BEFORE YOU START: WRITE YOUR NAME ON EACH PAGE!!!!

Read the questions carefully before answering to ensure that you fully understand what we are looking for. Answer the questions in sufficient detail to let us know that you fully understand the critical issues. Do not use the **shotgun** approach of throwing everything under the sun into your answer in the hope that something will hit the target because we may deduct points for statements that are counter to the correct answer. Good luck and wow us with your ecological knowledge!

PART A. Shorter answers, graphs or calculations. Your answers can be in point form but must be complete.

1. Biomes provide a striking example of a match between organisms and their environment on a broad geographic level.

(i) Name two biomes and identify a key feature of each (4 points):

Biome	**Feature**

These are just examples, anything from the list I handed out is OK

tundra	**extreme temperature variation**
desert	**dry**

(ii) If we were to compare two plants that occur in the same biome, say desert, but each occurs on a different continent, would this comparison be more likely to provide an example of an adaptive radiation or an evolutionary convergence? Explain why. (2 points)

Convergence, because each biome is a result of specific temperature and moisture conditions, and these conditions select for similar plant morphology. Example cactus in the Americas and Euphorbs in Africa that are unrelated taxa but are very similar in morphology.

2. Outline the key features aspects that together produce the process of natural selection. Which aspect is ecological, and why is it ecological? (6 points).

IF
1. Variation in phenotype (trait)
2. Heritable (genetic) basis of variation
3. Differential survival or reproduction that is due to phenotypic variation
4. THEN will get change in genes and phenotypes across generation (evolution)

Number 3 is the ecological part. The ecological aspect is the *reason why* differential survival or reproduction is associated with the phenotypic variation. Example: some phenotypes will be better at avoiding predators, or finding mates, etc..

3. The photo below shows a clear pattern: a bush surrounded by a bare area of soil with grass and other vegetation growing beyond the bare patch. Describe two different ecological mechanisms that could account for this pattern. Outline experiments you could conduct to test EACH of the two hypothesized mechanisms. For each hypothesis, discuss what result from your experiment would refute the hypothesis and what result would support the hypothesis (8 points).

Hypothesis 1: allelpathy (chemicals) from leaves or roots kills plants that are too close.

Experiment and Result: (a) trim back plant or remove altogether, bare patch should fill in. or (b) grind up leaves or roots into a solution and sprinkle solution on control plot away from plant, plants should die.

Hypothesis 2. Seed predators hide under bush, forage close to bush but not far, and remove seeds from area that is bare.

Experiment and Result: trap animals, bare patch should disappear'; put up seed predator exclosures, plants should grown in exclosures but not control plots.

Hypothesis 3: Bare patch is an animal trail.

Experiment and Result: Put up barriers that would cause animals to take different path, bare patch should grow back in.

4. The cost of inbreeding may favor the evolution of dispersal because individuals that fail to disperse may mate with relatives leading and produce less viable or inviable offspring. Outline an experiment you could do with plants to test for a cost of inbreeding. Be sure to identify any critical assumptions you make, and indicate what result from your experiment would indicate a cost to inbreeding (5 points).

We can take pollen from different individuals and by hand-pollenating plants, make crossed with different levels of relatedness or inbreeding. We can use plants growing at different distances from each other to make the crosses. If we assume that plants growing closer to each other are more likely to be related than plants growing farther apart, then we can use distance between donor and recipient and an index of inbreeding. (This makes sense because the whole point of dispersal, according to the inbreeding avoidance hypothesis, is to get farther away from relatives and reduce the chances of inbreeding). Evidence for a cost of would be that the offspring from closer matings do worse (worse growth, lower seed set, etc) than the offspring produced by more distant matings.

5. Graphical models of optimal foraging provide a nice way to examine the foraging decisions of an animal that is repeatedly making trips between foraging patches and a central place, as exemplified by a bird that forages for food to feed the chicks in its nest. Below is the skeleton of this graphical model which you need to complete (6 points).

(i) Label all axis including the two separate parts of the x axis

(ii) Draw the foraging intake curve to show prey gathered while foraging in the patch

(iii) Then show how to solve for the optimal number of prey items that maximizes the **rate** of energy returned to the nest

(iv) Also indicate the optimal number of prey items the forager should collect (it may not be an even number, don't worry about the tick marks)

6. According to population models, the density-dependent effects of intraspecific competition can have very different and interesting consequences for the population dynamics of populations with discrete breeding seasons compared to populations with continuous breeding. These consequences are best illustrated by contrasting the population dynamics (changes in N over time) predicted by the continuous logistic ($dN/dt = rN(1-N/K)$) versus the discrete logistic model ($N_{t+1} = N_t + r_D N_t(1-N_t/K)$).

(i) How do the population dynamics produced by these two models differ? (2 points)

Once at carrying capacity, the continuous stays at K; at high levels of r, the discrete model produces fluctuations, either stable limit cycles or chaos.

(ii) Why specifically do these two models produce such different outcomes? (1 point)

The discrete has time lags built in (one year time lag) so that density dependence depends on the population size last year, the continuous model does not have time lags, density-dependent changes in per individual population growth rate is instantaneous.

(iii) How can we confirm the reason for the difference? (2 points)

If we include time lags into the continuous model, we start to see more unstable population dynamics.

7. The following time budget data and energetic costs or benefits of activities is gathered for two strategies in a population of Anna's hummingbirds in the UCSC arboretum:
(1) ***Territorial individuals*** and (2) ***Non-territorial individuals.***

ACTIVITY	Costs of activity (Kcal/hour)	Time spent by territorial individuals in each activity	Time spent by non-territorial individuals in each activity
Foraging	3 Kcal/h	4 hours	8 hours
Sitting	1 Kcal/h	4 hours	2 hours
Fighting	5 Kcal/h	2 hours	0 hours

BENEFITS: The rate of food intake while foraging is:

7 Kcal/ hour for a **territorial** individual
3 Kcal/hour for a **non-territorial** individual

a) Based on the time budget data and the costs or benefits of each activity per hour of activity, determine whether an Anna's Hummingbird that is maximizing its **NET energy intake** (costs minus benefits) over the ten hour day should be territorial or non-territorial. Show all of your calculations (4 points).

	TERRITORIAL		NON-TERRITORIAL	
COSTS				
Foraging	3 Kcal/h x 4 h =	12 Kcal	3 Kcal/h x 8 h =	24 Kcal
Sitting	1 Kcal/h x 4 h =	4 Kcal	1 Kcal/h x 2 h =	2 Kcal
Fighting	5 Kcal/h x 2 h =	10 Kcal	5 Kcal/h x 0 h =	0 Kcal
TOTAL COSTS		**26 Kcal**		**26Kcal**
INTAKE				
Feeding intake	7 Kcal/h x 4 h =	**28 Kcal**	3 Kcal/h x 8 h =	**24 Kcal**
NET ENERGY INTAKE	28 - 26 = +**2 Kcal/10h**		24 - 26 = **-2Kcal/10h**	

Territorial is better.

b) Optimal foraging models are useful tools for determining what fitness currencies are important to organisms. If the currency that is being optimized by Anna's Hummingbird is minimizing their metabolic costs (not *net* costs, but Kcals spent), which strategy is better, territorial or non-territorial? Show why (you can refer to aspects of your calculations above). (2 points).

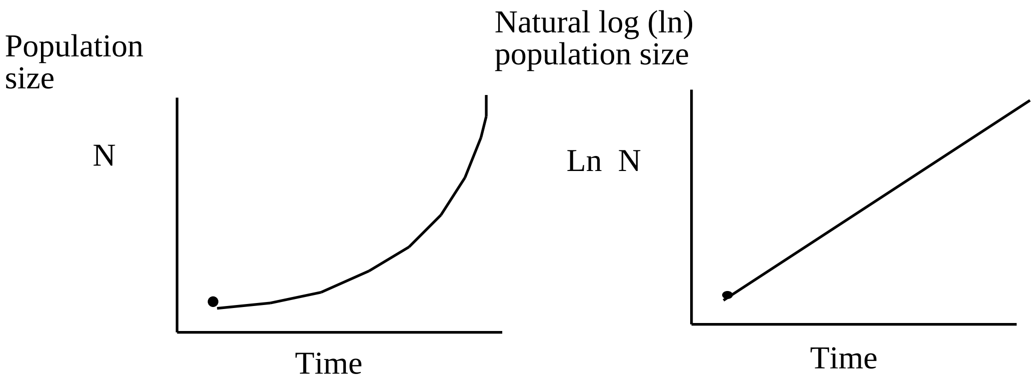
Total costs do not differ between the two strategies 26 Kcal = 26 Kcal.
Neither is better.

8. The population growth rate per individual, r, is a very useful population parameter that is used in many population models.

(i) If r = 2.4/year, what is r per month? (2 points)

Time units are divisible.
Therefore r per month = 2.4 ÷12 months/year = 0.2/month

(ii) If r > 0, what would the pattern of population growth look like on the two graphs below? The dot indicates the starting population size (2 points).



(iii) How could you estimate r from one of the graphs above, and which graph? (1 point)

The slope of the right graph is equal to r.

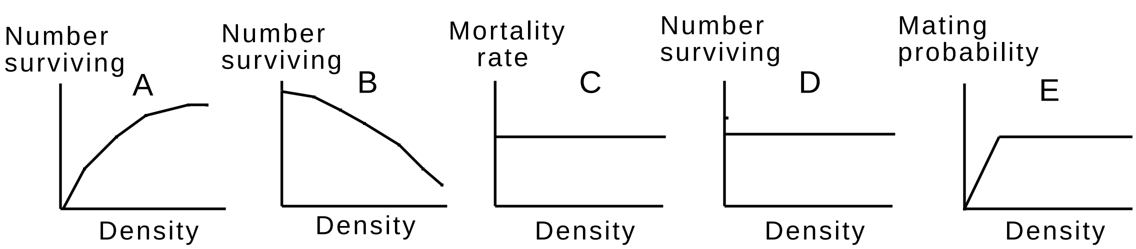
9. Match the graphs below to each of the following and write the graph letter in the space provided. There are more graphs than spaces to fill (Hint: pay attention to the axis labels). (4 points)

(a) __**C**__ Density-independence

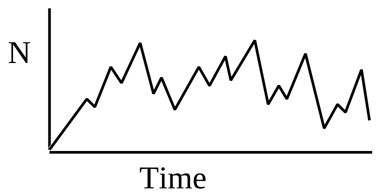
(b) __**D**__ Exactly compensating density-dependence

(c) __**E**__ Allee effect

(d) __**B**__ Overcompensating density-dependence



10. The graph below shows a population that fluctuates over time in a pattern known as chaos.



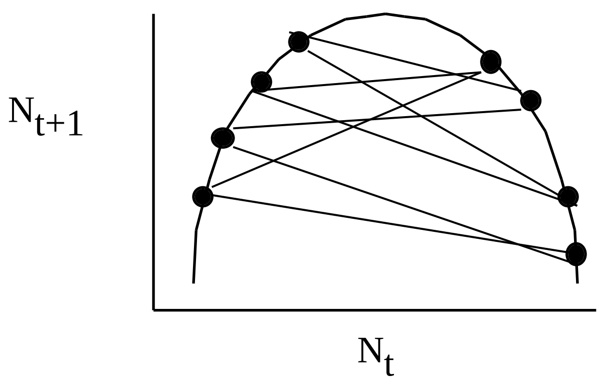
(i) What exactly is chaos? (2 points)

Chaos is a pattern that never shows repeating sequences, looks random but is not random.

(ii) Is chaos produced by random (stochastic) events and how do you know? (2 points).

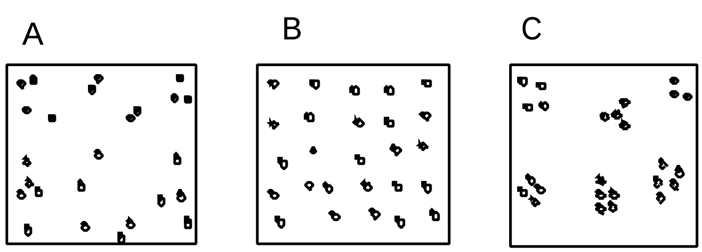
No, chaos is NOT random, because a deterministic model produces it (the discrete logistic). Also, the signature of chaos below is a clear, non-random pattern

(iii) If the above population dynamics are chaotic, then we should see the signature of chaos when plotted on the graph below. Fill in the signature of chaos (2 points)



11. The spatial distributions shown below represent: (3points)

(a) ___**A**___random dispersion
(b) ___**B**____uniform or spaced dispersion
(c) ___**C**__clumped dispersion



Describe one ecological mechanism that could produce pattern B and one that could produce pattern C (2 points**).**

B - territoriality, allelopathy, aggression
C - coloniality, clumped food, clumped resources

12. You are given the task of conserving a population of the Yellow-bellied Snorters. On your annual census, you notice that the population fluctuates in overall survival and production of young, and this is reflected in your estimates of λ across years. In good years you find that λ = 3.0, in bad years λ = 0.2. You also note that good and bad years occur with equal frequency. Your colleague insists that the snorter population is in fine shape because the arithmetic mean of λ is 1.6 and when they plugged this value into a deterministic population model, the population is predicted to grow quickly over the long-term. Being a well-trained ecologist, you correct them and insist that a stochastic population model is needed here.

a) What is the fundamental difference between a stochastic population model and deterministic population model? (2 points).

Stochasitic models incorporate chance deterministic models do not

b). Even without running any model you can do a quick calculation with the above λ values to obtain the correct estimate of an 'average' λ value that accurately predicts long-term prospects for the bear population. Show this calculation. Is the population growing, stable or declining over the long-term? Why? (4 points).

Growth is multiplicative, not additive. Therefore the growth rate of the population is reflected by the product of the two lambdas 3.0 x 0.2 = 0.6 which is less than a value of λ = 1 the value where the population is stable. Therefore this population will decline over the long run. Note that the geometric mean is the precise way to calculate the lambda (which in this case is the squareroot of 0.6). However, any number less than one will have a squareroot less than one, so simply showing that the product of the two lambdas is less than one is enough to show that the population will decline.

13. Body size affects just about all aspects of an organism's life. Due to allometric relationships between body size and many fundamental physiological and ecological variables, very small and very large animals live very different ecological lives (5 points)

(i) **Whole organism** metabolic rates scale Mass $^{0.75}$ with body size in the standard log-log plot. Given this, do smaller animals have larger or smaller **whole organism** metabolic rates than bigger animals? (1 point)

Smaller animals have smaller whole organism metabolic rates.

(ii) **Mass specific** metabolic rates scale Mass $^{-0.25}$ with body size in the standard log-log plot. Given this, do smaller animals have larger or smaller **mass specific** metabolic rates than bigger animals? (1 point)

Smaller animals have larger mass specific metabolic rates.

(iii) Describe three important ecological consequences of these relationships to the challenges faced by tiny animals (shrews, hummingbirds) versus large animals (deer, whale). (3 points)
Relative to big animals, small animals have shorter endurance times, need energy rich food, live shorter lives, can travel less far, must drop body temperature over night, must be risk sensitive foragers

14. Density-dependence is of special interest to ecologists because it can potentially explain what limits population growth in some species. In addition, it also provides a possible

explanation for the interesting population dynamics seen in some species (patterns of how N varies over time).

(i) What is meant by "density-dependence" (1 point)

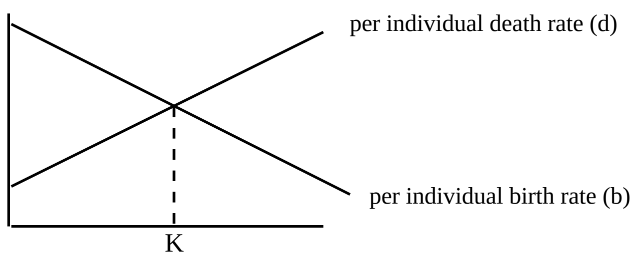
This is where birth rate or death ratevaries with density. It can be other correlates that affect births and deaths as long as these are rates or proportions (mating probability, proportion individuals without territories.

(ii) Describe two mechanisms of that can give rise to density-dependence (2 points)

competition, resource limitation, food limitation, Allee effect, territory limitation, cannibalism, predation, search image predation.

(iii) Using a graph showing, illustrate how the combination of a density-dependent birth rate (b, i.e., per individual) and a density-dependent death rate (d, also per individual) can "regulate" a population so that it will be stable at K, it's carrying capacity. Explain in words what the graph shows and why the population will be stable at K. (4 points)

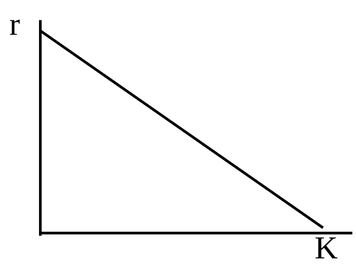
APPRAOCH 1



Density (N)

As density increases, the per indivudual birth rate (b) decreases while the per individual death rate (d) increases. Since r = b - d, r = 0 when b = d, which occurs by definition at K,the carrying capacity. Below K, b > d so r > 0 and population increases, above K b < d so r < 0 and population decreases. The population stabilizes at K.

APPROACH 2



Density (N)

This linear decrease in 1/N dN/dt with increasing density is the basic assumption of the logistic model. The line has a slope of -r/K. Therefore the equation for 1/N dN/dt = intercept (r) plus the slope times x (which is N). Thus $1/N\, dN/dt = r - (r/K)N = r(1 - N/K)$. Multiplying both sides by N gives the logistic equation: $dN/dt = r N(1 - N/K)$.

PART B. LONGER ESSAY. Answer 1 of the following 2 essay questions. 20 points.

*** ONLY ANSWER 1 QUESTION!!!*****

1. The Sociable Hellbunny occurs in two habitats, pine and oak forests. Pine is a good habitat because food resources are plentiful, while Oak is a bad habitat with fewer food resources. This type of variation in habitat quality can result in two very different patterns: (1) **source** versus **sink** habitats (and populations) or (2) an **'ideal free distribution'**, where sequentially settling individuals choose the habitat to settle in a way that maximizes their potential reproductive success **at the time they settle** (shown graphically in class).

(i) Compare and contrast these two different patterns by discussing both the assumptions and predictions of each.
(ii) What data (observational or experimental) would you need to collect for the Sociable Hellbunny to show that it fits the idea of source and sink habitats? What experimental manipulation and result would convince you that the Sociable Hellbunny chooses habitats as predicted by the ideal free distribution?
(iii) Are these two patterns mutually exclusive or could source and sink populations ever result from individuals that settle according to the ideal free distribution?

Source and sink habitats are identified based on the population growth rate in a habitat, excluding changes to the population due to immigration and emigration. Source habitats have per individual population growth rates greater than replacement ($\lambda > 1$, or $r > 0$) and maintain stable populations even though more individuals disperse out of the habitat than immigrate in. In a sink habitat, the population growth rate is below that needed for a stable population ($\lambda < 1$, or $r < 0$) and the populations is maintained only through immigration from source populations.

In an ideal free distribution, sequentially settling organisms are able to assess the value of the habitat to them at the point they settle, and choose the one that is best at the time they settle. Due to density-dependent competition for resources, the average value of a habitat decreases as the number of settlers increases. At some point, the value of the "good" habitat drops below the value of the "bad" habitat, and a settling individual does better by settling in the bad habitat. When all individuals have settled, the value of the two habitats should be roughly equal, and reproductive success or some other measure of performance (like food intake rate) should be equal. In addition, the density should be higher in the good habitat. Whether we see source-sink or ideal free depends on the social behavior of the organisms. For ideal free to occur, the animals must be free to go wherever they want. In contrast, source-sink will only occur if there is some sort of control of resources so that some individuals prevent others from access to good habitat, say through territoriality.

The critical data to collect to demonstrate a source and a sink population is to assess the population growth rates in the two habitats, and $\lambda > 1$ in a source, $\lambda < 1$ in a sink. In addition, we should see more individuals dispersing out of a source than immigrating into the source, but see more individuals immigrating to a source than leaving it. For ideal free, the best test would be a density manipulation. For example, in the potentially good habitat, identified by higher density, we can remove individuals and then compare these low density plots to control plots. There are two possible outcomes. If animals do not move after the experiment, then reproductive success should increase in the lower density plots. If animals do move to take advantage of the experimentally-produced better low density, high value habitat, then we should see movement out of control plots (both the good and bad habitats) until equilibrium is achieved again.

Yes, these patterns are mutually exclusive. An important prediction of ideal free is that individuals in good and bad habitats will have the same reproductive success (and any other measure that affects population growth). This is incompatible with source versus sink which requires that the reproductive success in the two habitats must be different, and different enough to create the required differences in λ between the two types of habitats.

2. Optimal foraging models are used to predict the foraging decisions of animals, to identify the constraints and trade-offs that shape these foraging decisions and to identify the foraging 'currencies' that are important to individuals in particular foraging contexts. In class we discussed three studies that tested for one or more foraging currencies: central place foraging by starlings flying back and forth between their nest and foraging patches, 'risk-sensitive' foraging by shrews choosing between a risky and a constant reward, and optimal territory size of sunbirds. Together, these studies illustrate how animals can vary in the foraging currency that is important to them, and how different approaches might be used to study different currencies.

(i) Describe these three studies, outlining their basic approaches to determining what currency was being optimized. Note that in the case of risk sensitivity, the currency can be the predictability of the reward (variation as opposed to just the mean).

(ii) Would you expect an animal to always optimize the same currency throughout its life? Illustrate your answer with biological reasons, either by referring to the above case studies, or with your own examples.

Starlings: tested whether birds are maximizing net rate of energy to nest; created diminishing rate of worms, travel time known and can therefore predict number of worms birds should take each time if were maximizing rate of worm return to nest. Behaved as predicted. This currency makes sense because these birds were feeding babies and more food to babies means more babies.

Shrews: tested whether shrews were risk sensitive foragers that pay attention to the variation in the reward for a given average reward. Trained shrews to choose between a variable versus a constant reward. They avoided the risky reward as long as they were in an energy surplus, but chose risky reward if were in an energy deficit. Makes sense because these animals have high relative metabolism and will starve easily. Animals in energy deficit need a big reward to survive so have to gamble on the risky choice that might have the big payoff.

Sunbirds. Approach was to use a model to make predictions about territory size that would be optimal if birds were maximizing different currencies (maximize rate of net energy intake, maximize time sitting, minimize costs (metabolic costs). Then compared predicted territory size to that observed for population and also looked at predicted and observed values for time budget activities. Predictions from model based on minimizing costs were the best. Minimizing metabolic costs would reduce wear and tear on birds and increase their lifespan.

No, we would not expect the same currency to hold throughout life. When an animal is feeding offspring, as is the bird feeding chicks, the more energy, the better, because chicks need food, and more food means more babies. However, when animals are not breeding, excess energy may not be that useful. Here, spending more time sitting and avoiding predation risk may be important. Or, perhaps minimizing total metabolic costs may be best since this reduced wear and tear on the body may allow the organism to live longer. Finally, for very small animals, variation in the reward may come into play and if the animal has low reserves and the starvation is possible, it may pay the animal to prefer risky (variable) rewards that could have a high reward or nothing (just like gambling).