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:

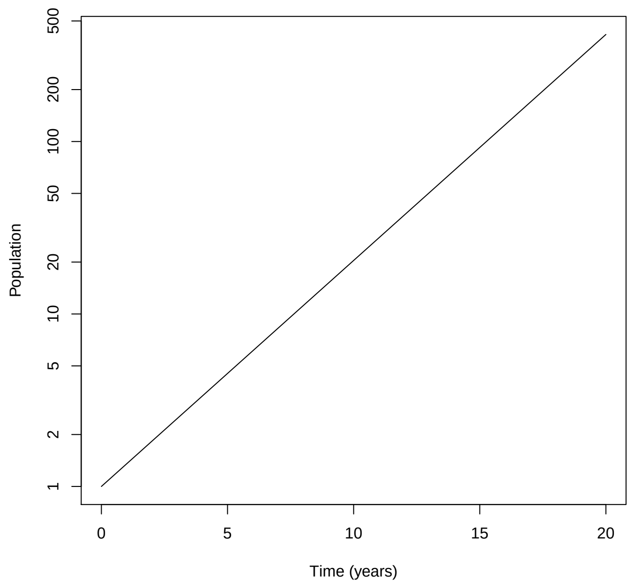
- $\ell_x = p_1 \times p_2 \times \ldots p_{x-1}$
- $\mathcal{R} = \sum \ell_x f_x$
- $\sum \ell_x f_x \lambda^{-x} = 1$
- $\mathrm{SAD}(x) \propto \ell_x \lambda^{-x}$

competition:

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

Linear

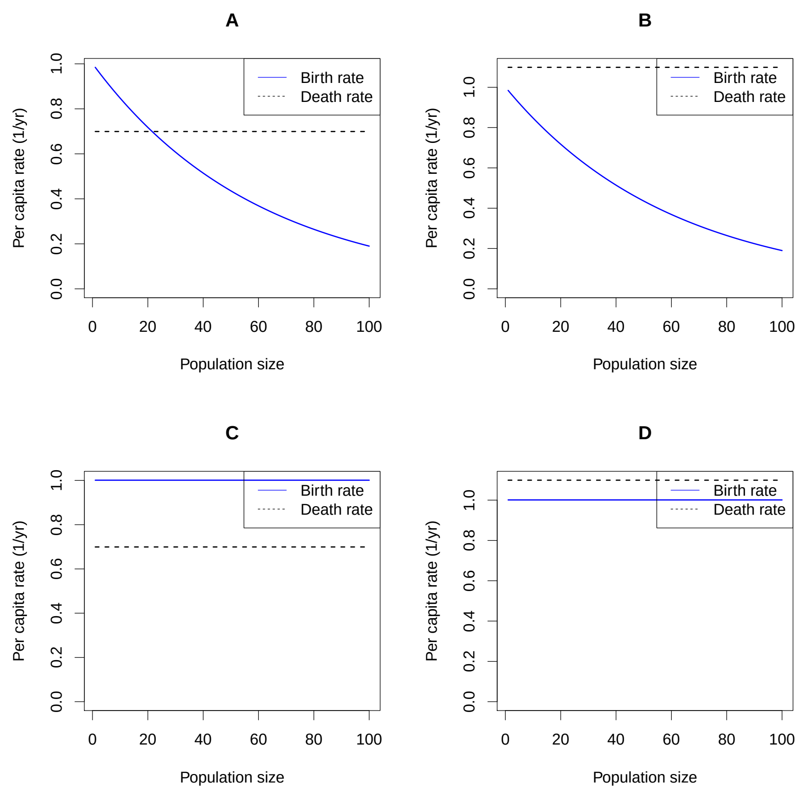
Use the picture below for the next two questions. It shows a time series for a continuous-time birth-death model.



1. This picture shows a population that is:

A. Increasing arithmetically
B. Increasing geometrically
C. Increasing arithmetically on the log scale, but geometrically on a linear scale
D. Increasing geometrically on the log scale, but arithmetically on a linear scale

2. Which of the small pictures shows the assumptions that generated the time plot?



A. A
B. B
C. C
D. D

This information is used for two questions. A microbial population grows in a flask with discrete, non-overlapping generations (i.e., survival to next generation $p = 0$), and finite rate of increase $\lambda = 1.5$. Its generation time is 1 day. The population takes 20 days to fill the whole flask.

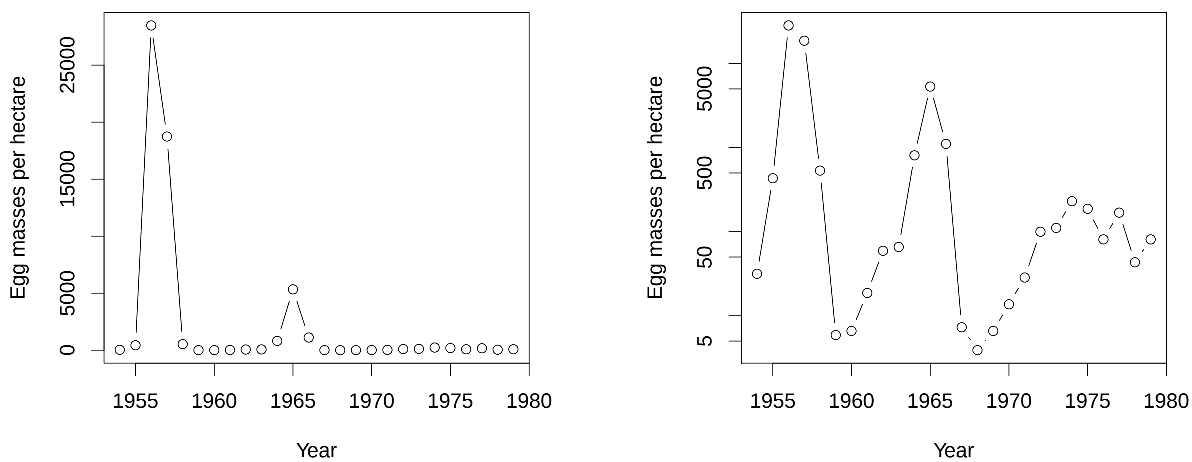
3. How much of the flask is filled after 19 days?

A. 5%
B. 50%
C. 67%
D. 95%
E. There is not enough information to tell

4. Which of the following *most* accurately describes the instantaneous growth rate r for this population?

A. $r < 0$
B. $r > 0$
C. $0 < r < 1$
D. $r > 1$
E. There is not enough information to tell

See the Gypsy picture. This picture is used for two questions.



5. Which of the following statements is *not* true?

A. The two pictures show exactly the same data
B. The pictures are equally valid, but show different perspectives
C. The picture on the left shows *multiplicative* differences
D. The picture on the left shows a *population-level* perspective

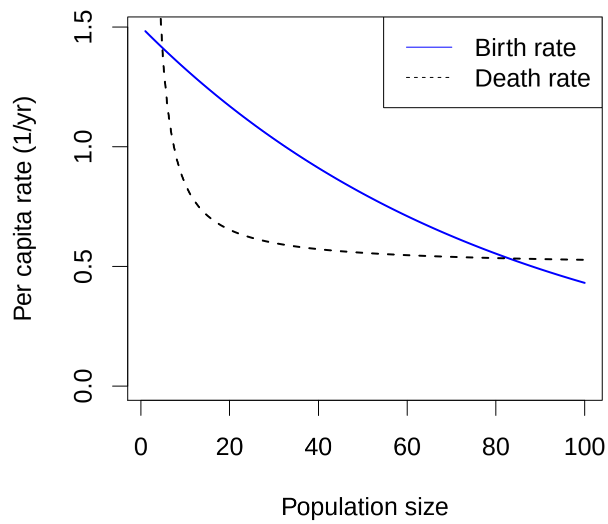
6. The most likely reason why the researchers counted egg masses instead of some other stage is:

A. They want to count as many individuals as possible
B. They did not want to have to worry about sex ratios
C. They wanted to use a structured population model
D. Egg masses were the easiest stage to count accurately
E. Egg masses are the most important life stage

Nonlinear

7. When an adult tree dies and falls in a hemlock forest, the seedlings that were already present and struggling for light in the area beneath it compete to grow tallest and take over the space. Eventually one of the seedlings wins and takes over the spot. This is an example of:

A. Contest competition that is a likely explanation for population cycles
B. Contest competition that is not a likely explanation for population cycles
C. Scramble competition that is a likely explanation for population cycles
D. Scramble competition that is not a likely explanation for population cycles

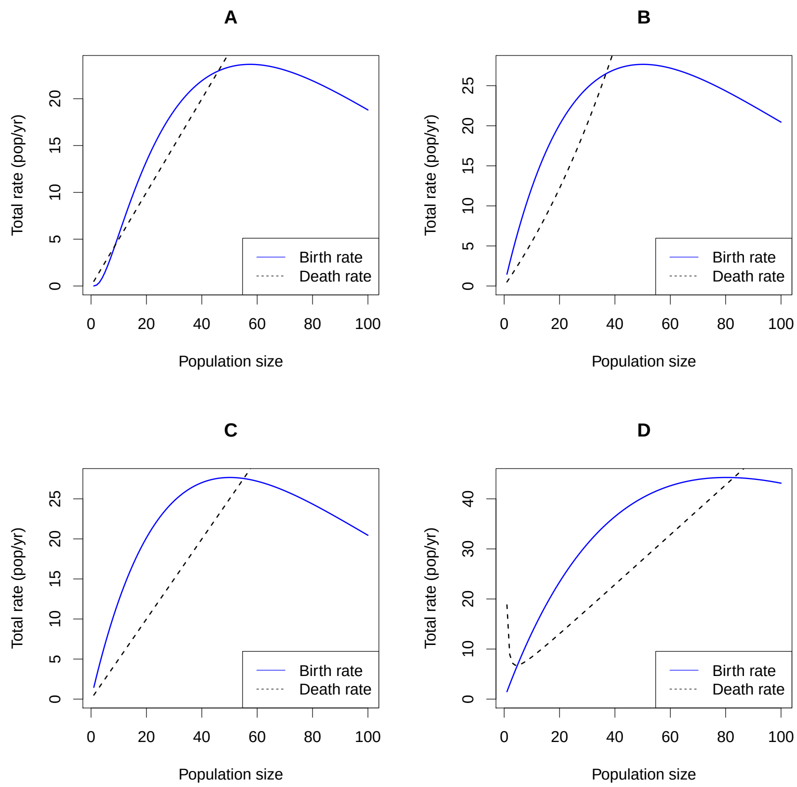


See the Rates pictures

8. The large figure shows ________ in the birth rate and ________ in the death rate

A. density dependence; density dependence
B. Allee effects; density dependence
C. Allee effects; Allee effects
D. density dependence; Allee effects

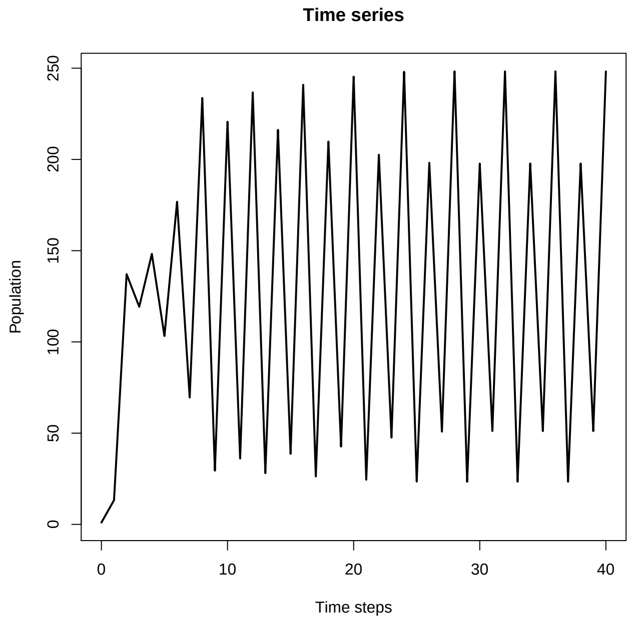
9. Which of the four small pictures was generated by the same model as the large picture?



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

10. This population has a ________ equilibrium at 0 individuals and a ________ equilibrium at 80 individuals

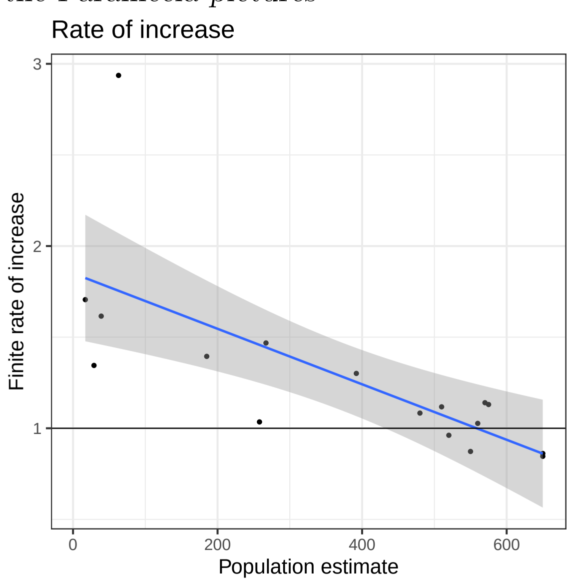
A. stable; stable
B. stable; unstable
C. unstable; stable
D. unstable; unstable

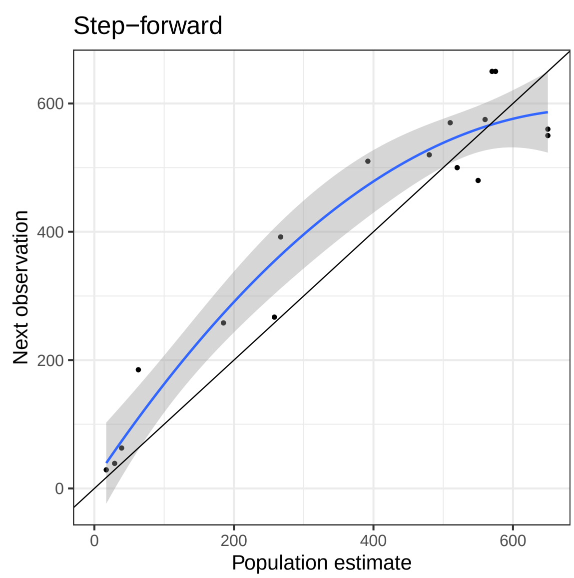


11. See the Cycles picture. This picture illustrates a time series that is:

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

See the Paramecia pictures





12. Based on the picture on the __________, we would say that simple discrete-time models __________ give a clear explanation of the stable dynamics we observe in paramecia

A. left; can
B. left; cannot
C. right; can
D. right; cannot

13. If an age-structured population with a constant life table reaches a stable age distribution, we *always* expect that if the population is __________ there will be __________ individuals in younger than older age classes

A. increasing; fewer
B. increasing; more
C. decreasing; fewer
D. decreasing; more
E. both B and C are correct

This information applies to three questions. In a population of ground squirrels, each adult female produces an average of 3 female offspring; 10% of these survive to the next reproductive season. We consider the group of three-year-old females (born three years ago). These females have a 50% chance of surviving to the next reproductive season. The sex ratio among the offspring is 1:1.

14. Based on the model used in class, the three-year-old females we are studying represent age class __________ if we count after reproduction, and age class __________ if we count before reproduction.

A. 3; 3
B. 3; 4
C. 4; 3
D. 4; 4

15. If we count *after* reproduction, the value of f for this group is

A. 0.15
B. 0.3
C. 0.75
D. 1.5

16. If we count *before* reproduction, the value of f for this group is

A. 0.15
B. 0.3
C. 0.75
D. 1.5

17. 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

18. 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. ℓ_x always increases as x increases
D. ℓ_x always decreases as x increases
E. p_x is always $\geq \ell_x$

19. Which of the following is *not* a plausible reason why we might see more saplings (medium-sized trees) than seedlings (small trees) in a forest?

A. Saplings are larger, and easier to see
B. Trees may spend more time in the sapling class than the seedling class
C. The population may be growing
D. The life table may not be constant

20. The value of p_1 in a life table

A. Is not affected by the survival between birth and the first census
B. Is often small because organisms take time to reach maturity
C. Is not affected by life-history tradeoffs
D. Must be greater than 1 in order for the population to increase

21. 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

22. Cole pointed out that producing one more offspring increases an organism's $\lambda = f + p$ by 1 – the same amount it increases if the organism changes from not surviving at all after reproduction to being immortal. He asked why in that case any organisms would evolve to be long-lived. Which of the following does *not* help to answer this question?

A. Closing the loop: it is not so easy to produce one more offspring who will survive to where you are now
B. Tradeoffs: organisms tend to evolve to a point where they are not able to increase survivorship without reducing fecundity
C. Population regulation: if the long term average value of λ is 1, it can't be easy to increase f by 1.
D. Bet hedging: long-lived organisms can deal better with variation in offspring success

23. A cohort of 400 turtles is 75% female and 25% male. If they have 500 total offspring, what is the average fitness of the males?

A. 0.75
B. 0.83
C. 1
D. 1.5
E. 2.5

24. Which of the following factors might produce adaptive pressure for an organism to adopt a semelparous strategy?

A. An environment highly variable in space
B. An environment highly variable in time
C. Very high mortality of reproductively mature adults
D. Very high mortality of juveniles

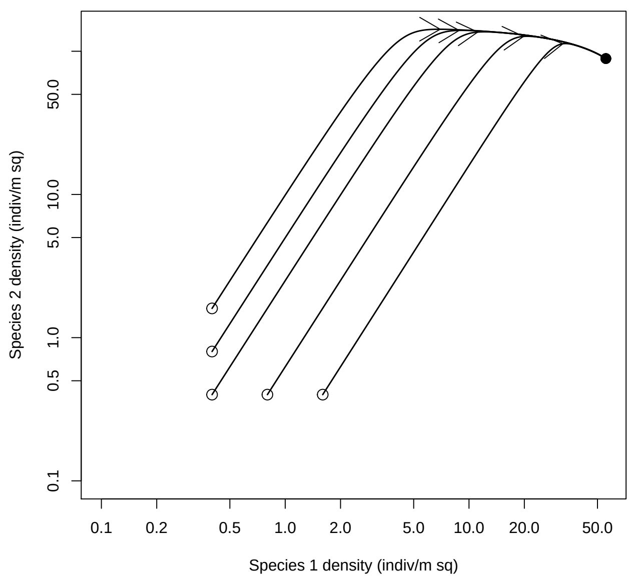
25. Which of the following is likely to lead to the evolution of a system where more *total* energy is invested in female than in male offspring?

A. Increased cost of producing females
B. Higher population density
C. Lower population density
D. Greater variation in male reproductive success
E. Restricted dispersal leading to within-family mating

26. Which of the following is a 'bet-hedging' adaptation that allows organisms to average over risk within a generation?

- **A.** Investment in males
- **B.** Iteroparity
- **C.** Long lifespan
- **D.** Short lifespan
- **E.** High R

The Competition picture is used in three questions. The path in the middle corresponds to a starting density of 0.4indiv/m^2 for each species.



27. 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

28. 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.

29. 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.

30. 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

31. We expect dominance 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. Both of the individual-level coefficients α show that one species competes more effectively than the other
D. Both of the population-level coefficients E show that one species competes more effectively than the other
E. Either C or D

32. The growth rate of species 1 in the presence of species 2 is given by $\frac{dN_1}{dt} = r(N_1 + \alpha_{21}N_2)N_1$. If species 1 is counted in units of indiv_1, species 2 in units of indiv_2, and time is counted in units of years, then the value of the function $r(N_1 + \alpha_{21}N_2)$:

A. Has units of 1/year
B. Has units of $1/\text{indiv}_2$
C. Has units of $\text{indiv}_1/\text{indiv}_2$
D. Has units of $\text{indiv}_1/\text{year}$

33. In a certain forest various species of grass compete with one another in open, sunlit, patches of ground. If these patches are short lived due to shading by trees, which destroys the grasses' ability to grow, which grass species would have the advantage?

A. The species with the highest carrying capacity K
B. The species with the highest individual-level competitive effect α on the other species.
C. The species with the highest population-level competitive effect E on the other species.
D. The species with the highest initial growth rate r_0
E. The species with the highest reproductive number in the absence of density dependence $\mathcal{R}_0$.

34. Which of the following is not a possible exception to the competitive exclusion principle (ie., a reason why competing species can coexist)

A. Species may not use resources in the same way
B. The environment may not be stable
C. Co-existence may not be long term
D. One species may be more efficient at using resouces than the other
E. The species may have different natural enemies

35. If $K_2 = 100$, $\alpha_{21} = 0.5$, and $\alpha_{12} = 2$, which of the following is definitely true?

A. Species 1 will win in competition regardless of starting densities
B. Species 2 will win in competition regardless of starting densities
C. The system demonstrates balanced competition
D. The system demonstrates founder control
E. Species 2 cannot invade species 1 when species 1 is at its (positive) equilibrium density

36. Which of the following effects tends to increase 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

37. A population of grouse and a population of foxes are at equilibrium under reciprocal control – ie., the grouse population is primarily controlled by fox predation, and the fox population is primarily controlled by the food supply of grouse. Fox hunting is now introduced to the area, with the idea that this will increase the number of grouse. Based on reciprocal control alone, what effect would you expect to see in *long term* equilibrium populations?

A. The equilibrium number of grouse will increase, but the equilibrium number of foxes will stay about the same
B. The equilibrium number of foxes will decrease, but the equilibrium number of grouse will stay about the same
C. The equilibrium number of foxes will decrease, and the equilibrium number of grouse will increase
D. The equilibrium number of foxes and grouse will both decrease

38. If two species have an exploitation relationship, then:

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

The following information is used for 2 questions. The initial growth rate of COVID-19 in a population is estimated at $r_0 = 0.2$/day and the reproductive number is estimated at $R_0 = 4$.

39. What is the initial doubling time of the disease?

A. 0.2 day
B. 0.29 day
C. 3.5 day
D. 5 day
E. 7.2 day

40. If social distancing reduces the average contact rate β by a factor of 4, the expected new value of r (rate of spread) is expected to be

A. 0.2/day (unchanged)
B. 0.1/day
C. 0.05/day
D. 0
E. -0.1/day

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