Chapter 13: Biodiversity and Conservation

Exercises — Chapter-end Exercises

Q1 Name the three important components of biodiversity.

SOLUTION

Biodiversity, as described by Edward Wilson, encompasses diversity at all levels of biological organisation. The three most important components are:

1. Genetic diversity: Diversity within a species at the genetic level. For example, India has more than 50,000 genetically different strains of rice and 1,000 varieties of mango. The medicinal plant Rauwolfia vomitoria shows variation in the potency and concentration of the active chemical reserpine across different Himalayan ranges.

2. Species diversity: Diversity at the species level — the variety of species in a region. For example, the Western Ghats have greater amphibian species diversity than the Eastern Ghats.

3. Ecological (ecosystem) diversity: Diversity at the ecosystem level. India, with its deserts, rain forests, mangroves, coral reefs, wetlands, estuaries and alpine meadows, has far greater ecosystem diversity than a Scandinavian country like Norway.

Answer: The three components are: (1) genetic diversity, (2) species diversity, and (3) ecological (ecosystem) diversity.

Q2 How do ecologists estimate the total number of species present in the world?

SOLUTION

Estimating the total number of species on Earth is a major challenge because a vast number of species are yet to be discovered and described. Ecologists use the following approach:

Species inventories are far more complete for temperate regions than for tropical regions. Biologists take an exhaustively studied group of insects (or another taxonomic group) and compare the ratio of temperate species to tropical species for that group. They then extrapolate this temperate-to-tropical ratio to other groups of animals and plants to arrive at a gross estimate of total species on Earth.

Using this statistical extrapolation, Robert May placed the global species diversity at about 7 million, though some extreme estimates range from 20 to 50 million. Currently, about 1.5 million species have been formally described (per IUCN 2004).

The estimates are uncertain because: (a) tropical regions are under-explored, (b) microbial/prokaryotic species are difficult to identify using conventional taxonomic methods, and (c) many species face extinction before they can be discovered and named.

Answer: Ecologists extrapolate the known temperate-to-tropical species richness ratio for well-studied insect groups to other taxa — yielding an estimated ~7 million total species (Robert May's estimate), against 1.5 million formally described.

Q3 Give three hypotheses for explaining why tropics show greatest levels of species richness.

SOLUTION

Tropical regions consistently harbour far more species than temperate or polar regions. Ecologists and evolutionary biologists have proposed the following three important hypotheses to explain this pattern:

(a) Long evolutionary time (historical hypothesis): Unlike temperate regions, which were subjected to frequent glaciations in the past that repeatedly disrupted ecosystems, tropical latitudes have remained relatively undisturbed for millions of years. This long, uninterrupted evolutionary time has allowed greater speciation and accumulation of species diversity.

(b) Constant and predictable environment (ecological hypothesis): Tropical environments are less seasonal and relatively more constant and predictable compared to temperate environments. Such stable conditions promote niche specialisation — organisms can evolve to exploit very narrow ecological niches — leading to a greater number of coexisting species.

(c) Greater solar energy and higher productivity (energetic hypothesis): The tropics receive more solar energy than temperate regions. This greater energy input contributes to higher primary productivity, which in turn can support more species at higher trophic levels, indirectly contributing to greater biodiversity.

Answer: Three hypotheses: (a) tropical latitudes had more evolutionary time (undisturbed for millions of years); (b) constant tropical environments promote niche specialisation; (c) greater solar energy leads to higher productivity, supporting more species.

Q4 What is the significance of the slope of regression in a species – area relationship?

SOLUTION

The species–area relationship discovered by Alexander von Humboldt shows that species richness increases with area up to a limit, following a rectangular hyperbolic curve. On a logarithmic scale, the relationship is linear and described by:

$\log S = \log C + Z \log A$

where S = species richness, A = area, Z = slope of the regression line (regression coefficient), and C = Y-intercept.

The slope Z indicates the rate at which species richness increases with increasing area.

For smaller regions (e.g., plants in Britain, birds in California, molluscs in New York state), the Z value lies in the range of 0.1 to 0.2, regardless of the taxonomic group or region. This means species richness increases modestly with area at smaller scales.

For very large areas such as entire continents, the slope is much steeper (Z values in the range of 0.6 to 1.2). For example, frugivorous birds and mammals in tropical forests of different continents show a slope of 1.15.

A steeper slope means that species richness increases much more rapidly with area at

continental scales — implying that large-scale habitat destruction (loss of entire continents' worth of habitats) results in far greater species loss than small-scale fragmentation.

Answer: The slope (Z value) indicates how rapidly species richness increases with area. Z = 0.1–0.2 for small regions; Z = 0.6–1.2 for continental scales, meaning larger areas support disproportionately greater diversity and their loss causes more severe species loss.

Q5 What are the major causes of species losses in a geographical region?

SOLUTION

The major causes of accelerated species loss are collectively called 'The Evil Quartet'. They are:

(i) Habitat loss and fragmentation: This is the most important cause. Tropical rain forests, once covering more than 14 per cent of Earth's land surface, now cover less than 6 per cent. The Amazon rainforest is being cleared for soya bean cultivation and beef cattle ranching. Habitat fragmentation harms mammals and birds requiring large territories and animals with migratory habits.

(ii) Over-exploitation: When human 'need' turns to 'greed', natural resources are over-exploited. Examples include the extinction of Steller's sea cow and the passenger pigeon due to overexploitation. Many marine fish populations are currently being overharvested, threatening commercially important species.

(iii) Alien species invasions: Introduced alien species can turn invasive and cause decline or extinction of native species. Examples include the Nile perch introduced into Lake Victoria (which caused extinction of more than 200 cichlid fish species), invasive weeds like Parthenium (carrot grass), Lantana, and water hyacinth (Eicchornia) in India, and the African catfish Clarias gariepinus threatening indigenous catfishes in Indian rivers.

(iv) Co-extinctions: When one species becomes extinct, other species that are obligatorily dependent on it also become extinct. For example, extinction of a host fish species leads to extinction of its unique parasites; extinction of one partner in a coevolved plant-pollinator mutualism leads to extinction of the other.

Answer: The four major causes ('Evil Quartet'): (i) habitat loss and fragmentation, (ii) over-exploitation, (iii) alien species invasions, and (iv) co-extinctions.

Q6 How is biodiversity important for ecosystem functioning?

SOLUTION

Biodiversity — particularly species richness — plays a crucial role in maintaining ecosystem health, stability, and functioning. Key points are:

(a) Stability: Communities with higher species diversity tend to be more stable. David Tilman's long-term outdoor plot experiments showed that plots with more species displayed less

year-to-year variation in total biomass, indicating greater stability.

(b) Productivity: Tilman also showed that increased species diversity contributes to higher productivity in ecosystems.

(c) Resistance to disturbances and invasions: Species-rich communities are more resistant to environmental perturbations (such as drought) and less susceptible to invasion by alien species.

(d) Ecosystem services: Biodiversity underpins critical ecosystem services such as pollination, oxygen production, climate moderation, flood control, soil conservation and pest control. For example, the Amazon forest produces approximately 20 per cent of Earth's atmospheric oxygen.

(e) The rivet popper analogy: Paul Ehrlich's 'rivet popper hypothesis' compares an ecosystem to an airplane held together by rivets (species). Loss of any species weakens the ecosystem, but loss of key species (like losing rivets from the wings) that drive major ecosystem functions is especially dangerous.

Loss of biodiversity in a region leads to: decline in plant production, lowered resistance to environmental perturbations like drought, and increased variability in ecosystem processes such as plant productivity, water use, and pest/disease cycles.

Answer: Greater species diversity leads to higher ecosystem stability, productivity, and resistance to disturbances and invasions. It also underpins essential ecosystem services (pollination, oxygen production, flood control). Loss of species destabilises ecosystem processes.

Q7 What are sacred groves? What is their role in conservation?

SOLUTION

Sacred groves are tracts of forest set aside by local communities for religious and cultural reasons. All the trees and wildlife within these tracts are venerated and given total protection by the community — no cutting, hunting, or disturbance is permitted.

In India, sacred groves are found in:
— Khasi and Jaintia Hills in Meghalaya
— Aravalli Hills of Rajasthan
— Western Ghats regions of Karnataka and Maharashtra
— Sarguja, Chanda and Bastar areas of Madhya Pradesh

Role in conservation:
Sacred groves serve as important refuges for rare and threatened plant and animal species. In Meghalaya, for example, the sacred groves are the last refuges for a large number of rare and threatened plants that may have disappeared from the surrounding degraded landscape. They help preserve local biodiversity, protect watersheds and forest patches, and often conserve species not found anywhere else in the vicinity. They represent an indigenous, community-based in situ conservation strategy that has existed for centuries.

Answer: Sacred groves are community-protected forest tracts with religious sanctity where all flora and fauna are preserved. They serve as refuges for rare and threatened species and represent a traditional in situ conservation approach.

Q8 Among the ecosystem services are control of floods and soil erosion. How is this achieved by the biotic components of the ecosystem?

SOLUTION

Biotic components — particularly plants and soil organisms — play a vital role in controlling floods and soil erosion through several mechanisms:

(a) Vegetation canopy interception: The leaves and branches of trees and other plants intercept rainfall, reducing the impact of rain drops on the soil surface and slowing down the rate at which water reaches the ground. This reduces surface runoff.

(b) Root systems and soil binding: Plant roots bind soil particles together, significantly reducing soil erosion by water and wind. Deep root systems of trees especially help anchor soil on slopes.

(c) Infiltration enhancement: Plant roots and soil organisms (earthworms, burrowing insects, fungi, bacteria) create channels and improve soil structure, increasing the soil's water-absorption capacity. Greater infiltration means less surface runoff, thus reducing both flooding downstream and soil erosion.

(d) Water retention and slow release: Forest soils, enriched by organic matter from decomposers and detritivores, act like sponges — absorbing large quantities of rainwater and releasing it slowly into streams and rivers. This reduces peak flood flows.

(e) Riparian vegetation: Plants along river banks and stream edges hold the banks together, preventing riverbank erosion and reducing sediment load in water bodies.

Thus, by slowing water flow, binding soil, improving infiltration, and regulating the water cycle, biotic components provide the ecosystem service of flood and erosion control.

Answer: Biotic components control floods and erosion through: interception of rainfall by vegetation, binding of soil by plant roots, enhancement of soil infiltration by roots and soil organisms, and retention-and-slow-release of water by humus-rich forest soils.

Q9 The species diversity of plants (22 per cent) is much less than that of animals (72 per cent). What could be the explanations to how animals achieved greater diversification?

SOLUTION

Although plants are the primary producers that form the base of all food chains, animals have achieved far greater species diversification (72 per cent of all described species vs. 22 per cent for plants). Possible explanations include:

(a) Mobility and habitat exploitation: Animals are mobile and can actively seek out and colonise

diverse habitats, microhabitats and niches. This mobility allows geographic isolation and promotes speciation at a much higher rate than in sessile plants.

(b) Diverse feeding strategies and co-evolution: Animals have evolved an enormous variety of feeding strategies — herbivory, carnivory, omnivory, parasitism, filter feeding, etc. Co-evolution with their food sources (especially plants and other animals) has driven rapid diversification. Insects, which alone make up more than 70 per cent of all animal species, have co-evolved extensively with flowering plants.

(c) Insects — an evolutionary success story: The extraordinary diversification of insects is a major reason animals outnumber plants in species count. Insects evolved wings, diverse mouthparts, complex life cycles (complete metamorphosis), and the ability to exploit virtually every terrestrial microhabitat. Their small body size also allowed resource partitioning at a fine scale.

(d) Greater phenotypic and ecological diversity: Animals have evolved diverse body plans, sensory systems, reproductive strategies, and behaviours that plants — being autotrophic and largely stationary — could not. This morphological and ecological flexibility has opened up many more evolutionary niches.

(e) Shorter generation times: Many animal groups (especially invertebrates) have shorter generation times, enabling faster evolutionary change and more rapid accumulation of new species.

In essence, animal mobility, co-evolutionary arms races, and the spectacular radiation of insects are the primary drivers of their greater species diversity.

Answer: Animals achieved greater diversification due to: mobility enabling colonisation of diverse habitats and geographic isolation; diverse feeding strategies and co-evolution; the extraordinary radiation of insects (>70% of all animals); and greater morphological/behavioural flexibility opening up more ecological niches.

Q10 Can you think of a situation where we deliberately want to make a species extinct? How would you justify it?

SOLUTION

Yes — the most widely discussed example is the deliberate eradication of the smallpox virus (Variola virus). Smallpox caused millions of human deaths over centuries. After a global vaccination campaign, the World Health Organization (WHO) declared smallpox eradicated in 1980. The virus now exists only in two high-security laboratories (CDC, USA and VECTOR, Russia). Many scientists have argued for the complete destruction of these remaining stocks to prevent any future accidental release or bioterrorism threat.

Justification for deliberate extinction in this case:
— The species (Variola virus) is an obligate human pathogen with no known beneficial role in any ecosystem — it serves no ecological function beyond infecting and harming humans.
— Its existence poses a continuous risk to human populations, especially as routine

vaccination has stopped and herd immunity has declined.
— There is no known natural host reservoir other than humans, so its eradication would not cause co-extinctions or disrupt any ecosystem process.
— The benefit to humanity (permanent elimination of a lethal disease) is enormous and unambiguous.

Other potential examples (more debatable):
— The mosquito species Anopheles gambiae (primary vector of malaria) has been proposed as a target for genetic drive-based eradication. However, this is far more controversial because mosquitoes occupy ecological roles (as food for other organisms, as pollinators in some contexts) and any unintended ecological consequences are harder to predict.

Conclusion: The ethical principle that every species has intrinsic value does hold, but in rare cases — where a species is an obligate human parasite with no ecological value and whose existence causes immense human suffering — deliberate extinction can be ethically justified on the grounds of the greater good for human (and broader) welfare.

Answer: Yes — deliberate extinction of the smallpox virus (Variola) is justifiable: it is an obligate human pathogen with no ecosystem role, and its eradication permanently eliminates a lethal disease. More debatable: genetically driving Anopheles gambiae (malaria vector) to extinction, though ecological consequences are less certain.