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:

- $\ell_x = p_1 \times p_2 \times \dots p_{x-1}$
- $\mathcal{R} = \sum \ell_x f_x$

competition:

- α_{ij} = effect **of** species i **on** species j
- $C = \alpha_{12}\alpha_{21}$
- $E_{ij} = \alpha_{ij} K_i / K_j$

disease:

- $\mathcal{R}_0 = \beta D = \beta/\gamma$ *or*
- $\mathcal{R}_0 = \beta D = \beta/(\gamma + \mu)$

1. Compared to the instantaneous rate 0.05/hr, the instantaneous rate 1.2/day:

A. Means exactly the same thing
B. Is not directly comparable, because they refer to different time steps
C. Is comparable, and refers to a larger (faster) rate
D. Is comparable, and refers to a smaller (slower) rate

2. If a simple model assumes individuals are independent of each other, then __________ birth rates should __________ with the size of the population.

A. per capita; increase
B. per capita; decrease
C. total; increase
D. total; decrease

3. 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, 5% 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 λ?

A. 0.075
B. 0.15
C. 0.75
D. 1.5
E. There is not enough information to say

4. A population of pine trees is declining exponentially with reproductive number $\mathcal{R} = 0.5$. The trees live about 100 years on average. If we calculate the finite rate of increase λ using a time step of $\Delta t = 1$year, we expect that

A. λ is 0.5
B. λ is close to 0.5
C. λ is close to 1
D. λ is 1

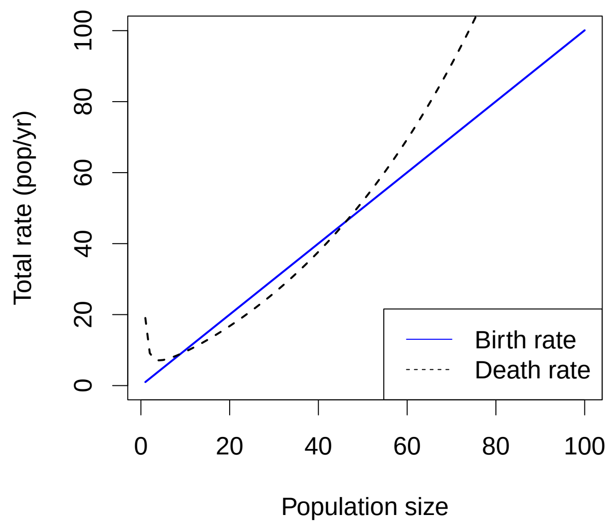
5. In a simple model of population regulation, where the only effect of population size is crowding, we would expect __________ to always go down __________.

A. The birth rate; through time
B. The birth rate; as population increases
C. The reproductive number $\mathcal{R}$; through time
D. The reproductive number $\mathcal{R}$; as population increases

6. Which of the following would *not* be expected to lead to Allee effects?

A. Individuals co-operating to find food
B. Individuals having difficulty finding mates
C. Individuals competing for breeding sites
D. Individuals co-operating to look out for predators

Use this picture for the next two questions.

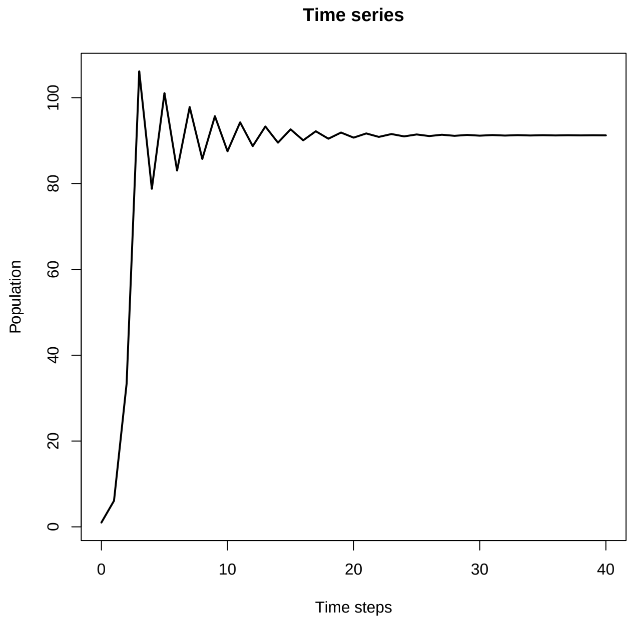


7. The picture above shows:

A. An Allee effect in the birth rate and density dependence in the birth rate
B. An Allee effect in the birth rate and density dependence in the death rate
C. An Allee effect in the death rate and density dependence in the birth rate
D. An Allee effect in the death rate and density dependence in the death rate

8. A population following this conceptual model would:

A. Increase from a low population or decrease from a high population to equilibrium
B. Increase to equilibrium from a low population and from a high population
C. Decrease to zero from a low starting population, but increase from an intermediate or high population
D. Increase from an intermediate population, but decrease from a high or low population

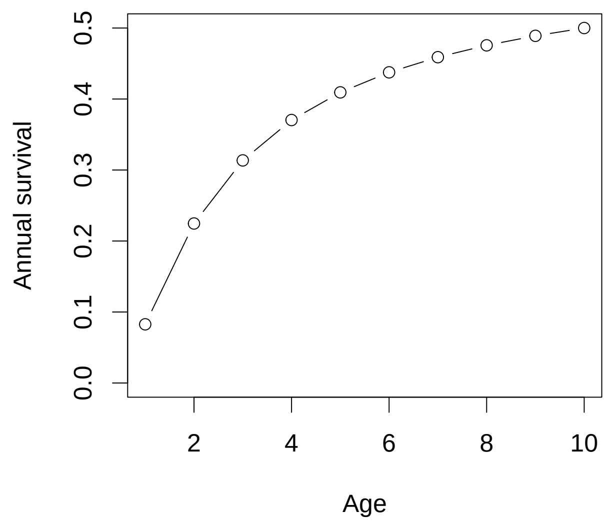


9. This picture illustrates a time series that is:

- **A.** Converging smoothly to a stable equilibrium
- **B.** Converging with oscillations to a stable equilibrium
- **C.** Converging with oscillations to an unstable equilibrium
- **D.** Oscillating without convergence around an unstable equilibrium

10. Which of the following is *not* a likely reason why population growth rate now may depend on population size in the past?

- **A.** Depletion of resources
- **B.** Competition for space
- **C.** Predators and pathogens
- **D.** Length of the organism's life cycle

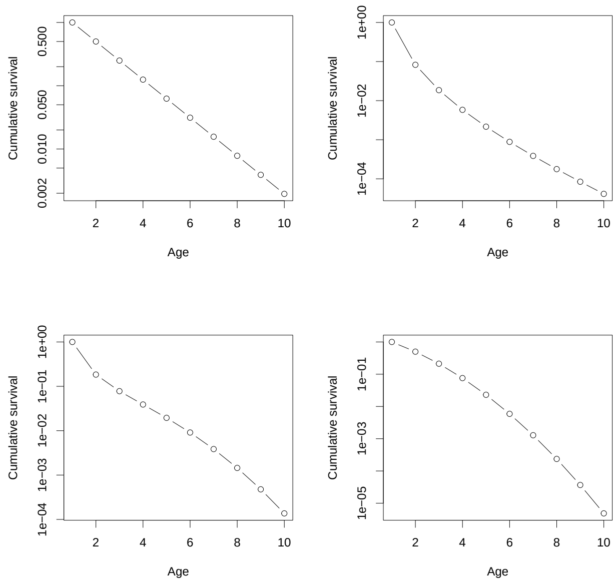


Use the picture above for the following 2 questions.

11. What does this picture of survivorship in an idealized age-structured population indicate about *mortality* in this population?

A. Mortality is constant
B. Mortality is elevated in older individuals
C. Mortality is elevated in younger individuals
D. Mortality is elevated in both older and younger individuals

12. The pictures below show *cumulative* survival. Which one corresponds to the picture shown above?



A. Upper left
B. Upper right
C. Lower left
D. Lower right

Use the life table below for the next two questions:

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

13. What is ℓ_3 for this population?

A. 0
B. 0.5
C. 1
D. 1.5
E. Insufficient information to say

14. What is R for this population?

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

15. In a population of perennial plants, seeds have a 5% probability of surviving to become adults and reproduce the first year. Adult plants (one-year-old and up) have an 80% chance of surviving each year to reproduce again. In this population, ℓ_2 is ________ if we measure before reproduction, and ________ if we measure after reproduction

A. 0.04; 0.05
B. 0.05; 0.04
C. 0.05; 0.8
D. 0.8; 0.05
E. 0.8; 1

This information is used for 2 questions. In a population of squirrels, newborn females have a 20% probability of surviving to reproduce in the next breeding season. One-year-old females have a 50% chance of surviving the next year, and older females have a 80% chance of surviving each year. We census *after* reproduction (we call the first group we count, the newborns, $x = 1$; thus the one-year-olds correspond to $x = 2$).

16. What is the value of p_1 in this population?

A. 0.08
B. 0.2
C. 0.4
D. 0.5
E. 0.8

17. What is the value of ℓ_3 in this population?

A. 0.08
B. 0.1
C. 0.2
D. 0.4
E. 0.5

18. An annual plant population spreads its seeds across a particular valley, which has patches of sandy soil, and patches of loamy soil. A successful adult produces on average 50 seeds. Of the seeds that land on loamy soil, 3% survive to be successful adults. Of the seeds that land on sandy soil, 1.2% survive to be successful adults. If half the seeds land on sandy and half on loamy soil on average, what is the long term average value of the finite rate of increase λ for this population?

A. 0.9
B. 0.95
C. 1
D. 1.05
E. 2.1

19. A population of dung beetles produces more female than male eggs. The males and females seem to mix randomly, and males compete for sex with females. The balance argument for sexual allocation would predict that, on a __________ basis, there is __________ investment of resources in in producing females than in producing males

A. population; higher
B. population; lower
C. Per-offspring; higher
D. Per-offspring; lower

20. Cole's paradox asks why some plants are iteroparous (reproduce more than once). Which of the following points does *not* help to explain Cole's paradox?

A. Plants must deal with variation in reproductive success through time
B. Plants must deal with variation in reproductive success across space
C. Plant offspring may be less likely to survive than established plants
D. Plant populations are regulated

21. Which of the following is *not* a 'bet-hedging' adaptation that allows organisms to average over risk within a generation?

A. Long-distance seed dispersal
B. Semelparity
C. Delayed germination of seeds (seed dormancy)
D. Occasional migration behavior (like lemmings who seek new habitats when overcrowded)

22. We expect mutual exclusion to occur when

A. Each species does better in an environment dominated by its own species than it does in an environment dominated by the other species
B. Each species does better in an environment dominated by the other species than it does in an environment dominated by its own species
C. One species does relatively better in an environment dominated by its own species, while the other does relatively better in an environment dominated by the other species
D. One species does better than the other in any environment

23. In a certain environment, algal species compete primarily for light in small pools, which may be disturbed. If the disturbance rate is very *low*, which species would we expect to dominate?

A. The species with the highest growth rate at high light ($r_{\max}$)
B. The species with the lowest $r_{\max}$
C. The species with the highest light level at which it reaches equilibrium
D. The species with the lowest light level at which it reaches equilibrium

24. Two species are coexisting stably. Based on this information, what is the strongest correct statement you can make about the population-level competitive effects E?

A. Both must be < 1
B. Both must be > 1
C. At least one must be < 1
D. At least one must be > 1
E. None of the above

25. If $\alpha_{12} = 2$ oaks/maple, $\alpha_{21} = 1$ maple/oak, $N_1 = 100$ maple/ha, $N_2 = 200$ oak/ha, what is $\tilde{N}_2$ (the strength of competition as seen by species 2)?

A. 300 maple/ha
B. 400 maple/ha
C. 300 oak/ha
D. 400 oak/ha
E. Not enough information to answer

26. In competition between grass and trees, what is a reason that interspecific competion might be stronger than intraspecific competition?

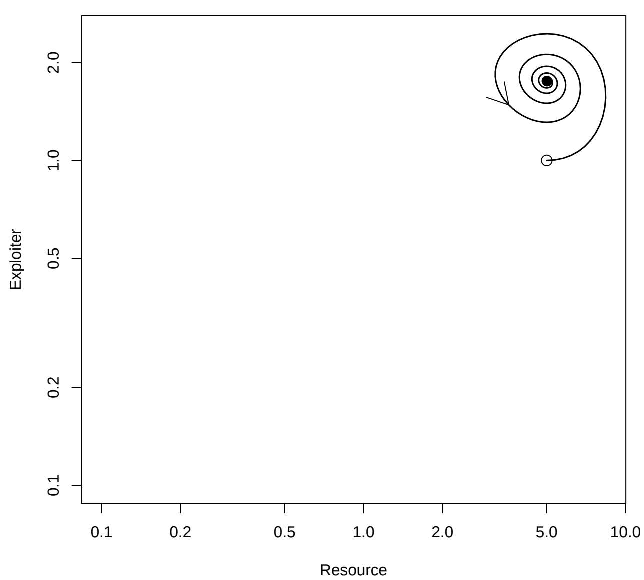
A. If grasses encourage frequent, low-intensity fires, which they tolerate well but trees don't
B. If grass uses water in shallow soil layers while trees use water in deep soil layers
C. If the two species both compete for light
D. If individuals of both species use water in proportion to their biomass
E. If the two species have leaves present at different times of year

27. Two bird species can both survive and reproduce in a wide range of habitats, but species A outcompetes species B wherever their habitats with $R > 1$ overlap (suppose neither species competes with any other species). We would say:

A. Species B's realized niche is larger than its fundamental niche
B. Species A's realized niche is smaller than its fundamental niche
C. Species A and species B have realized niches that are the same size
D. Species B's realized niche is smaller than its fundamental niche
E. Species B's realized niche is the same size as its fundamental niche

28. Which of the following effects tends to decrease oscillations in a predator-prey interaction model?

A. Density dependence in the predator
B. Density dependence in the prey
C. Predator satiation
D. Either A or B
E. Either B or C



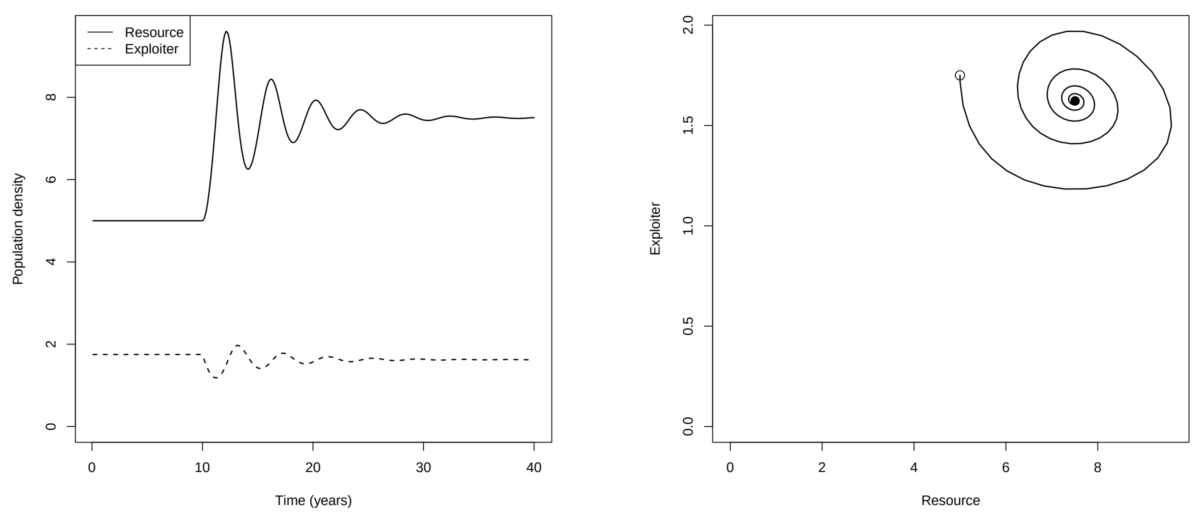
Use the figure above for the next two questions. It shows a simple model of an interaction between an exploiter and a resource species.

29. The figure above shows:

A. Unstable oscillations
B. Neutral oscillations
C. A limit cycle
D. Damped oscillations

30. This figure is consistent with a simple model that has:

A. No density dependence and weak predator satiation
B. No density dependence and strong predator satiation
C. Prey density dependence and weak predator satiation
D. Prey density dependence and strong predator satiation



Use the figure above for the next two questions. It shows a time plot and a phase plot from the *same simulation* of a predator-prey model. We change the parameters at time 10, to reflect a perturbation to the system.

31. At time 10, what changes in our simulation?

A. The removal rate of the predator is increased (e.g., we start catching sharks)
B. The removal rate of the prey is increased (e.g., we start catching fish)
C. The removal rate of both the predator and the prey is increased
D. A predator satiation term is added

32. This model has

A. No reciprocal control or density dependence
B. No reciprocal control and density dependence in the prey
C. Strong reciprocal control and no density dependence
D. Strong reciprocal control and density dependence in the prey

33. If r_f and r_e represent the instantaneous *per capita* growth rates of a resource and exploiter species with density N_e and N_f respectively, which of the following is (almost) always true?

A. r_e increases when N_e increases
B. r_f increases when N_e increases
C. r_e increases when N_f increases
D. r_f increases when N_f increases
E. None of the above

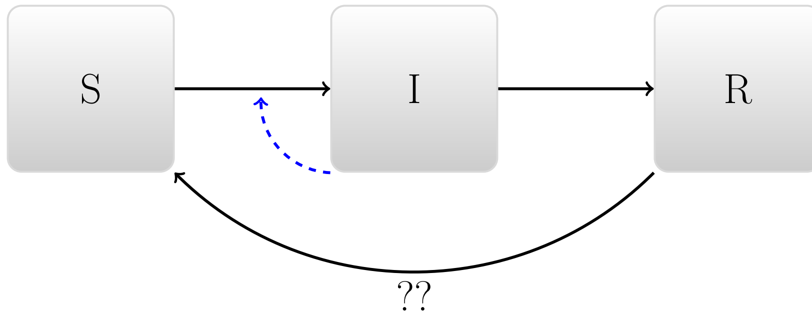
34. If we learn that the disease generations of HIV are faster than we thought, this would mean that estimates of population-level spread would be:

A. faster, assuming we already know the value of r
B. slower, assuming we already know the value of r
C. faster, assuming we already know the value of $\mathcal{R}$
D. slower, assuming we already know the value of $\mathcal{R}$

35. A disease has a reproductive number of 4. According to our simple model, if we want to stop it from spreading, we should vaccinate:

A. At least 1/4 of the population
B. At least 1/2 of the population
C. At least 3/4 of the population
D. At least 4/5 of the population
E. The whole population

Use the following figure for the next 3 questions.



36. In a model of disease stages, like the one shown above, $\mathcal{R}$ refers to

A. The number of infected cells an infected cell produces during its lifetime
B. The number of new cases (of infection) per susceptible individual
C. The number of new cases caused by a case
D. The exponential rate of growth of infected cells
E. The exponential rate of growth of infected hosts

37. The arrow labeled ?? above indicates the process of

A. Infected individuals being removed
B. Recovered individuals dying
C. Recovered individuals losing immunity
D. Susceptibles becoming infected
E. Infected individuals affecting the process of susceptibles becoming infected

38. If the model above is run to equilibrium, would we expect to see: 1) everyone in box S; 2) people in box S and R, but not I; 3) people in all three boxes?

A. 1)
B. 2)
C. 3)
D. Either 1) or 2)
E. Either 1) or 3)

39. A disease with a high $\mathcal{R}_0$ is spreading in a population. An intervention that reduces $\mathcal{R}_0$ slightly would be expected to have __________ effect on the peak level of disease, and __________ effect on the total size of the epidemic.

A. no; relatively large
B. relatively small; relatively large
C. relatively large; no
D. relatively large; relatively small

40. Pathogen aggressiveness tends to evolve to balance:

A. Reproductive number $\mathcal{R}$ against host death rate μ.
B. Reproductive number $\mathcal{R}$ against death plus recovery $\mu + \gamma$.
C. Transmission rate β against host death rate μ.
D. Transmission rate β against death plus recovery $\mu + \gamma$.