ANSWER KEY. Answers and explanations appear after each question, marked by a bar at the left. Answers written in table cells are in italics.

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Populations Study Guide

Biology | ANSWER KEY

Show your work with units. Use complete sentences when a question asks you to explain.

Key relationships	**Percent change** = (new − old) ÷ old × 100	**Times greater** = larger value ÷ smaller value	**Population change** = births + immigration − deaths − emigration	**Quadrats**: density = mean count ÷ quadrat area; population = density × total area	**Mark-recapture**: N ≈ (M × C) ÷ R

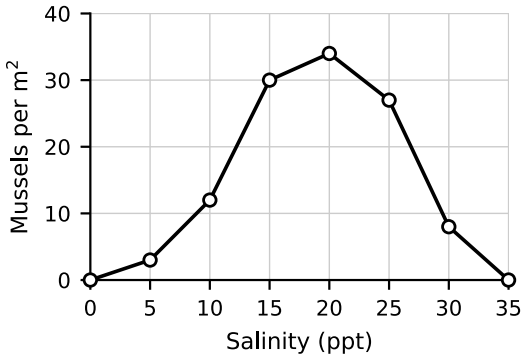
Part 1. Niches and Tolerance Ranges

1. The graph shows how many mussels live at sites with different salinity in an estuary, where a river meets the sea (sample data). Salinity is the amount of salt in water, in parts per thousand (ppt).

(a) Is salinity an abiotic or a biotic factor? Name one biotic factor that could also affect where the mussels live.

(b) Use the graph to estimate the optimum range and the upper limit of tolerance for salinity.

(c) A few mussels live at 30 ppt. Which zone of the tolerance range is this? Describe what happens to individuals in this zone.



(a) **Abiotic** (nonliving). Biotic, any one: **sea stars or crabs that eat mussels, the plankton they eat, competitors for space on rocks.**

(b) **Optimum: about 15 to 25 ppt** (27 to 34 mussels per m^2). **Upper limit: between 30 and 35 ppt**, since there are 8 per m^2 at 30 ppt and none at 35 ppt.

(c) **Upper zone of stress.** Individuals can survive, but growth and reproduction fall, so there are fewer of them.

2. A drought hit a prairie between year 1 and year 3. The table shows sample data.

	Year 1	**Year 3**	**Percent change**
Butterfly G (caterpillars eat 14 kinds of plants)	480	432	***-10%***
Butterfly S (caterpillars eat one kind of milkweed)	320	64	***-80%***
Milkweed plants per hectare	900	200	***-78%***

(a) Complete the table. Round to the nearest whole percent.

(b) Which butterfly is the specialist? Write a claim that explains why it declined more than the other butterfly. Support it with evidence and reasoning.

(a) G: (432 − 480) ÷ 480 × 100 = −10%. S: (64 − 320) ÷ 320 × 100 = −80%. Milkweed: (200 − 900) ÷ 900 × 100 ≈ −78%.

(b) **Butterfly S is the specialist. Claim: S declined more because it depends on one food plant. Evidence: milkweed fell 78%, and S fell 80%, while G fell only 10%. Reasoning: G can switch to its other 13 food plants, but S has no other food, so a change in one resource hits it hard.** Must include: S is the specialist, numbers for both butterflies and the milkweed.

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Part 2. Population Sampling

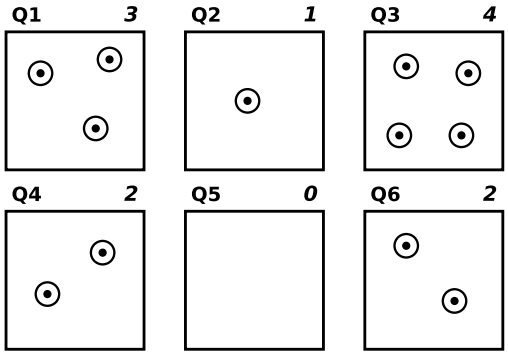
3. A student places six quadrats at random in a 600 m^2 meadow and counts the wild strawberry plants (circles) in each (sample data). Each quadrat is 0.5 m × 0.5 m, so its area is 0.25 m^2.

(a) Count the plants in each quadrat. Find the mean number of plants per quadrat.

(b) Find the population density in plants per m^2.

(c) Estimate the number of wild strawberry plants in the meadow.

(d) Another student put all six quadrats in the sunniest corner, where the plants grow best. Would that estimate be too high or too low? Explain.



> (a) **3, 1, 4, 2, 0, 2.** Total 12 plants. Mean: 12 plants ÷ 6 quadrats = **2.0 plants per quadrat**. (b) 2.0 plants ÷ 0.25 m^2 = **8.0 plants per m^2**.
> (c) 8.0 plants/m^2 × 600 m^2 = **about 4,800 plants**. (d) **Too high.** The quadrats were not placed at random, so the sample is **biased** toward the best spot.

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4. Researchers catch 72 crayfish in a creek, mark each shell with a dot of paint, and release them. Four days later they catch 54 crayfish, and 12 of them have paint dots.

(a) Estimate the number of crayfish in the creek.

(b) Crayfish shed their shells as they grow. Suppose some marked crayfish shed their shells, and their marks, before the second catch. Would the estimate be too high or too low? Explain.

(c) Name one other assumption the estimate depends on.

> (a) N ≈ (M × C) ÷ R = (72 × 54) ÷ 12 = **324 crayfish**.
> (b) **Too high.** Fewer marked crayfish would be counted, so R would be too small, and dividing by a smaller R gives a larger N.
> (c) Any one: **marked crayfish mix evenly with the others; none are born, die, move in, or leave between catches; the paint does not change a crayfish's chance of being caught.**

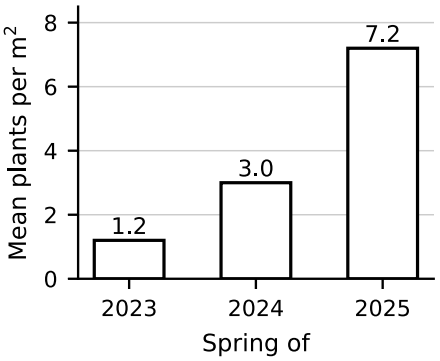
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5. An invasive plant is spreading in a 2,000 m^2 woodland. Each spring, students use the same method: ten 1 m^2 quadrats placed at random (sample data).

(a) Estimate the number of these plants in the woodland in each year.

(b) How many times greater was the density in 2025 than in 2023?

(c) A classmate says, "We only counted 10 m^2, so these numbers tell us nothing about the woodland." Explain why the estimates are still useful.



> (a) 1.2 plants/m^2 × 2,000 m^2 = **2,400**; 3.0 × 2,000 = **6,000**; 7.2 × 2,000 = **14,400** plants. (b) 7.2 ÷ 1.2 = **6 times greater**.
> (c) **Each number is an estimate, not an exact count, but random placement keeps it from being biased, and using the same method every year makes the years fair to compare.** The trend shows the plant is spreading fast.

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Part 3. Exponential and Logistic Growth

6. The table follows a colony of bats in a cave for two years (sample data).

	Start	Births	Immigration	Deaths	Emigration	End of year
Year 1	1,200	300	60	180	120	***1,260***
Year 2	***1,260***	240	30	300	90	***1,140***

(a) Complete the table.

(b) Find the percent change in the colony over the two years.

(c) In year 2, 270 bats were added to the colony. Explain why it still got smaller.

> (a) Year 1: 1,200 + 300 + 60 − 180 − 120 = 1,260. Year 2: 1,260 + 240 + 30 − 300 − 90 = 1,140. (b) (1,140 − 1,200) ÷ 1,200 × 100 = **−5%**, a 5% decrease.
>
> (c) **More bats were removed than added: 300 deaths + 90 emigrants = 390 removed, compared with 270 added, so the colony lost 120 bats.**

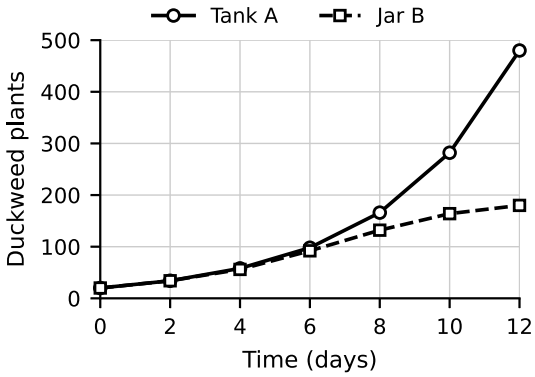
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7. Students start two containers with 20 duckweed plants each. Tank A is a large tank that gets fresh nutrient water every day. Jar B is a small jar, and its water is never changed (sample data).

(a) Which container shows exponential growth, and which shows logistic growth? Describe the shape of each graph.

(b) How many times larger was each population on day 12 than on day 0? Estimate the carrying capacity of jar B.

(c) Explain why jar B leveled off. Predict what will eventually happen in tank A, and explain.



> (a) **Tank A: exponential, J-shaped** (it grows faster and faster). **Jar B: logistic, S-shaped** (it rises, then levels off).
>
> (b) A: 480 ÷ 20 = **24 times**. B: 180 ÷ 20 = **9 times**. Jar B's carrying capacity is **about 180 to 200 plants**.
>
> (c) **In jar B, nutrients and space ran short, so fewer new plants were added and growth slowed near K. Tank A will run out of space on the water surface, so its growth will also slow and level off.**

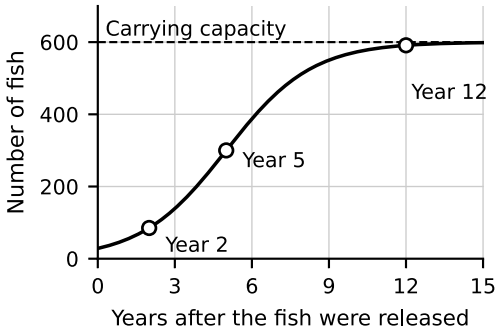
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8. Fish are released into a new reservoir. The graph shows the logistic model of their growth, and the table gives births and deaths for three years (sample data). No fish move in or out.

(a) Complete the table. Net change = births − deaths.

(b) Which of the three years is on the steepest part of the curve? How do the table data support your answer?

(c) Explain why births and deaths are almost equal in year 12.



Year	Births	Deaths	Net change
2	60	20	***+40***
5	150	60	***+90***
12	110	105	***+5***

> (a) Year 2: 60 − 20 = **+40**. Year 5: 150 − 60 = **+90**. Year 12: 110 − 105 = **+5**.
>
> (b) **Year 5.** It has the largest net change (+90 fish), and the steepest part of the curve is where the population increases fastest.
>
> (c) **In year 12 the population is near the carrying capacity. Food and space are limited, so fewer young survive, and the number added is about equal to the number lost.**

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Part 4. Limiting Factors

9. A seabird nests in burrows on a small island and feeds on fish near the island. Each nesting pair needs one burrow and 400 kg of fish per season (sample data).

Resource on the island	Amount available	Pairs it could support
Burrows	1,800 burrows	***1,800 pairs***
Fish	540,000 kg per season	***1,350 pairs***

(a) Complete the table. What is the carrying capacity, and what is the limiting factor?

(b) A conservation group digs 500 new burrows. Will the carrying capacity change? Explain.

(c) Instead, the fish supply rises by 20%. Find the new carrying capacity.

> (a) Fish: 540,000 kg ÷ 400 kg per pair = 1,350 pairs. **K = 1,350 pairs. Food (fish) is the limiting factor**, because it is the scarcest resource.
>
> (b) **No.** Food still supports only 1,350 pairs, so extra burrows do not help. (c) 540,000 kg × 1.20 = 648,000 kg; 648,000 kg ÷ 400 kg per pair = **1,620 pairs** (still below the 1,800 burrows, so food still limits).

10. (a) Classify each limiting factor as density-dependent or density-independent.

Limiting factor	Density-dependent or density-independent
(1) A late frost kills the flowers on every cherry tree in an orchard.	***Density-independent***
(2) In crowded tide pools, barnacles grow over each other, and fewer survive.	***Density-dependent (competition)***
(3) Owls catch a larger share of the voles in years when voles are abundant.	***Density-dependent (predation)***
(4) A hurricane floods a beach where sea turtles nest.	***Density-independent***

(b) In one cold winter, a small vole population fell from 100 to 60, and a large one fell from 1,000 to 600. Calculate the percent change for each. Do the data show that the cold was density-dependent or density-independent? Explain.

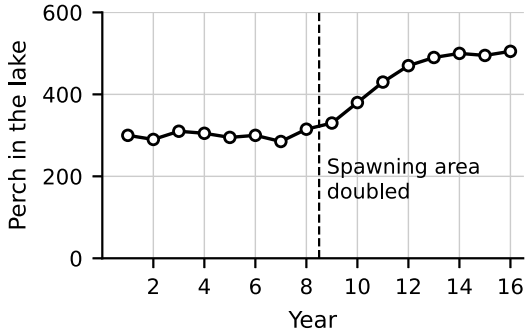
> (b) Small: (60 − 100) ÷ 100 × 100 = −40%. Large: (600 − 1,000) ÷ 1,000 × 100 = −40%. **Density-independent**, because the cold killed the same share of each population no matter how crowded it was.

11. The graph shows a perch population in a lake (sample data). After year 8, a new dam raised the water level and doubled the shallow area where perch lay their eggs.

(a) Estimate the carrying capacity before and after the change.

(b) Find the percent change in the carrying capacity.

(c) What was most likely the limiting factor before year 9? Support your claim with evidence and reasoning. Then explain what it means that the spawning area doubled but the carrying capacity did not.



> (a) **Before: about 300 perch. After: about 500 perch.** (b) (500 − 300) ÷ 300 × 100 ≈ **67% increase**.
>
> (c) **Claim: spawning area limited the perch. Evidence: the population stayed between 285 and 315 for 8 years, then rose to about 500 after the spawning area doubled. Reasoning: a stable population sits near K, and adding more of the limiting resource raised K.** K rose only 67%, not 100%, so **another factor, such as food, now limits the population**.

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Part 5. Reproductive Strategies

12. Lizards of one species live on two islands. Each female lays one clutch of eggs per season (sample data).

	Eggs per clutch	Mass of each egg (g)	Total egg mass (g)	Hatchlings that reach adulthood	Surviving young per clutch
Island A	12	0.4	***4.8***	10%	***1.2***
Island B	4	1.2	***4.8***	40%	***1.6***

(a) Complete the table.

(b) Use the total egg mass to explain the trade-off the females on the two islands make.

(c) Which island's lizards tend toward the r-strategy end? Use the table to explain.

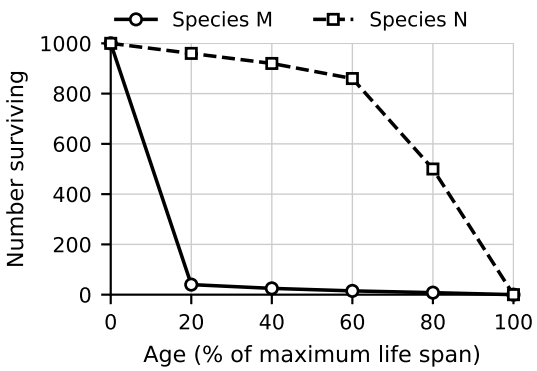
> (a) A: 12 × 0.4 g = 4.8 g; 12 × 0.10 = 1.2 young. B: 4 × 1.2 g = 4.8 g; 4 × 0.40 = 1.6 young.
>
> (b) **Both females put the same total, 4.8 g, into eggs, so energy is limited. Island A splits it into many small eggs; island B puts it into a few large eggs, and more of those young survive.**
>
> (c) **Island A**: more, smaller eggs, and a lower share of them survive.

13. The graph shows survivorship for two species, each starting with 1,000 individuals (sample data).

(a) What percent of each species died between age 0 and 20% of the life span?

(b) Match each species to a survivorship type: Type I, Type II, or Type III. Explain how you know.

(c) Which species most likely gives more parental care to its young? Explain using the curves.



> (a) M: (1,000 − 40) ÷ 1,000 × 100 = **96%**. N: (1,000 − 960) ÷ 1,000 × 100 = **4%**.
>
> (b) **M: Type III**, most die very young, then the curve levels off. **N: Type I**, most survive until late in life, then the curve drops steeply.
>
> (c) **Species N.** Its young almost all survive the early part of life, which fits much care for each offspring; M loses 96% of its young early.

14. The table lists traits of species T (sample data).

Offspring per breeding season	Parental care	Time to mature	Life span
400	None	25 years	About 60 years

(a) Which of T's traits point toward the r-strategy end, and which point toward the K-strategy end?

(b) Predict the shape of the survivorship curve for T's young during their first year. Explain.

(c) A student says every species is either an r-strategist or a K-strategist. Use species T to respond.

> (a) **r-end: many offspring (400) and no parental care. K-end: slow to mature (25 years) and a long life span (about 60 years).**
>
> (b) **A steep early drop, like Type III:** with no care, most of the 400 young are likely to die young. (c) **The student is wrong.** r and K are two ends of a range. Species T has traits from both ends, so it falls in between.

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Part 6. Group Behavior

15. A hawk attacks groups of small birds. In a successful attack, it catches one bird. Larger groups spot the hawk sooner, so fewer attacks succeed (sample data).

Group size	Attacks that succeed	Chance that a given bird is caught in one attack
1	60%	***60%***
5	40%	***8%***
20	20%	***1%***

(a) Complete the table. Chance = percent of attacks that succeed ÷ group size.

(b) How many times lower is the chance for a bird in a group of 20 than for a bird alone?

(c) Name the two benefits of group living that this model shows. Which column shows each one?

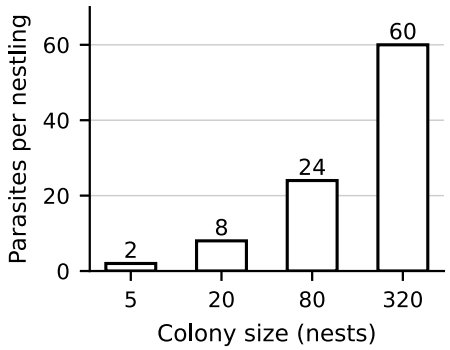
> (a) 60% ÷ 1 = 60%; 40% ÷ 5 = 8%; 20% ÷ 20 = 1%. (b) 60% ÷ 1% = **60 times lower**.
> (c) **Many eyes**: the hawk is spotted sooner, so fewer attacks succeed (second column). **Dilution**: each bird is a smaller share of the targets (dividing by group size).

16. A swallow species nests in colonies. Blood-feeding bugs live in the nests. The graph shows sample data.

(a) Describe the pattern. How many times more parasites does a nestling have in a colony of 320 nests than in a colony of 5?

(b) Explain why parasites are a cost of group living that grows as the colony gets larger.

(c) Name one benefit that could make a large colony worth this cost.



> (a) **Parasites per nestling increase as colony size increases.** 60 ÷ 2 = **30 times more**.
> (b) **Nests are close together, so the bugs spread easily from nest to nest, and a larger colony has more nests for them to spread through.**
> (c) Any one: **many eyes (predators are spotted sooner), dilution, or defending the colony together.**

17. Wild dogs hunt in packs. The table shows sample data for packs of different sizes.

Pack size	Successful hunts per 10 tries	Meat per dog per day (kg)
2	2	3.0
4	5	4.5
8	8	3.6
16	9	2.0

(a) Find the percent change in meat per dog from a pack of 4 to a pack of 16.

(b) A student says, "The bigger the pack, the better off each dog is." Evaluate this claim. Use claim, evidence, and reasoning, with data from both columns.

> (a) (2.0 − 4.5) ÷ 4.5 × 100 ≈ **−56%**, a 56% decrease.
> (b) **Claim: the student is only partly right. Evidence: successful hunts rose from 2 to 9 per 10 tries as packs grew from 2 to 16, but meat per dog was highest in packs of 4 (4.5 kg) and fell to 2.0 kg in packs of 16. Reasoning: teamwork helps a pack catch prey, but each kill is shared by more dogs, so competition is a cost. The net effect is best at a medium pack size.** Must include: data from both columns, a benefit and a cost.

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