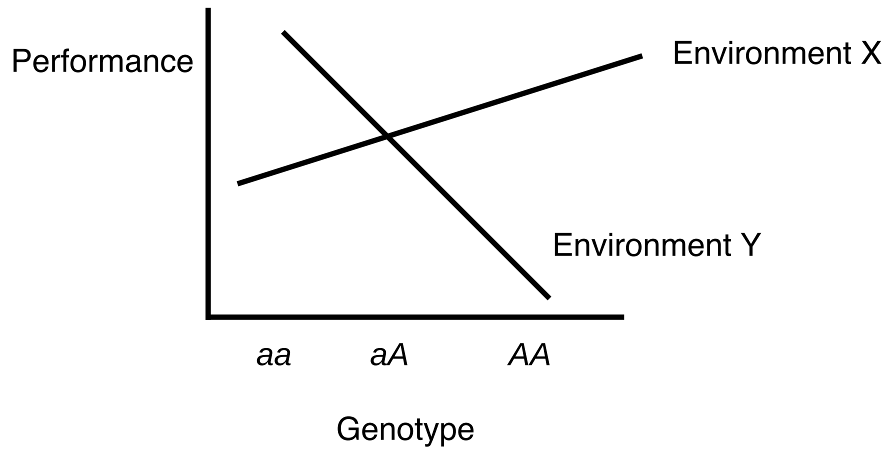
I. Competition and phenotypic traits

The performance of a genotype depends on the environment. Imagine that a species has a single gene with two alleles: *a* and *A*. The combination of these alleles determines the phenotype of the organism (e.g., bird's beak size) and its performance in an environment (e.g., type of seeds consumed.) In the figure below, we plot the performance of the three genotypes in two environments.



1. Which genotype dominates in environment X? In environment Y?

2. Imagine the environment varies from year to year, from environment X, to environment Y, and back, due to periodic changes in climate. What genotype would be favored? Why?

II. Biotic control

Last season, a farmer's crops were eaten by locusts. To lessen the effects of this pest, the farmer introduces a genetically modified (GM) group of locusts into the fields. Theses GM-locusts compete with the natural locusts, but don't eat the farmer's crops. This is a form of biotic control: a pest is reduced by introducing a competitor.

Assume we can model independently each population of locusts using the Lotka-Volterra formula:

$dN/dt = r_N N (1 - N/K_N)$ (natural locusts)

$dM/dt = r_M M (1 - M/K_M)$ (GM locusts)

1. What are the parameters in this model? Define each in words.

2. These equations include within-locust competition (i.e., competition between the natural locusts.) Identify the intra-specific competition terms in the model.

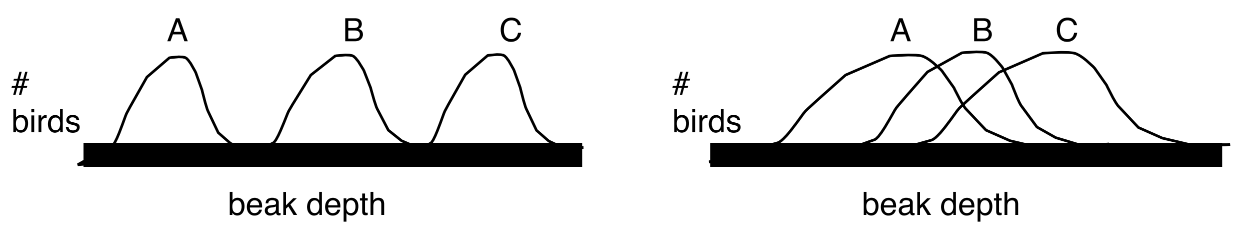
3. Include inter-specific locust competition (i.e., competition between the natural locusts and GM locusts) in the model. (Hint: you'll need to add a new term to the end of each differential equation.)

4. Find the fixed points of the natural locust population N in terms of the model parameters.

5. We want to eliminate this pest. Is this possible? If so, what parameters must be tuned? Can you suggest methods the farmer could use to improve the pest control?

III. Characteristic competition

You observe an island in the Pacific Ocean and study the native bird populations. You find 3 species of birds that share the environment of the entire island and consume seeds found naturally on the island. Below we plot two examples of the number of birds versus the beak depth for the three species (labeled A, B, and C).



1. Which of the two plots do you expect characterizes the distribution of birds on the island? Why?

2. Imagine you take species A and B to an uninhabited island with flora identical to that found in the birds' home island. Your future students return 200 years later and observe the bird populations. Sketch a distribution like those above for the new island in the distant future. Explain your reasoning.

IV. Predator-Prey

1. List some examples of predator-prey systems.

2. The typical equations for predator-prey interactions are:

$$dR/dt = r\,R - c\,R\,P$$
$$dP/dt = a\,(c\,R\,P) - d\,P$$

Looking at these equations, which variable (R or P) denotes the predator? Which variable denotes the prey? How can you determine this from the equations?

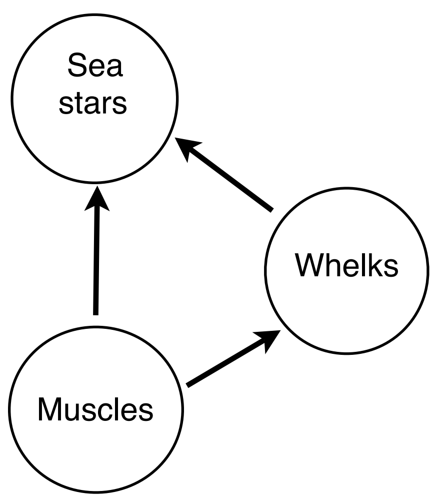
3. Define in words all parameters in the model.

4. In the first equation, what is the effect of the term: c R P?

5. In the second equation, what is the effect of the term: a (c R P)?

V. Trophic Interactions.

Consider the following diagram of trophic interaction between sea stars, whelks, and muscles in an inter-tidal environment:



Here the arrows point from the prey to the predator.

1. What species is the top predator? What species is the intermediate predator?

2. Using this diagram, discuss what might regulate the abundance of the whelks? Describe “top-down” regulation and “bottom-up” regulation of the whelks.

3. What type of experiment might you use to test abundance regulation of the whelks?

4. Imagine a virus eliminates the entire muscle population. What do you expect would eventually happen to the remaining sea star and whelk populations?

VI. Diversity

You examine two desert regions in the southwest United States, observe five species of scorpions, and record their abundances in the following table.

Desert 1	
Species	# observed
A	10
B	8
C	12
D	9
E	11

Desert 2	
Species	# observed
A	40
B	2
C	1
D	4
E	3

1. What is the probability of observing each species in each desert?

2. Calculate Simpson’s Index: $D = 1 / \Sigma p_i^2$ for each desert population.

3. Calculate the Shannon-Weiner entropy: $H = - \Sigma p_i \ln p_i$ for each desert population.

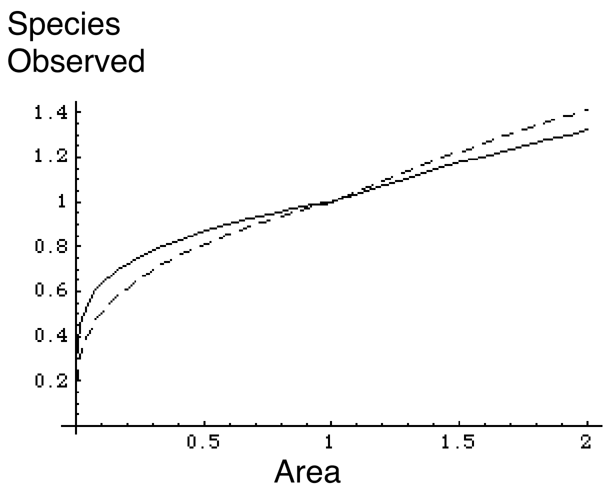
4. Which population has higher evenness? Which population has higher functional diversity?

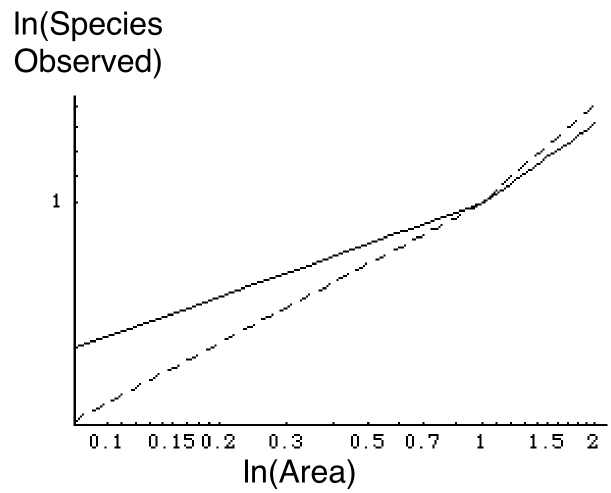
5. Which desert region do you expect is better prepared to survive dramatic climate changes?

VII. Species Area Relationship

A researcher observes two areas: a New England forest and an Alaskan tundra, and records the number of species found in each.

1. In the figures below are plotted the observed data; forest=dashed curve, tundra=solid curve. We plot on the left the data in a log/log scale. Using the figure on the right, determine in which area the diversity of species scales more rapidly with area.





2. Identify the area at which a change in scaling occurs. Call this area T (to denote ‘threshold’).

3. Is the scaling for areas less than T larger or smaller than for areas greater than T? What could be the explanation for this change in scaling?

4. Imagine extending this analysis to include greater areas. Do you expect the scaling will change? If so, how will it change?

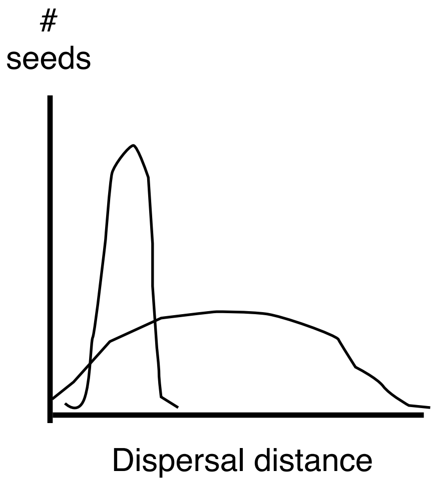
IIX. Succession

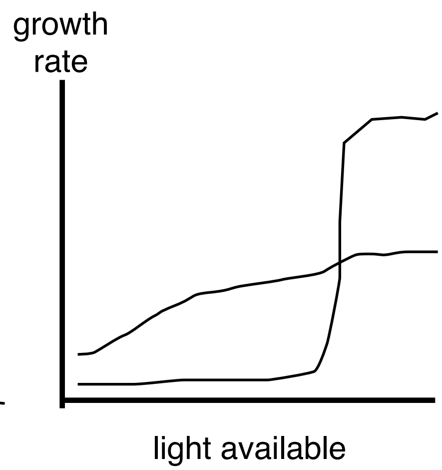
A thunderstorm occurs over a New England forest, destroying a large area of trees. We’ll sketch out the natural succession of trees in this area.

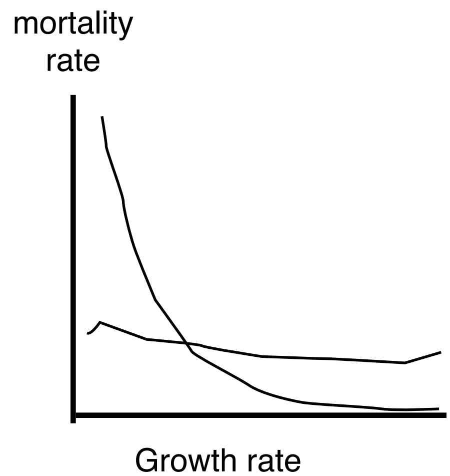
1. The first trees to appear are early successional species. What are the general characteristics of these species?

2. In the future appear late successional species. What are their general characteristics?

3. In each of the plots below there are two curves. One curve represents an early successional species. The other curve a late successional species. Label each curve in each plot. Justify each label.







IX. Humped distributions

Draw all of the “humped curves” we’ve discussed in lecture so far. Label and describe each. (Hints: remember diversity of species versus disturbance frequency in an environment, diversity of species versus productivity of an environment, rate of population growth versus population size in a competitive population, scaling factor of diversity versus log area examined.)

X. Photosynthesis

In what environments are the C3, C4, and CAM pathways of photosynthesis most likely to occur? What makes each advantageous in particular environments?