Chapter 11: Organisms and Populations

Exercises — Chapter-end Exercises

Q1 List the attributes that populations possess but not individuals.

SOLUTION

A population is a group of individuals of the same species sharing a defined geographical area. Populations have certain attributes that cannot be described for a single individual:

1. Birth rate (natality): The per capita number of births in the population over a given time period. An individual can give birth, but a 'birth rate' is a population-level statistic (e.g., 0.4 offspring per lotus per year).

2. Death rate (mortality): The per capita number of deaths in the population over a given period (e.g., 0.1 individuals per fruitfly per week). A single organism simply dies; a death rate is a property of the whole population.

3. Sex ratio: The proportion of males and females in the population (e.g., 60% females and 40% males). An individual is either male or female, not a ratio.

4. Age distribution / Age pyramid: The percentage of individuals belonging to different age groups (pre-reproductive, reproductive, post-reproductive) presented as an age pyramid. Its shape indicates whether a population is growing, stable or declining. A single individual has only one age.

5. Population density (N): The total number (or biomass, or per cent cover) of individuals in a defined area at a given time. An individual has no 'density'.

6. Intrinsic rate of natural increase (r): The inherent potential of the population to grow, calculated as $r = b - d$ (birth rate minus death rate). This is a population-level parameter.

7. Carrying capacity (K): The maximum population size that a given habitat can sustain with its available resources — a property of the population in relation to its environment, not of any single individual.

Answer: Populations possess birth rate, death rate, sex ratio, age distribution (age pyramid), population density, intrinsic rate of natural increase (r), and carrying capacity (K) — attributes that have no meaning for a single individual.

Q2 If a population growing exponentially double in size in 3 years, what is the intrinsic rate of increase (r) of the population?

SOLUTION

For exponential growth the integral equation is:
$N = N_0 e^r$

Given: the population doubles in $t = 3$ years, so $N = 2N_0$.

Substituting:

$2N_o = N_o \times e^{rx3}$

$2 = e^{3r}$

Taking the natural logarithm of both sides:

$\ln 2 = 3r$

$r = \ln 2 / 3$

$r = 0.6931 / 3$

$r \approx 0.231$ per year

Answer: $r = \ln 2 / 3 \approx 0.231$ per year

Q3 Name important defence mechanisms in plants against herbivory.

SOLUTION

Plants cannot move away from herbivores and have therefore evolved a wide variety of morphological and chemical defence mechanisms:

Morphological defences:

1. Thorns: Sharp thorns on Acacia and Cactus deter browsing animals from eating them.
2. Silica crystals and tough leaves: Physical barriers that make leaves difficult to chew or digest.

Chemical defences:

3. Toxic chemicals / secondary metabolites: Many plants produce and store chemicals that make herbivores sick, inhibit their feeding or digestion, disrupt their reproduction or even kill them. Examples include:
   - Calotropis produces highly poisonous cardiac glycosides, which is why cattle and goats do not browse on it.
   - Nicotine (tobacco plant), caffeine (tea/coffee), quinine (Cinchona), strychnine, and opium are plant-produced chemicals that function as defences against grazers and browsers.
4. Cryptic colouration / camouflage: Some plants mimic their surroundings to avoid detection (less common in plants; more so in prey animals).

In summary, plants use thorns (morphological) and a wide array of toxic secondary metabolites (chemical) as the most important defences against herbivory.

Answer: Important plant defences against herbivory are: (i) morphological — thorns (Acacia, Cactus); (ii) chemical — toxic secondary metabolites such as cardiac glycosides (Calotropis), nicotine, caffeine, quinine, strychnine, and opium that deter, harm or kill herbivores.

Q4 An orchid plant is growing on the branch of mango tree. How do you describe this interaction between the orchid and the mango tree?

SOLUTION

The orchid is an epiphyte — it uses the mango tree merely as a physical support to grow at a height where it can get adequate sunlight. The orchid derives benefit (support, light access) from this association.

The mango tree, however, is neither harmed nor benefited by the presence of the orchid. The orchid does not draw nutrition from the mango tree (it is not a parasite) and does not cause structural damage to it.

This interaction — where one species benefits and the other is unaffected — is called commensalism.

The orchid is the commensal (benefited species, +) and the mango tree is the host (unaffected species, 0). The interaction can be represented as (+, 0).

Answer: This is commensalism (+, 0): the orchid (epiphyte) benefits by using the mango tree as a support to access sunlight, while the mango tree is neither harmed nor benefited.

Q5 What is the ecological principle behind the biological control method of managing with pest insects?

SOLUTION

The ecological principle behind biological control is predation — specifically, the ability of a natural predator to regulate the population density of its prey.

In predation, a predator kills and feeds on its prey, thereby keeping the prey population under check. When a pest insect (prey species) causes damage in a crop or an ecosystem, introducing or encouraging its natural predator (or parasitoid) can reduce the pest population to economically acceptable levels.

A classic example: the prickly pear cactus (Opuntia) introduced into Australia in the 1920s spread uncontrollably over millions of hectares because its natural predator was absent. When a cactus-feeding moth (its natural predator from its native habitat) was introduced, the cactus population was brought under control.

The key ecological insight is that predators in nature are 'prudent' — they do not drive their prey to extinction because that would also lead to their own extinction. Properly chosen biological control agents regulate pest populations sustainably without the side-effects of chemical pesticides.

Answer: The ecological principle is predation: a natural predator (biological control agent) regulates the prey (pest) population density, keeping it under check in a sustainable manner.

Q6 Define population and community.

SOLUTION

Population:

A population is a group of individuals of the same species that live together in a well-defined geographical area, share or compete for similar resources, and potentially interbreed. Although interbreeding implies sexual reproduction, groups resulting from asexual reproduction are also considered populations for ecological studies. Examples: all cormorants in a wetland, all rats in an abandoned dwelling, all lotus plants in a pond.

Community:

A community (or biotic community) is an assemblage of populations of different species living together and interacting in a defined geographical area. It includes all the plants, animals, and microorganisms of an area. Communities are characterised by their species composition, species diversity, and the various interspecific interactions (competition, predation, parasitism, mutualism, commensalism, amensalism) among the constituent populations. No species in nature lives in isolation — all form part of a community.

Answer: Population: a group of individuals of the same species sharing a defined area and potentially interbreeding. Community: an assemblage of populations of different species living together and interacting in a defined area.

Q7 Define the following terms and give one example for each:
(a) Commensalism
(b) Parasitism
(c) Camouflage
(d) Mutualism
(e) Interspecific competition

SOLUTION

(a) Commensalism:

An interspecific interaction in which one species benefits and the other species is neither harmed nor benefited (+, 0 interaction).

Example: An orchid growing as an epiphyte on a mango tree branch. The orchid gets support and access to sunlight; the mango tree is unaffected. Another example: cattle egrets forage near grazing cattle — the egrets benefit by catching insects flushed out by the moving cattle, while the cattle are unaffected.

(b) Parasitism:

An interspecific interaction in which one species (the parasite) benefits at the expense of the other species (the host), which is harmed (+, − interaction). The parasite derives food and/or shelter from the host and may reduce the host's survival, growth or reproductive success.

Example: Cuscuta (dodder plant) is a holoparasite that grows on hedge plants; having lost its chlorophyll and leaves, it derives all nutrition from the host plant, harming it. In animals, the human liver fluke (a trematode) parasitises the human liver, using two intermediate hosts (snail

and fish) to complete its life cycle.

(c) Camouflage:
A defence mechanism (a form of cryptic colouration) in which an organism resembles its background or surroundings so closely that it becomes difficult for predators (or prey) to detect it.
Example: Some species of insects and frogs are cryptically coloured to blend with leaves, bark or soil, making them very difficult for predators to spot.

(d) Mutualism:
An interspecific interaction that confers benefits on both the interacting species (+, + interaction). Both partners gain from the association.
Example: The fig tree and the fig wasp share an obligate mutualism. The female wasp pollinates the fig inflorescence while searching for an egg-laying site; in return, the fig provides some of its developing seeds as food for the wasp larvae. Neither can reproduce successfully without the other. Another example: lichens — an intimate mutualism between a fungus and photosynthesising algae or cyanobacteria.

(e) Interspecific competition:
An interaction between individuals of two different species in which both species suffer because they compete for the same limited resources (food, space, light, etc.) (−, − interaction). The fitness (measured as r, the intrinsic rate of natural increase) of both species is reduced in each other's presence.
Example: In shallow South American lakes, visiting flamingoes and resident fishes compete for zooplankton, their common food resource. Another example: on the rocky sea coasts of Scotland, the larger barnacle Balanus competitively excludes the smaller barnacle Chthamalus from the intertidal zone.

Answer: (a) Commensalism (+,0): one benefits, other unaffected — orchid on mango. (b) Parasitism (+,−): parasite benefits, host harmed — Cuscuta on hedge plants. (c) Camouflage: cryptic colouration to avoid detection — colour-matched insects/frogs. (d) Mutualism (+,+): both benefit — fig tree and fig wasp. (e) Interspecific competition (−,−): both species suffer competing for the same resource — flamingoes and fishes competing for zooplankton.

Q8 With the help of suitable diagram describe the logistic population growth curve.

SOLUTION

Logistic Population Growth Curve (Verhulst-Pearl Logistic Growth / S-shaped / Sigmoid curve):

Diagram description — Figure 11.3 (curve b):
Draw a graph with Time (t) on the X-axis and Population density (N) on the Y-axis. Draw a horizontal dashed line at the top labelled K (carrying capacity). Draw an S-shaped (sigmoid) curve starting near the origin and rising to level off asymptotically at K.

Labels to include on the diagram:
- X-axis: Time (t) →

- Y-axis: Population density (N) ↑
- Horizontal dashed asymptote at the top: K (Carrying capacity)
- The S-shaped curve labelled: Logistic growth curve (curve b), with the equation dN/dt = rN((K−N)/K) written alongside
- Phase 1 (bottom, gentle slope): Lag phase — slow initial growth as population is small
- Phase 2 (middle, steep slope): Acceleration phase — rapid growth as population increases
- Phase 3 (upper, slope decreasing): Deceleration phase — growth slows as N approaches K
- Phase 4 (top, flat): Asymptote — population stabilises at N = K

(For comparison, also show curve a — the J-shaped exponential curve — rising steeply without levelling off, with equation dN/dt = rN)

Description:

No population in nature has unlimited resources; sooner or later resources become limiting. In a habitat with limited resources, a population initially shows a lag phase (slow growth), followed by an acceleration phase (rapid growth), then a deceleration phase as resources become increasingly limiting, and finally reaches an asymptote (plateau) when the population density equals the carrying capacity (K) of the habitat. A plot of population density (N) against time (t) produces a sigmoid (S-shaped) curve.

This growth is described by the Verhulst-Pearl logistic equation:
$dN/dt = rN \times ((K - N) / K)$

Where:
N = Population density at time t
r = Intrinsic rate of natural increase
K = Carrying capacity

The term (K − N)/K is the unutilised growth opportunity (the 'damping factor'). When N is very small relative to K, (K−N)/K ≈ 1 and growth is nearly exponential. As N approaches K, (K−N)/K approaches 0 and growth rate approaches zero. When N = K, growth stops completely.

Since resources for most animal populations are finite and become limiting sooner or later, the logistic growth model is considered more realistic than the exponential model.

Answer: The logistic (S-shaped / sigmoid) growth curve shows four phases: lag → acceleration → deceleration → asymptote at carrying capacity K. It is described by dN/dt = rN((K−N)/K). The curve levels off at K because resources become limiting as population grows.

Q9 Select the statement which explains best parasitism.
(a) One organism is benefited.
(b) Both the organisms are benefited.
(c) One organism is benefited, other is not affected.
(d) One organism is benefited, other is affected.

SOLUTION

Evaluating each option:

(a) One organism is benefited — This is incomplete; it does not describe what happens to the other organism. It could apply to commensalism or parasitism.
(b) Both the organisms are benefited — This describes mutualism (+, +), not parasitism.
(c) One organism is benefited, other is not affected — This describes commensalism (+, 0), not parasitism.
(d) One organism is benefited, other is affected — This correctly describes parasitism: the parasite (+) benefits by deriving food/shelter from the host, while the host (−) is harmed. The host suffers reduced survival, growth and reproduction.

Option (d) is the best description of parasitism.

Answer: (d) One organism is benefited, other is affected.

Q10 List any three important characteristics of a population and explain.

SOLUTION

Three important characteristics of a population:

1. Population density (N):
Population density is the number of individuals of a species present per unit area (or volume) at a given time. It is the most fundamental measure of a population's status in its habitat. Population density can be expressed as total numbers (e.g., number of tigers in a reserve), biomass (e.g., per cent cover of a plant), or relative measures (e.g., fish caught per trap). It fluctuates over time due to changes in birth rate, death rate, immigration and emigration. Ecologists use it to assess the impact of competition, predation, disease or pesticides on the population. Example: the Siberian cranes at Bharatpur wetlands number fewer than 10, while Chlamydomonas in a pond may number in millions.

2. Birth rate (natality) and Death rate (mortality):
Birth rate is the per capita number of births added to a population per unit time. Death rate is the per capita number of deaths in the population per unit time. Together they are the primary drivers of population size change under normal conditions (along with immigration and emigration). If birth rate exceeds death rate, population grows; if death rate exceeds birth rate, population declines.
Example: If a pond has 20 lotus plants and 8 new plants are added through reproduction, birth rate = 8/20 = 0.4 offspring per lotus per year. If 4 of 40 fruitflies die in a week, death rate = 4/40 = 0.1 per fruitfly per week.

3. Age distribution (Age pyramid):
A population at any time consists of individuals of different ages — pre-reproductive, reproductive and post-reproductive. When the percentage of individuals in each age group is plotted, the resulting structure is called an age pyramid. The shape of the age pyramid reflects the growth status of the population:
- Broad base (more pre-reproductive individuals): rapidly growing population
- Equal proportions at all ages: stable (stationary) population

- Narrow base (fewer young, more old): declining population

Age pyramids are commonly drawn for human populations to show the distribution of males and females across age groups, and are used by governments for demographic planning.

Answer: Three key population characteristics: (1) Population density (N) — number of individuals per unit area, the primary measure of population status; (2) Birth rate and death rate — per capita rates that drive population growth or decline; (3) Age distribution (age pyramid) — proportions of pre-reproductive, reproductive, and post-reproductive individuals, whose shape indicates whether a population is growing, stable or declining.