

**Formulas***discrete time growth:*

- $N_T = N_0 \lambda^T$
- $\lambda = f + p$
- $\mathcal{R} = f/(1 - p)$

*continuous time growth:*

- $N(t) = N(0) \exp(rt)$
- $r = b - d$
- $\mathcal{R} = b/d$

**structured growth:**

- $\ell_x = p_1 \times p_2 \times \dots p_{x-1}$
- $\sum \ell_x f_x \lambda^{-x} = 1$
- $\text{SAD}(x) \propto \ell_x \lambda^{-x}$

1. Which of the following is true of the stable age distribution of a population with  $R = 1$ ?

- A. It is exactly proportional to  $\ell_x$
- B. It may either increase or decrease with age
- C. It is more top-heavy than the  $\ell_x$  curve
- D. It is more bottom-heavy than the  $\ell_x$  curve
- E. It increases exponentially

2. Which of the following is a true statement about life tables

- A.  $p_x$  always increases as  $x$  increases
- B.  $p_x$  always decreases as  $x$  increases
- C.  $\ell_x$  always increases as  $x$  increases
- D.  $\ell_x$  always decreases as  $x$  increases
- E.  $p_x$  is always  $\geq \ell_x$

3. Consider a 500kg moose, a 30kg beaver and a 15kg fox. Which animal is the most different in mass from the others?

- A. The moose is most different on any scale
- B. The fox is most different on any scale
- C. The beaver is the national animal of Canada and therefore cannot even be compared to the other two animals!
- D. The moose is most different when considered on the linear scale and the fox is most different when considered on the log scale
- E. The fox is most different when considered on the linear scale and the moose is most different when considered on the log scale

Use the following information for the next two questions. A population of oak trees is estimated to be at stable age distribution, with a constant life table, with reproductive number  $\mathcal{R} = 0.9$ . It takes the trees several years to reach maturity and reproduce.

4. This population is

- A. declining
- B. stable
- C. increasing
- D. showing damped oscillations
- E. there is not enough information to answer this question

5. What is the *most accurate* statement you can make about the finite rate of growth  $\lambda$ , measured with a time step of one year?

- A. We expect  $\lambda < 0.9$
- B. We expect  $\lambda = 0.9$
- C. We expect  $\lambda < 1$
- D. We expect  $0.9 < \lambda < 1$
- E. We expect  $0.9 < \lambda$

6. A new species is trying to invade a stable resident population (we don't know whether it will be successful). Which of the following is a true statement about reproductive numbers in this situation?

- A. The resident has  $\mathcal{R} > 1$
- B. The invader has  $\mathcal{R} > 1$
- C. The resident has  $\mathcal{R} = 1$
- D. The invader has  $\mathcal{R} = 1$

7. A species of introduced rat reproduces very well on islands near South America with no other rats, but does not survive under very similar conditions on the mainland, where other species of rat are present. It is likely that the mainland environment \_\_\_\_\_ part of the fundamental niche and \_\_\_\_\_ part of the realized niche for this species.

- A. is; is
- B. is; is not
- C. is not; is
- D. is not; is not

8. Which of these is *not* an effect that tends to *balance* the tendency of populations to grow or decline exponentially without limit?

- A. Allee effects
- B. Competition for access to resources
- C. Resource depletion
- D. Dynamics of natural enemies

9. Which of the following is *not* an example of a tradeoff?

- A. Birds with heavier beaks that allow them to access more kinds of food have higher mortality before reaching maturity
- B. Bushes which survive better in dry conditions grow more slowly in wet conditions
- C. Trees grown in full sunlight grow faster and have more resistance to diseases
- D. Rabbits which need less food to survive produce fewer offspring when food is plentiful

Use this information for the next two questions. The simple, time-delayed continuous model we studied is written  $\frac{dN(t)}{dt} = (b(N(t - \tau)) - d(N(t - \tau)))N(t)$

10. In this model,  $\tau$  represents:

- A. The characteristic time for exponential growth
- B. The time delay for the population size to affect growth rates
- C. The carrying capacity
- D. Density dependence

11. This model shows what range of behaviour?

- A. Smooth convergence to equilibrium only
- B. Smooth convergence and damped cycles only
- C. Damped cycles and persistent cycles only
- D. Persistent cycles or chaotic behaviour only
- E. All of the above behaviours

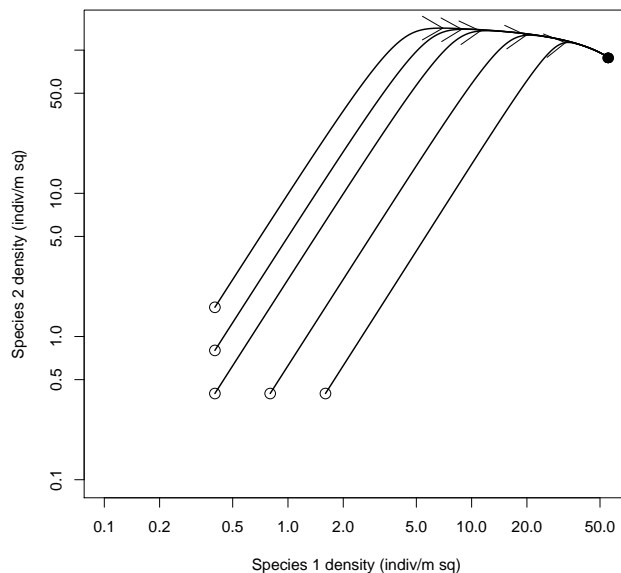
12. Malaria no longer spreads effectively in the Southeastern United States, although the mosquito and human populations that used to spread it are still present. We interpret this to mean that for the malaria parasite in this region and at this time:

- A.  $\mathcal{R}$  (but not necessarily  $\lambda$ )  $< 1$
- B.  $\mathcal{R}$  and  $\lambda$  are both  $< 1$
- C.  $\mathcal{R}$  (but not necessarily  $\lambda$ )  $> 1$
- D.  $\mathcal{R}$  and  $\lambda$  are both  $> 1$

13. A species of annual plant produces an average of 100 seeds per reproductive adult. Half of these seeds, on average, land in forest clearings – these seeds have a 4% chance of surviving to be reproductive adults. The other half land in the forest, and have only a 1% chance of surviving. What is the finite rate of increase  $\lambda$  for these plants?

- A. 1
- B. 1.25
- C. 1.5
- D. 2.5
- E. 5

Use the picture below for the next three questions. The path in the middle corresponds to a density of 0.4 indiv/m<sup>2</sup> for each species.



14. This picture shows what sort of competition outcome?
- A. Species 1 dominates
  - B. Species 2 dominates
  - C. The species co-exist
  - D. There is mutual exclusion
15. Assuming density dependence can be neglected at low densities, which species has the higher value of  $r_{\max}$ ?
- A. Species 1
  - B. Species 2
  - C. They have the same value of  $r_{\max}$
  - D. Either species can have a higher value, depending on initial conditions.
16. From this picture, we can conclude that:
- A. Both of the competition coefficients  $\alpha < 1$ .
  - B. Both of the competition coefficients  $\alpha > 1$ .
  - C. Both of the population-level competitive effects  $E < 1$ .
  - D. Both of the population-level competitive effects  $E > 1$ .
  - E. We cannot make any of these conclusions from this picture.
17. Suppose that adults of a species of annual plants each have 500 seeds per year. On average, 3% of the seeds germinate to become sprouts; on average, 10% of the sprouts survive to become adults in the next year. If we use a time step of one year, what is the finite rate of increase  $\lambda$ ?
- A. 0.075
  - B. 0.15
  - C. 0.75
  - D. 1.5
  - E. There is not enough information to say

Use the life table below for the next three questions:

$x$	$f_x$	$p_x$
1	0	0.5
2	1	1
3	2	0

18. What is  $\ell_3$  for this population?

- A. 0.25
- B. 0.5
- C. 1
- D. 1.5
- E. Insufficient information to say

19. What is  $R$  for this population?

- A. 0.5
- B. 1
- C. 1.5
- D. 2
- E. 3

20. Which of the following is the most precise true statement you can make about this population?

- A.  $\lambda \approx 0.667$
- B.  $\lambda$  is less than 1
- C.  $\lambda$  equals 1
- D.  $\lambda$  is between 1 and  $R$
- E.  $\lambda$  is greater than  $R$

21. The annual survival of older organisms

- A. Must be greater than 1 in order for the population to increase
- B. Is typically less than the survival of younger organisms
- C. Is always less than the fecundity of younger organisms
- D. May be either greater or less than the survival of younger organisms
- E. Is always negative

22. Two species are said to be *competitors* when

- A. The growth rate of each is lower in the presence of the other
- B. They do not affect each other's growth rates
- C. The growth rate of each is higher in the presence of the other
- D. The growth rate of one is higher in the presence of the other, but the growth rate of the other is lower in the presence of the first one

23. We expect founder effects to occur when

A. Each species does better in an environment dominated by competitors than in an environment dominated by its own species

B. Each species does better in an environment dominated by its own species than in an environment dominated by competitors

C. One species does better in an environment dominated by its own species, while the other does better in an environment dominated competitors

D. One species does better than the other in environments dominated by either species

*Use the following information for the next three questions.* In a population of dandelions: adults produce 80 seeds each; 1% of seeds survive to become adults; 50% of first-year adults survive to reproduce again; second-year adults never survive

24. If we call second-year adults age 2, what is the value of  $\ell_2$ ?

A. 0.005

B. 0.01

C. 0.5

D. 1

25. If we calculate the long-term growth rate  $\lambda$  of a population under these parameters, we would expect:

A.  $\lambda = 1$

B.  $\lambda = \mathcal{R}$

C.  $\lambda$  is between 1 and  $\mathcal{R}$

D.  $\mathcal{R}$  is between  $\lambda$  and 1