KEY

Before starting WRITE YOUR NAME ON EACH PAGE!

You have tons of time. **Take your time** and **read each question carefully** to ensure you fully understand **exactly** what we are after and don't jump to conclusions too quickly.

SCRATCH PAPER AT END: There is a page of scratch paper for you to use to organize your thoughts, make outlines for the essay questions, etc...

PART A. Short answers, graphs and calculations

1. You have just completed your study of a cohort of your favorite organism, the Surfing Cruz-Dude. You began your study by ear-tagging 1000 females, followed the entire cohort until the last one died, and noted the number of babies each female produced, on average, at each age. You just compiled all of your data and found the following: of the original 1000 newborns (i.e. age 0) you followed, 500 survived to year 1 where they had (on average) 1 baby each, 150 survived to year 2, where they had 2 babies each, and none survived to year 3.

Age	Number alive	Babies/ female	**Proportion surviving**	**Pn surviveX babies/female**
X	s_x	b_x	$\mathbf{l_x}$	$\mathbf{l_x b_x}$
0	1000	0	**1**	**0**
1	500	1	**0.5**	**.5**
2	150	2	**0.15**	**.3**
3	0	0	**0**	**0**

$R_o = \Sigma l_x b_x = 0.8$

(a) Is this population growing, declining or stable? To answer, complete the life table, calculate R_o and tell us why the population is changing in the direction it is. (4 points)

This population is declining because $R_o < 1$

(b) Why does the value of R_o tell you whether the population is stable, increasing or decreasing? (tell us in words what R_o represents biologically). (2 points)

R_o measures the average number of babies produced over the lifetime by each baby in the cohort start the life table with. Therefore, when $R_o < 1$, we have fewer babies at the end of the generation than we started with (decline).

(c) In what basic way does R_o differ from r or λ? (1 point)

R_o is independent of real time and measures growth rate per generation, which can vary dramatically among species.

(d) Why do we look at females in the life table? (1 point)

Females produce the babies and it is production of babies that limits population growth.

2. Three basic patterns of survivorship, or survivorship curves, are recognized, as illustrated in the graph immediately below.

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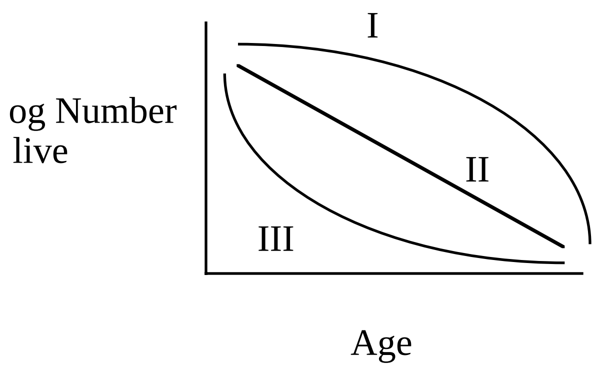
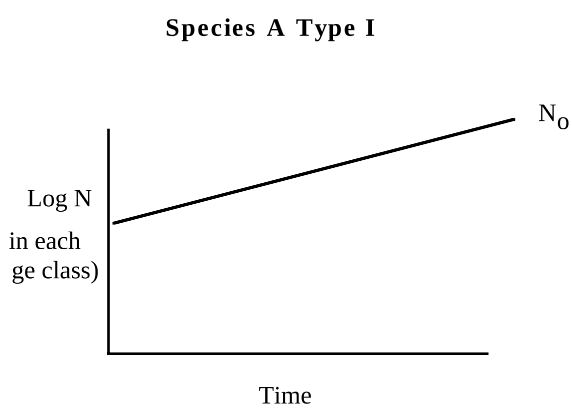


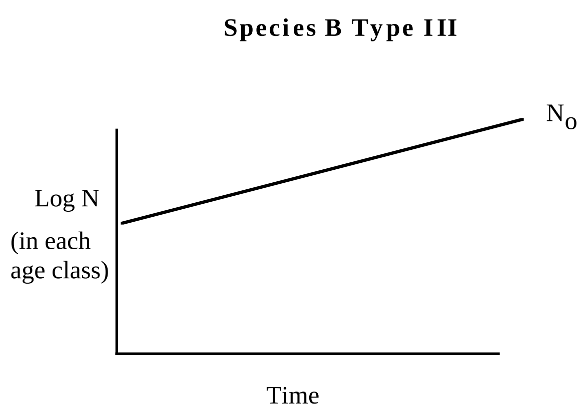
(a) Provide an example organism that would have Type I curve and Type III curve. (2 points)

Type I **humans, mammals**

Type III **fish, insects**

(b) If the life table of a population remains the same over time (i.e., across generations), 'stable age distributions" will form over time. Consider two species: species A has a type I pattern of survival while species B has a type III pattern of survival. Each species has three age classes – newborns, yearlings, and two year olds. If each species does show a stable age distribution draw in the lines for the number of yearlings (N_1) and number two year olds (N_2) for each species, relative to the number of newborns (N_o) shown. Your lines must clearly show the difference between the two species that would result from their different patterns of survival. (4 points)





KEY

3. The population dynamics of infectious disease can be represented with a simple model: $R_p = S\beta L$, where R_p = is the rate at which the disease spreads from one host to another and S is the number of individuals in a population who are susceptible to the disease.

(a) What do the other two symbols represent? (2 points)

β **transmission rate of disease among hosts**

L **time that the host is infectious**

(b) At what value of R_p does the disease begin to spread and an epidemic start? (1 point)
When of R_p >1. (The answer of R_p = 1 is incorrect as the disease remains stable)

(c) This model can explain why cases of measles show population cycles. With reference to the model, explain what causes the two phases of a cycle, an **epidemic** whereby measles begins to spread, and the **crash**, where the cases of new infections drops. Explain what causes the number of susceptibles to change in each phase. (4 points)

The disease can spread when the density of suseptibles to exceeds the transmission threshold density. As the disease spreads, it reduces the density of susceptibles because once sick, hosts become immune from the disease. When enough people have had the disease, the density of susceptibles falls below the transmission threshold and the disease crashes. Births of babies creates a new pool of susceptibles, and when enough babies are born so that the density of susceptibles exceeds the transmission threshold, the disease spreads.

(d) How can we prevent measles from cycling in epidemics and why, specifically does this approach work? (2 points)

Vaccines or immunization works because it removes individuals from the pool of susceptibles, thus dropping S below the threshold.

4. Human destruction of habitats like forests often leave us with islands of suitable habitat in a sea of unsuitable habitat. This scenario describes what happens when we set aside areas of habitat as reserves or parks. The application of the theory of island biogeography to human-created islands of habitat led to an important debate over the design of reserves: for a given total area that can be preserved, is it better to save a **S**ingle **L**arge **O**r **S**everal **S**mall reserves, the so-called SLOSS debate. List two reasons why it would be better to create a single reserve that is as large as possible, and two reasons why it might be better to create several smaller reserves. (4 points)

2 reasons why we should make a single large reserve:

- **more species per area (assuming all smaller patches would be the same habitat)**
- **bigger patches have bigger pops of all species; extinction is less likely.**
- **bigger areas can maintain top predators which, if lost, can have a huge impact on the community structure**
- **genetic diversity is higher in larger patches (populations**)

2 reasons why we should make several smaller reserves:

- **get more species if different reserves have different habitats**
- **spread risk of disasters like disease, fire**

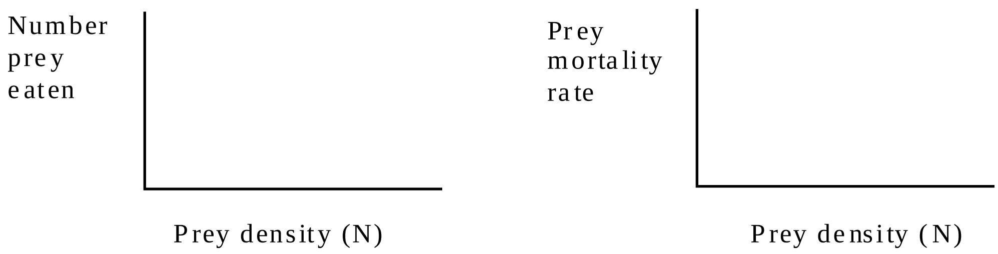
KEY

5. Ecologists have long been interested in the conditions under which predators can stabilize their prey populations (i.e. keep the prey populations in check and from increasing). One aspect of predator behavior of particular interest is the ‘functional response.

(a) What exactly is a functional response? (2 points)

the relationship between an individual predator’s rate of prey consumption and the density of that prey

(b) One type of functional response in particular can potentially impose the type of density-dependent predation on prey that can limit and stabilize prey numbers. On the graphs below, draw this functional response **(only one, no points if you draw all three)** in terms of **number** of prey eaten (left graph) and in terms of the **percapita mortality rate** of prey (or proportion of prey population consumed) (right graph). (2 points)



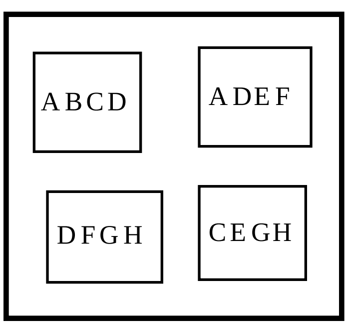
(c) Explain **in words** why this type of functional response is thought to stabilize prey population growth rate (i.e. in words) and indicate on the above right graph the range of prey densities over which density-dependent regulation of prey is possible. (2 points)

Density-dependence will stabilize a population only when birth rate drops with increases in density, when survival drops with increasing density, or both. The type III is the only response where prey mortality rate increases with density.

(d) Name two specific behavioral mechanism that can give rise to this type of functional response? (2 point)

- **prey-switching by the predator (search image predation)**
- **a limited number of good hiding places for the prey.**

6. The diagram below shows diversity on various spatial scales: each smaller box is a **different** type of habitat and the letters indicate the different species in each of the four habitats (some species are found in more than one habitat). The larger box is the entire region.



(a) Calculate the average alpha (α) diversity, the beta (β) diversity and the gamma (γ) diversity for this set of observations. (3 points)

alpha = 4 (= average per habitat)

beta = 2 (= gamma/alpha)

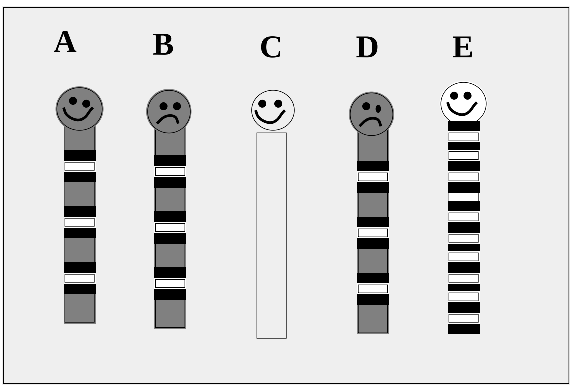
gamma = 8 (= total in region)

(b) Which species is the most extreme habitat specialist? (1 point) **Species B (only in 1 habitat)**

7. The box below shows four species of snakes, each identified by its own letter. The snakes vary in their markings, which provide some sort of visual signal, and in their toxicity as well. Snakes with **smiles** are **harmless**, those with **frowns** are **poisonous**. The background pattern inside the box is the background on which predators would look for the snake. **Important details**: These 5 species are the only ones we need to consider and the resemblance of the three similar snakes (A,B,D) is due to convergence, not common ancestry.

Identify the snake(s) that fit the following descriptions by filling in letters next to the description (5 points):

Mullerian mimic(s)	**D & B (OK if only one of these is listed)**
Batesian mimic(s)	**A**
Aposomatic coloration	**D and B (must have both)**
Cryptic	**C**

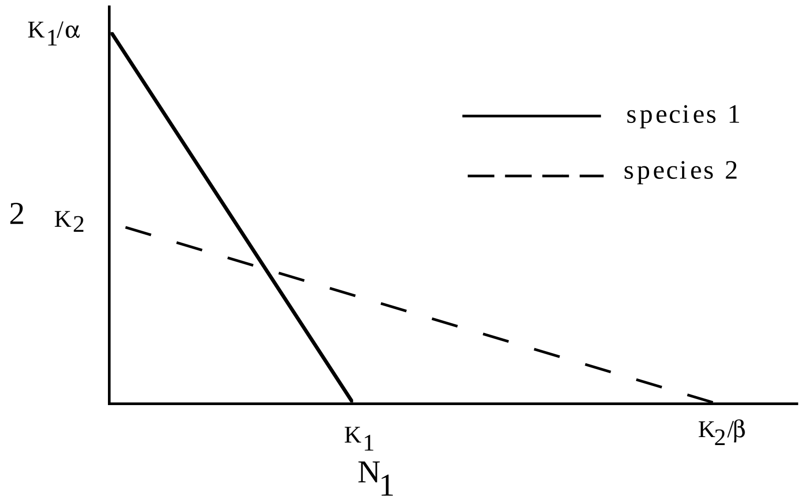


8. Using two graphs, illustrate the key difference between the terms 'open' (individualistic) or 'closed' (superorganism) communities, as applies to the debate over whether or not plant communities are functional units with discrete boundaries. Be sure to label your axes (4 points)

KEY

9. The Lotka-Volterra interspecific competition model explores the outcome of competition between two species. This can be done graphically by examining the joint change in populations of two competing species, relative to each of their isoclines.

(a) Show with the use of arrows and vectors the joint movement of both populations for each distinct region of the graph below (distinct regions with respect to the isoclines). Show with big dots (one, two or three dots if necessary) what the outcome of competition in this system. (3 points)

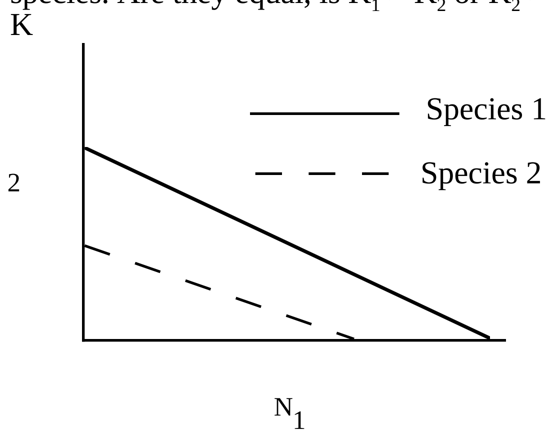


(b) What do we call the above outcome? (1 point): **Stable coexistence**

(c) Assuming there is no predator involved here (i.e. just competition) what kind of experimental evidence would indicate that the **specific** outcome shown above is occurring in nature? Describe both the experiment(s) and the result(s) from the experiment(s) needed to show the specific case shown above. (4 points)

The prediction is that both species are suppressing the densities of its competitors so that both are below their carrying capacity they would have without competition. Need to do reciprocal removal experiments. Remove species 1 and species 2 should increase in density (numbers) on the experimental plot relative to a control plot. Remove species 2 and species 1 should increase in density (numbers) on the experimental plot relative to a control.

(d) The graph below shows the isoclines for two competing species whose competition coefficients are equal: i.e., $\alpha = \beta$. Given this, and your understanding of how the Lotka-Volterra competition models are put together, what can you conclude about the relative size of the carry capacity of each species. Are they equal, is $K_1 > K_2$ or $K_2 > K_1$? (2 points)

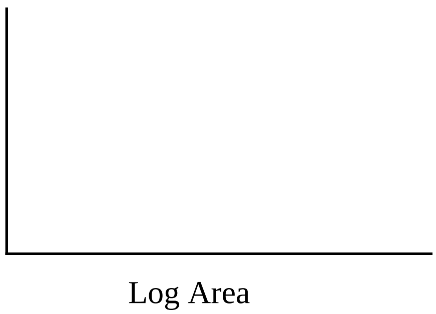


$K_1 > K_2$ because the only things that affect the outcome of competition are the competition coefficients and carrying capacity. Since there is no difference in the competition coefficients, the only way to have species 1 exclude species 2 is by species 1 having a larger carrying capacity.

KEY

10. The equilibrium theory of island biogeography was developed to explain two interesting relationships:(a) the relation between diversity (number of species) and area and (b) the difference in patterns of diversity between mainland areas and islands (including distance between an island and mainland source):

(a) Draw the two species-area relationships that illustrates the **two patterns described** above and **fully label the Y axis**. (3 points)



(b) Fill in the graph below to illustrate the how the Theory of Island Biogeography can explain why bigger islands have more species than smaller islands. **Label the X axis** and **all of your immigration and extinction lines** and be sure to **indicate the equilibrium numbers of species** on each of the two islands (5 points)

(c) If you surveyed two islands of identical size and distance from the mainland, does the theory predict that you will find an identical list of species on two islands will be the same? Why or why not? (2 points)

The number of species will be the same, but the list will not be identical because whether any given species occurs on an island depends on chance colonization and extinction.

11. Consider Scum Lake, named because it is scummy, green and full of algae. Scum Lake is well known for being a lousy fishing spot because it only contains small minnow fish. To remedy this, somebody adds bass to the lake, a species popular with fishers. (Bass are top predators that eat the smaller minnows.) The bass do well and now one year later, Scum Lake is no longer scummy and green, but is crystal clear with few algae. Explain , with reference to food webs and trophic levels, why this change has taken place. In particular, why the does the number of trophic levels in a food web affect whether or not the "world is green"? (6 points)

This change occurred because the number of trophic levels in a food web can have a huge impact on the degree to which plants (or other primary producers) are limited by nutrients that enter the system from below (bottom up) or are limited by herbivores from above (top-down regulation of plants. The following shows how number of trophic levels affects green-ness

1 level : only plants; world is green
2 levels: plants and herbivores. Plants limited by herbivores, world less green
3 levels: plants, herbivores, and primary predators: predators eat herbivores, plants not limited by herbivores so world is green.
4 levels: plants, herbivores, primary predators, secondary predators. Secondary predators eat primary predators, relaxed predation on herbivores who now limit plants, world less green.

In Scum Lake, adding bass changed the system from a 3 trophic level to a 4 trophic level food web, and the lake became less green. Bass munched minnows, zooplankton releases from predation and increased herbivory on plants.

12. Senescence is the pre-programmed deterioration in performance of an organism as it increases in age. On a proximate (immediate) level, senescence is due to genes that have nasty effects on the organism later in life, but not early in life. Life history theory provides an evolutionary explanation for senescence based on natural selection. Outline the basic idea. (6 points)

Due to extrinsic survival patterns, there are always more younger individuals than older individuals in populations. Thus, nasty genes that act late in life affect fewer individuals than genes that act early in life. Therefore, natural selection is weaker against nasty late-acting genes. Pleiotropic genes that have good affects early in life but nasty effects late in life have a net positive effect on fitness because more individuals get the positive effects than the late nasty effects.

KEY

PART B. Essay question. Answer one of the following three essay questions. ANSWER ONLY 1 QUESTION (20 points)

1. Ecologists developed the concept of 'metapopulations' to examine the population dynamics of species that life in habitats that are patchily distributed.
(a) What is a metapopulation? In words or basic equations, outline the key features of the basic metapopulation model, including its main assumptions and predictions.
(b) What data would one need to collect from a field study to provide convincing evidence for metapopulation dynamics in a species?
(c) What are the important implications of metapopulations for ecologists and conservation biologists?

A metapopulation is a population of populations inhabiting a landscape of patchily distributed habitat. Each population can go extinct by chance and each empty patch can be recolonized by dispersal. All patches are assumed to be the same and extinction and recolonization are random. Metapopulation theory examines the equilibrium frequency of occupied patches, as determined by the birth rate of new populations through dispersal, and the death rate of populations through extinction. Specifically, the equilibrium proportion of occupied patches (P) is determined by the ratio of the extinction rate over the colonization rate (P = 1- u/m, where u is extinction rate, m is recolonization rate). The metapopulation can persist if m > u, and at equilibrium we expect some patches to be empty.

One must demonstrate four things to provide convincing evidence for a metapopulation and these were all shown for the butterfly example
i) the patches are actually populations where births and deaths occur and most individuals spent their entire lives in the patch
ii) all patches can go extinct
iii) the organisms disperse sufficient distances so that all patches can be potentially recolonized
iv) extinctions among patches are asynchronous (i.e. not correlated); we do not have good year/bad year effects

Several implications:

i) Empty patches are critically important to keep the metapopulation stable. Removing them could reduce the colonization rate m and cause the whole metapopulation to crash.
ii) Metapopulations may impact species interactions like predation or competition and allow the persistence of species that would otherwise be outcompeted or wiped out by predators.
iii) Simple population models that ignore spatial aspects (immigration, emigration) may be insufficient. Also, simple field studies that focus on a single population (patch) may also be inadequate.
iv) Metapopulation structure was a big part of the spotted owl debate which had a huge impact on forestry practices in West Coast old growth forests.
v) They are cool.

2. Aspects of the biology of the European cuckoo and the songbirds they parasitize provide convincing evidence that co-evolution has shaped traits and behaviors of the cuckoos and their hosts.

(a) What is co-evolution and what, **in general terms**, is required to provide evidence for it ?

(b) Outline the hypothesized co-evolutionary process that has taken place between cuckoos and their hosts. For each of the two participants – cuckoos and hosts – indicate specifically which trait or behavior has negatively impacted the other participant and how this has caused natural selection for an evolutionary response by the harmed party.

(c) Outline the observational and experimental evidence for each of the proposed steps of the co-evolutionary process.

Co-evolution occurs when two interacting species cause reciprocal evolution in each other. Thus species A harms species B, which causes natural selection in B for traits to reduce the impact of A. The evolutionary response in B now has an impact on species A, leading to natural selection in A for enhanced performance in interactions with B. And so on.... Co-evolutionary interactions can be very dynamics without a stable endpoint or winner.

In Europe, we see currently see different genetic strains of cuckoos, each specializing on parasitizing different host species, and each laying eggs that mimic the eggs of their hosts. Since we are at a point where co-evolution has already taken place, we need to reconstruct what is likely to have taken place. We assume that initially there was a generalist cuckoo that parasitized many species of hosts, that these hosts were 'naive' and accepted the cuckoo eggs, even though they were different from their own (not mimetic).

Step 1: Cuckoo parasitism is very costly for hosts, this results in natural selection to reduce the costs of parasitism.
Step 2. Evolution in hosts. We see the evolution of egg-rejection in hosts, who reject eggs that are different from their own.
Step 3. Evolution in parasites. Egg rejection by hosts reduces the fitness of the generalist parasite, which results in natural selection for egg-mimicry by cuckoos. This leads to specialization in cuckoos to mimic specific hosts.

Prediction 1: Cuckoo parasitism is costly. Observation: cuckoo chicks remove all host eggs, host fitness is zero when parasitized.

Prediction 2: Cuckoo parasitism selected for egg-rejection in hosts. Observation: species of hosts whose diets make them unsuitable as hosts (seed-eaters) do not reject eggs. Therefore egg-rejection is associated with cuckoo parasitism, not some other factor. Experiment: compare egg rejection in host species that occur in areas with and without cuckoos (England vs. Iceland). Add non-mimetic model eggs to nests and look at rejection rates. Rejection rates are lower where cuckoos do not occur.

Prediction 3. Egg-rejection by hosts selects for egg mimicry in parasites. Experiment: Add model eggs that are either mimetic or non-mimetic to host nests. We find that the non-mimetic eggs are rejected more. Egg rejection reduces parasite fitness so egg rejection of non-mimetic eggs produces natural selection for mimetic eggs.

KEY

3. You have conducted a comparison of many species of annual and perennial plants within the plant family Bushacea and found a clear pattern: on average, the annual species have far more babies (seeds) than the perennial species. There are two approaches to explaining this kind of life history variation: r–and–K selection versus optimality (or optimal demography).
(a) With reference to the number of babies produced by annuals and perennials, contrast and compare these two different approaches to understanding variation in life history traits.
(b) What type of experimental evidence or observational evidence would allow you to distinguish between an r–and-K selection explanation and an optimality explanation for the observed difference in seed numbers between annuals and perennials.

r-and- K selection theory seeks to explain variation in life history traits like seed number in terms of the how traits affect (i) population growth rate or (ii) the organism's ability to compete in a crowded world. r-selected species are those who live in habitats or regions where disturbance (storms, fire, etc.) keeps their population below carrying capacity. In such cases, natural selection is expected to favor traits that allow for a rapid population growth rate (hence r-selection), such as large numbers of offspring, small offspring, early maturation. In contrast, K-selected species are those who are typically at carrying capacity (hence K-selection) and for whom selection is thought to favor traits that enable the organism to withstand competition and use resources efficiently (e.g. making a few large competitively superior babies, or late maturation). As an example, arctic organisms, who live in an unstable and fluctuating world were thought to be r-selected, while tropical organisms live in a much more stable environment and were proposed to be K-selected. TEST: According to this view, the annual plants are predicted to occur in unstable environments and should be below carrying capacity, while the perennials should occur in stable environments and be at carrying capacity.

Optimality focuses on patterns of mortality and trade-offs between traits (size versus number of seeds or growth versus reproduction) and assumes that natural selection will favor those traits that maximize reproductive success in a given environment relative to other traits that are possible. In terms of life tables, the optimal life history is the one that produces the largest population growth rate (i.e. that maximizes λ or r) compared to other life histories that are feasible. For example, if we compare the factors that affect the population growth rate of an annual versus perennial plants, we can determine the conditions when one is favored over the other by comparing their population growth rates. Annuals only breed once, so we do not have to consider the survival of the female. λ_A is the product of number of babies (B_A) times their survival (S_O). A perennial differs in that the adult lives to future years and her survival must be factored in. Thus, λ for a perennial is the sum of the number of babies (B_P) time survival (S_O) plus adult survival (S_P). The strategies yield the same fitness when $B_A - B_P = S_P / S_O$. The annual strategy is favored over the perennial strategy is favored are (i) when annuals can make far more babies (when $B_A >> B_P$) and/or survival of babies is relatively high compared to adult survival (i.e., S_P / S_O is a small number).
TEST: We cannot compare the adult survival of the annuals and perennials because annuals never survive. We can however compare the survival of babies in annuals relative to perennials and expect survival to be higher in the annuals.