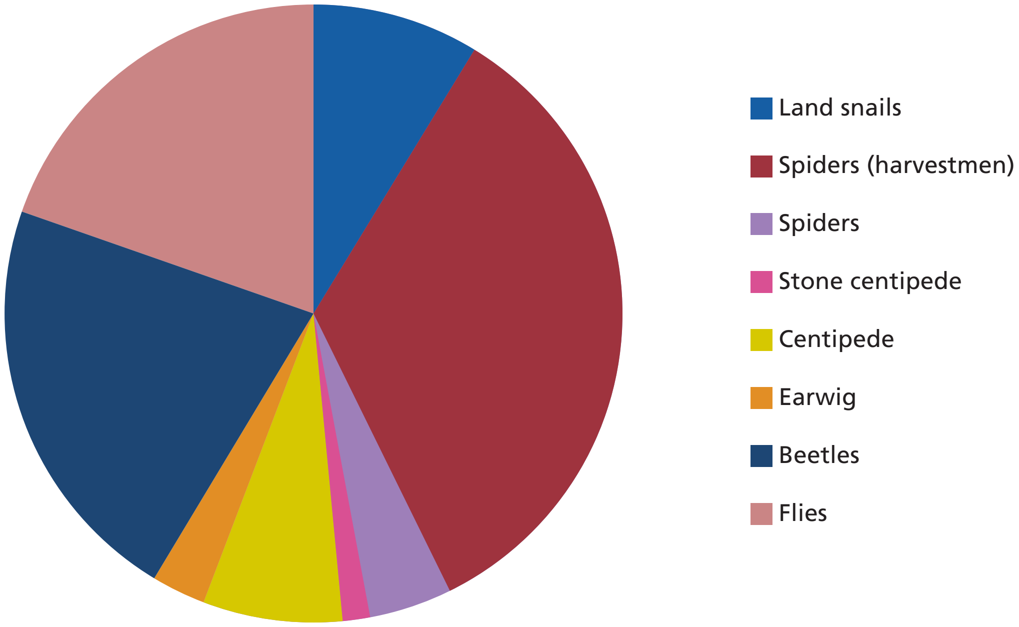

▲ **Figure 4a** Rhododendron infestation and clearance up until 1989

Source: *Killarney National Park Management Plan, 1990*, The Office of Public Works



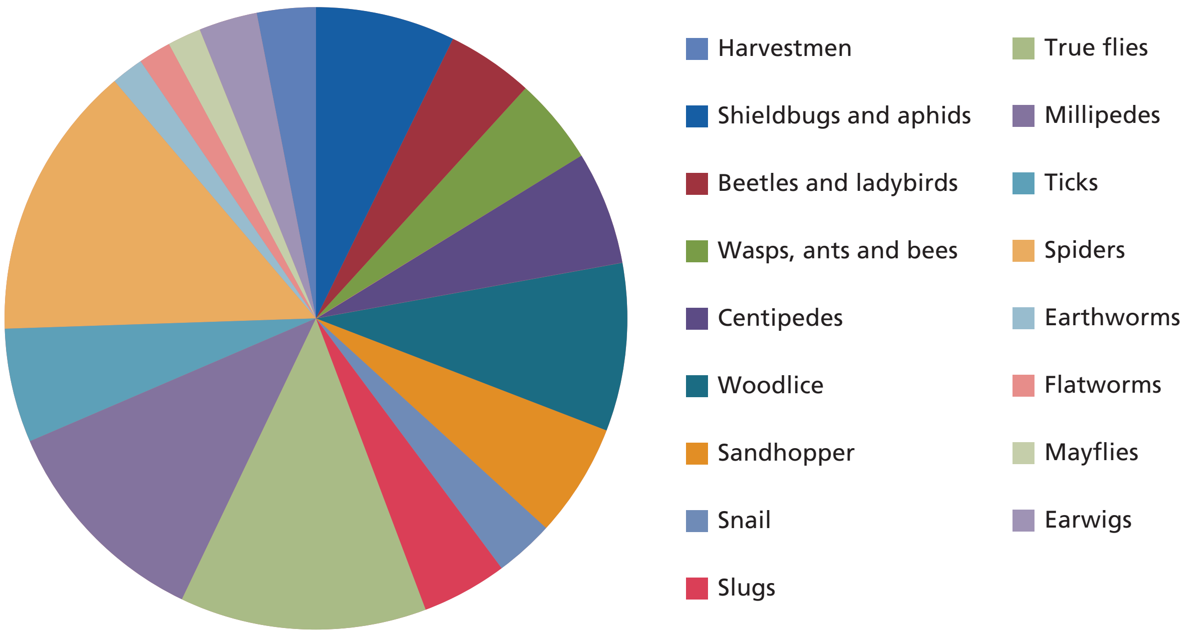

▲ **Figure 4b** Rhododendron infestation and clearance up until 2014

Source: Adapted from *UNESCO, Killarney National Park Biosphere Reserve, 2017*, Department of Arts, Heritage, Regional, Rural and Gaeltacht Affairs




▲ **Figure 5a** Composition of invertebrate community in rhododendron stands at Killarney National Park

Source: https://www.killarneynationalpark.ie/about-us-killarney/biodiversity/




▲ **Figure 5b** Composition of invertebrate community in native woodland at Killarney National Park

Source: https://www.killarneynationalpark.ie/about-us-killarney/biodiversity/

## Factfile 2: Methods of treating rhododendron

- **Remove regrowth from cut stems and treat.**

  Rhododendron stems should be cut as close to the ground as possible. Low-cut stumps produce less growth and therefore minimize the use of herbicides. After 18–24 months, regrowth is removed and herbicide applied. The method is easy to use and reduces the risk of herbicide being carried into surrounding areas.

- **Stem and plant base treatment using a chain saw**

  The rhododendron is cut as close to the base as possible. Larger stems may be cut a number of times. Herbicide is applied immediately to fresh saw cuts, and a dye is used to show which areas have been treated. Plant death normally occurs within one year. Leaf death takes longer in winter.

  *Advantages include* – can be used on most rhododendron plant types; very good kill rate; cost-effective; low volume of herbicide required; no soil disturbance; effective in light showery weather.

  *Disadvantages include* – second large-scale work phase needed if standing dead plants are to be removed; potential fire risk; standing dead plants and subsequent litter may inhibit regeneration and site management.

- **Stem treatment**

  This requires making a downward cut. Herbicide should be applied. Leaf die-back begins 3-4 weeks after treating the plant.

  *Advantages include* – a good kill rate; minimal herbicide use; no soil disturbance; minimal risk of herbicide drift; limited equipment needed; cost-effective.

  *Disadvantages include* – requires mainly dry weather; all plant stems require treatment; second large-scale work phase required if dead plants are to be removed; standing dead plants and litter pose a fire risk.

  This method is most effective for single-stem plants.

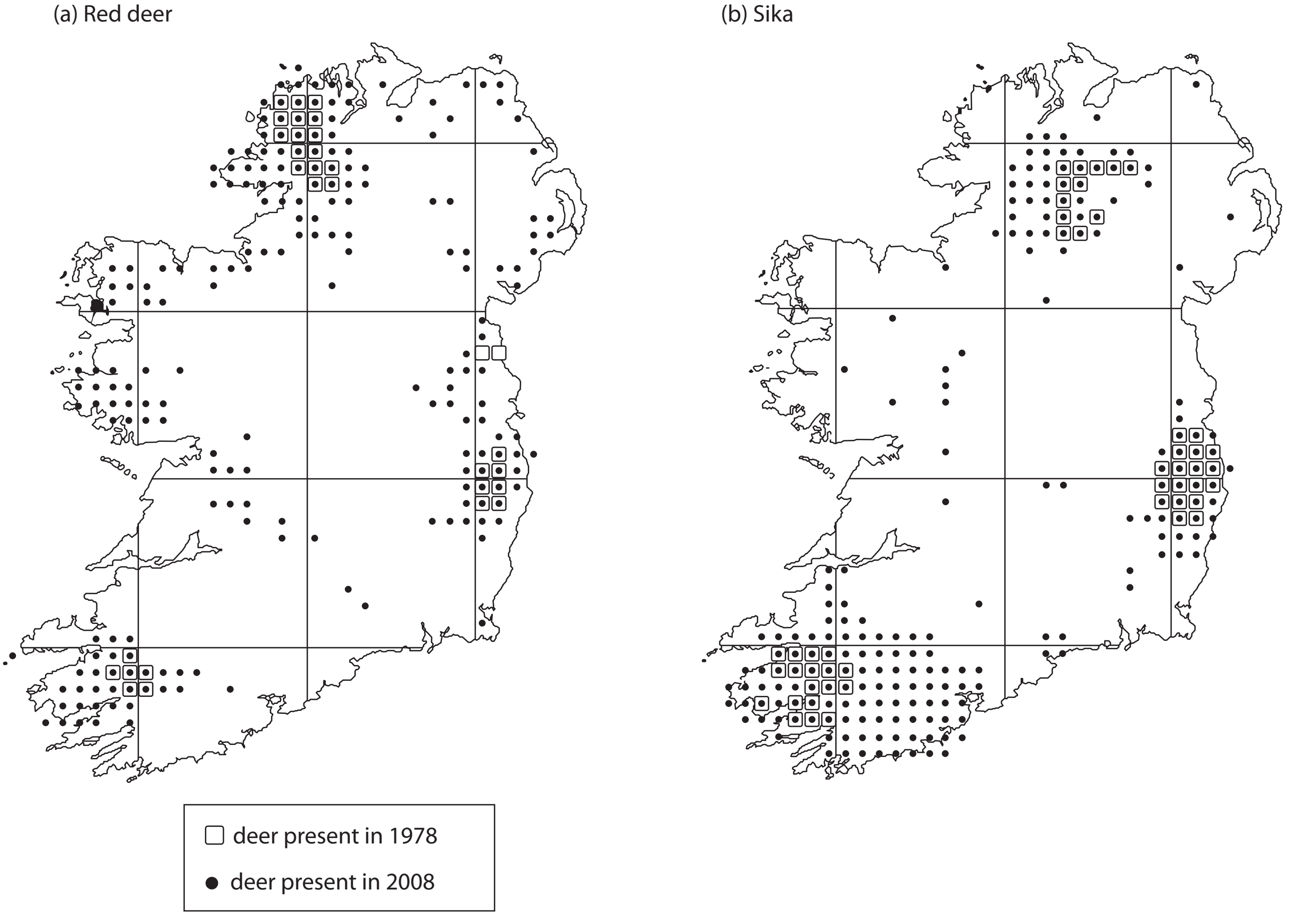
▼ **Table 2** The value of ecosystem services provided by native woodlands

| | |
|---|---|
| Amenity (non-market value) | €65 million per year |
| Tourism expenditure | €60 million per year |
| Health | €4 million per year |
| Biodiversity utility value | €60 million per year |
| Water quality, flood and erosion control | €3 million per year |
| Carbon storage and sequestration | €45 million per year |
| Timber and wood fuel | €37 million per year |

Source: Bullock, C. and Hawe, J., *The natural capital values of Ireland's native woodland*, Woodlands of Ireland, 2014.

## Factfile 3: Sika deer in Inisfallan Island, Killarney National Park

- Introduced into Ireland in 1860.
- Two females and a male were introduced to Killarney in 1864.
- Maximum density 50 deer per 100 ha.
- In 2010 a group of sika deer swam 1.5 km to colonize Inisfallan Island (8.5 ha).
- In 2018 four sika deer were found to have starved on the island and a further 27 were culled. Fifteen deer remained on the island.
- Trees had been stripped bare by the deer and much of the ground vegetation destroyed.
- The forest has been unable to regenerate due to the sika deer grazing/browsing.
- Deer are protected under the 1976 Wildlife Act.
- The only natural predators of deer, the wolf and the Golden Eagle, are now extinct.




▲ **Figure 6** Distribution of red deer and sika deer in Ireland

Source: Carden, R. F. et al, 2011, Distribution and range expansion of deer in Ireland, *Mammal Review*, 2011, Vol. 41, 4, 313–325.

▼ **Table 3** Expansion of deer population in Ireland, 1978–2008

| Species | Number of squares occupied in 1978 | Number of squares occupied in 2008 | Total increase in range 1978–2008 |
|---|---|---|---|
| Red deer | 31 | 206 | 564.5% |
| Sika | 47 | 213 | 353.2% |

Source: Carden, R. F. et al, 2011, Distribution and range expansion of deer in Ireland, *Mammal Review*, 2011, Vol. 41, 4, 313–325.