**Formulas**
*discrete time growth:*

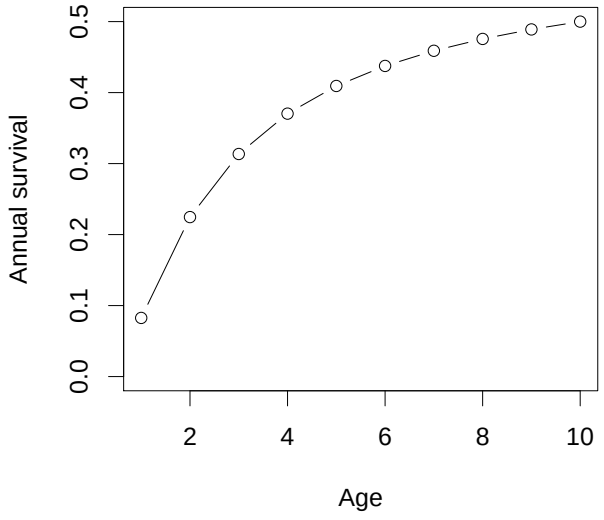
- $N_T = N_0\lambda^T$
- $\lambda = f + p$
- $\mathcal{R} = f/(1-p)$

*continuous time growth:*

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

**structured growth:**

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

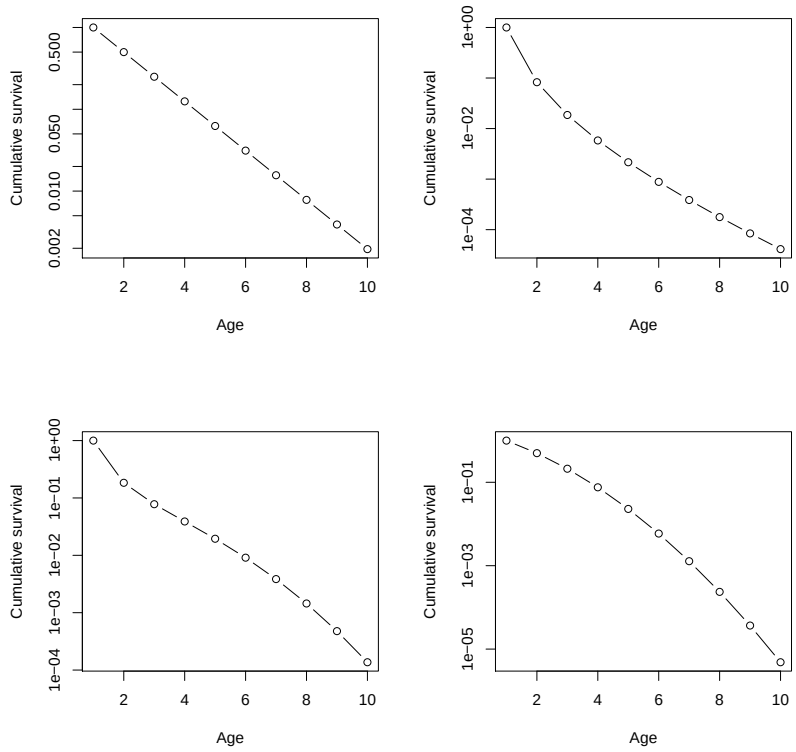



*Use the picture above for the following 2 questions.*

**1.** 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

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




**3.** A correct mathematical explanation for bet-hedging strategies is that: organisms average over environments _____ generations to achieve a higher mean; the _____ mean.

**A.** within; arithmetic
**B.** within; geometric
**C.** between; arithmetic
**D.** between; geometric

**4.** A pile of radioactive material is decaying *continuously* at an instantaneous rate of 1% per minute. After two minutes, what proportion is left?

**A.** A little more than 98%
**B.** Exactly 98%
**C.** A little less than 98%
**D.** About 30%
**E.** None

**5.** Which of the following would you expect to lead to a population producing more females than males at birth?

**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

**6.** The carrying capacity for an organism in an environment is the density at which crowding reduces the average of _____ to zero:

**A.** The birth rate
**B.** The death rate
**C.** The recruitment rate
**D.** The amount of free habitat
**E.** The difference between the birth rate and the death rate

**7.** Which of the following is true of the age distribution of a decreasing population with a constant life table?

**A.** It matches the $\ell_x$ curve exactly
**B.** It is more top-heavy (more individuals in older age classes) than the $\ell_x$ curve
**C.** It is more bottom-heavy (more individuals in younger age classes) than the $\ell_x$ curve
**D.** Insufficient information to answer
**E.** A population can't be decreasing if it has a constant life table

**8.** If every individual of an annual species has 100 offspring, which are dispersed such that within any year half of them land in good spots (5% survival) and half of which land in bad spots (1% survival), which of the following is closest to its long-term average growth rate?

**A.** 0.5
**B.** 1
**C.** 2.2
**D.** 3
**E.** 6

**9.** If an annual species produces an average of 10 offspring in odd years and an average of 1 offspring in even years, which of the following is closest to its long-term average growth rate?

**A.** 1
**B.** 3
**C.** 3.2
**D.** 5.5
**E.** 10

**10.** Which of these traits would be characteristic of an r-strategist?

**A.** Large final size
**B.** Good dispersal
**C.** Production of a small number of high-quality offspring
**D.** Good competitive ability
**E.** Iteroparity

**11.** Polio has a finite-time growth rate $\lambda$ of about 11, and a generation time of about 10 days. If we start with one case, about how many cases do we expect to see (provided there is no density-dependence) 20 days later?

**A.** 2.2
**B.** exp(2.2)
**C.** 22
**D.** 121
**E.** 220

**12.** A population meets the assumptions of the balance argument for sexual allocation. If the population has more females than males at birth, this means 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

**13.** The value $f_x$ in a life table incorporates: survival of the $x$ year old individual from _____, survival of new individuals from the reproductive period to the census time, and _____ the number of new individuals produced by an individual during the reproductive period.

**A.** the reproductive period to the census time; not
**B.** the reproductive period to the census time; also
**C.** the census time to the reproductive period; not
**D.** the census time to the reproductive period; also

**14.** If we are thinking about a simple, continuous-time model, then for a population to be regulated:

**A.** The average reproductive number $\mathcal{R}$ must be low at high density and higher at either low or intermediate density
**B.** The birth rate $b$ must be low at high density and higher at either low or intermediate density
**C.** The death rate $d$ must be high at high density and lower at either low or intermediate density
**D.** All of the above

**15.** Which of the following is *not* usually an advantage of dispersal:

**A.** More likely to find a suitable habitat
**B.** Less likely to compete with siblings
**C.** Distributes risk (bet hedging)
**D.** Genetic mixing

**16.** A population of oak trees is estimated to be at stable age distribution, with a constant life table, with reproductive number $\mathcal{R}= 1.2$. It takes the trees several decades to reach maturity and reproduce. This population is

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

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

**A.** Birds with heavier beaks are more efficient at cracking seeds and better at defending territory
**B.** Bushes which survive better in dry conditions grow more slowly in wet conditions
**C.** Trees which grow fastest in full sunlight have higher mortality in the shade
**D.** Rabbits which need less food to survive produce fewer offspring when food is plentiful

Answer questions on this page *in pen*. *Briefly* show necessary work and equations. Points may be *deducted* for wrong information, even when the correct information is also there.

**18.** A rat population is growing without any population regulation. Females produce an average of 0.8 offspring each year for two years. The probability of each offspring surviving to reproduce is 0.8; one-year-old rats survive to age 2 with probability 0.8; two-year-old rats never survive, because they don't want your life table to be too long. The sex ratio in the population is 1:1.

a) (2 points). Explain *briefly* how you calculate the values of $f_x$ for this population. You should explain whether you are counting before or after reproduction (either is fine).

b) (2 points). Explain briefly what values you use for $p_x$ to be consistent with your census choice in the previous answer.

c) (1 point) Explain briefly what $\ell_x$ means, and show how you calculate the values.

d) (1 point) Fill in the life table and calculate $\mathcal{R}$ for this population.

| $x$ | $f_x$ | $p_x$ | $\ell_x$ | $\ell_x f_x$ |
|---|---|---|---|---|
| 1 | | | | |
| 2 | | | | |
| $\mathcal{R}$ | | | | |

e) (1 point) Write an expression showing the relationship between $\lambda$, $\mathcal{R}$ and 1 (e.g., $\lambda > \mathcal{R} = 1$ or $\lambda < 1 < \mathcal{R}$).

f) (1 point) Write an equation that you could use to calculate $\lambda$ for this population. Fill in numbers for all values except for $\lambda$.