

# 7.014 Problem Set 7

Please print out this problem set and record your answers on the printed copy. Answers to this problem set are to be turned in to the box outside 68-120 by 5:00pm on MONDAY May 14, 2007. Problem sets will **not** be accepted late. Solutions will be posted online.

1. You study the population growth of a hypothetical flightless bird, the Bamboozle. Currently Bamboozles live in two places: Cambridge, MA and Cambridge, England. You have compiled the following tables for each of the populations:

| Age Class<br>(in years) | Population        |       |                    |       |
|-------------------------|-------------------|-------|--------------------|-------|
|                         | Cambridge, MA USA |       | Cambridge, England |       |
|                         | $l_x$             | $m_x$ | $l_x$              | $m_x$ |
| 0                       | 1                 | 0     | 1.0                | 0     |
| 1                       | 0.5               | 0     | 0.9                | 0     |
| 2                       | 0.2               | 2.0   | 0.8                | 0     |
| 3                       | 0.1               | 4.5   | 0.8                | 1.5   |
| 4                       | 0.05              | 1.0   | 0.7                | 0     |
| 5                       | 0                 | -     | 0                  | -     |

(a) Cohort vs. Static

(i) What is the difference between a cohort and static life table?

*A cohort table is created by monitoring the changes in population of a group of organisms (of a single species) that were all born at the same time throughout their lifetime. You would also collect information about the number of offspring from these organisms. A static table is built by determining the age of death for a group of organisms after they died. Therefore, you often do not know when these organisms were born. Alternatively, a static table could also be created by collecting data about a group of live organisms all of the same age at one time point (i.e. – not over the course of their life).*

(ii) Can you tell just by looking at a life table whether it is a static or cohort table? Why or why not? Explain your answer.

*Generally, static tables will not include information about fecundity, so you should be able to tell. However, leaving out fecundity, static and cohort tables can look very similarly. The difference in interpreting the data is that information from the static table will mostly be inferred and will be approximate at best.*

(a) Which type of life table, static or cohort, provides the most useful data about the survivorship of the species? Explain your answer.

*A cohort table provides more information. A static life table is built by determining the age of death of a cross-section of the population. The static life table does not directly show the survivorship or fecundity of that population as it matures, experiencing changes in the environment. Instead, these numbers must be derived using the assumption that the mortality experienced by a cohort at any age stays constant. On the downside, following a cohort over many years is usually difficult.*

(b) What three things need to be measured to create a cohort table?

1. Total population at age 0.
2. Total number of birds dying each year.
3. Number of birds born to the cohort at each age group.

(c) Determine  $N_x$  for each Bamboozle population. Assume 100 animals at age 0 for both populations.

| Age Class<br>(in years) | Population        |       |       |                    |       |       |
|-------------------------|-------------------|-------|-------|--------------------|-------|-------|
|                         | Cambridge, MA USA |       |       | Cambridge, England |       |       |
|                         | $N_x$             | $l_x$ | $m_x$ | $N_x$              | $l_x$ | $m_x$ |
| 0                       | <b>100</b>        | 1     | 0     | <b>100</b>         | 1.0   | 0     |
| 1                       | <b>50</b>         | 0.5   | 0     | <b>90</b>          | 0.9   | 0     |
| 2                       | <b>20</b>         | 0.2   | 2.0   | <b>80</b>          | 0.8   | 0     |
| 3                       | <b>10</b>         | 0.1   | 4.5   | <b>80</b>          | 0.8   | 1.5   |
| 4                       | <b>5</b>          | 0.05  | 1.0   | <b>70</b>          | 0.7   | 0     |
| 5                       | <b>0</b>          | 0     | -     | <b>0</b>           | 0     | -     |

(d) Would you consider the survival of either of these populations to be in trouble? Show your work.  
*The USA population is in trouble because its net replacement rate is less than one. This means that the population is decreasing over time.*

$$R_0 = \sum l_x m_x$$

$$R_0 \text{ USA} = 0.9$$

$$R_0 \text{ England} = 1.2$$

(f) Which population (USA or England) has the longer generation time? Generation time is determined as the average age at which the population replaces itself. Show your work **or** explain your reasoning.  
*The English Bamboozles have a longer generation time.*

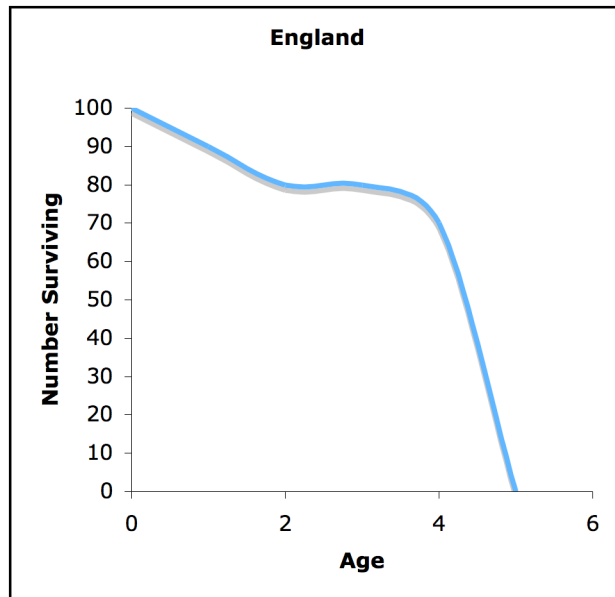
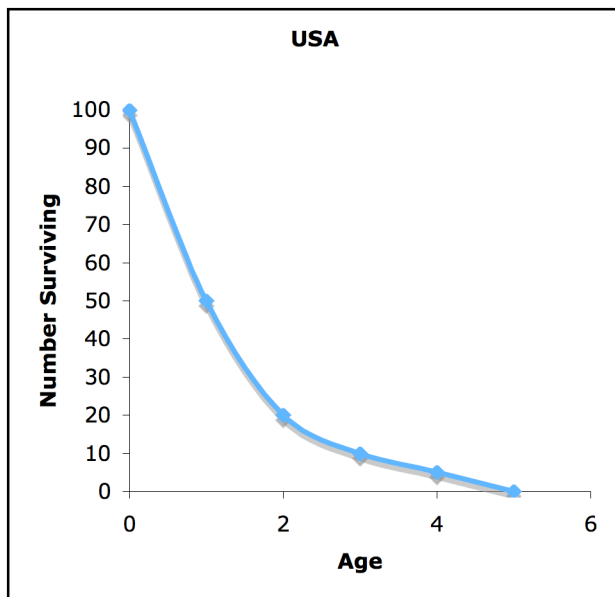
1. Generation time is determined as:  $G = \frac{\sum x l_x m_x}{R_0}$  where  $x = \text{age class}$ .

$$G \text{ USA} = 2.6$$

$$G \text{ England} = 3$$

2. The chart also shows the same information. The USA Bamboozles have offspring between the ages of 2 and 4, with the average being age 2.5. The English Bamboozles, only have offspring at age 3.

(g) For each of the two populations, draw an approximate survival curve on the graphs below:



(h) If the environment were to change suddenly (e.g. – a drastic drop in temperature), which one of these populations would be better suited to surviving? Explain your choice.

*The USA population would be more likely to survive as this population has more characteristics necessary to survive changes in the environment. Such characteristics include more offspring to survive the change and a shorter generation time that allows these birds to reproduce more quickly.*

**2.** Prior to World War II, advances in public health had been largely limited to affluent, industrialized countries. But since then, improvements in public health have been made in many of the poorer countries of the world — always with dramatic effects on death rates. In 1945, the death rate in Sri Lanka was 22/1000 yr<sup>-1</sup>, but after a mosquito-control program to reduce malaria, the death rate dropped to 10/1000 yr<sup>-1</sup> year in 9 years. Currently, the death rate is 6/1000 yr<sup>-1</sup>. The birth rate has also fallen over the past 60 years from 37/1000 yr<sup>-1</sup> to 17/1000 yr<sup>-1</sup>.

(a) Assuming this population is growing according to a simple exponential growth equation, what is r, the intrinsic rate of increase, for Sri Lanka today? Show your work.

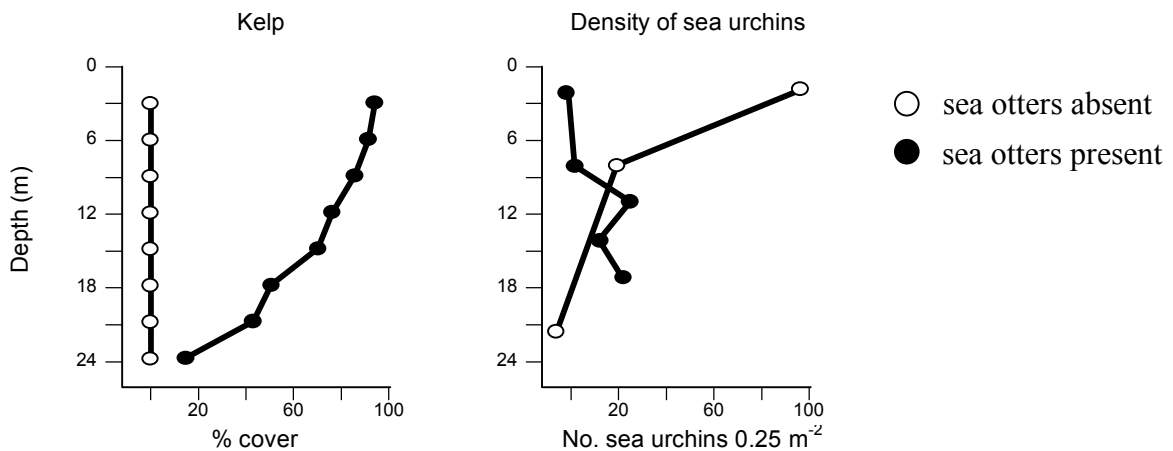
$$r = b - d$$

$$r = 17/1000 - 6/1000 = 0.017 - 0.006 = 0.011 = 1.1\% \text{ yr}^{-1}$$

(b) What is the current doubling time for Sri Lanka’s population? Show your work.

$$T_d = \frac{\ln 2}{r} = \frac{0.69}{0.011} = \frac{0.69}{.011} \approx 63 \text{ years}$$

**3.** You work with a team that studies the ecological relationship between several species off the coast of Adak Island in Alaska. You collected the following data about the density of kelp and sea urchins under two different conditions: presence and absence of otters.



Interactions among sea otters, sea urchins, and vegetative cover in kelp beds off the coast of Adak Island. Symbols on the left graph are the same as the right.

(a) What is a keystone predator?

*A keystone predator is one that has a large impact on the local environment despite having a small population (i.e. has a disproportionate effect on its environment relative to its abundance)*

(b) Based on the data from the graph:

i- draw a food web diagram indicating the relationship between the three organisms

ii – circle which organism that you think best represents the keystone predator

iii – Provide at least two justifications from the data for why you drew your particular food web.



Some justifications:

1. *in the absence of otters, sea urchin population increases*
2. *in the presence of otters, sea urchin population decreases*
3. *a decrease in sea urchins (sea otters present), results in an increase in kelp.*
4. *an increase in sea urchins (sea otters absent), results in a decrease in kelp*

**4.** You are interested in the effect of inter- and intraspecific competition between two plant species: thistle and wheat. To do your study, you create a de Wit plot. This experiment involves first growing each of the plants alone at specific seed densities. You then grow the two plants *together* in the same pot at a *constant* overall seed density, but vary the amount of each type of seed (*i.e.* – your constant seed density might be 20 seeds, but first you plant with 5 thistle seeds and 15 wheat seeds and next with 10 thistle seeds and 10 wheat seeds). If you plot *all* of the data on a single plot, the resulting curves indicate both intraspecific competition and interspecific competition. Below are your data:

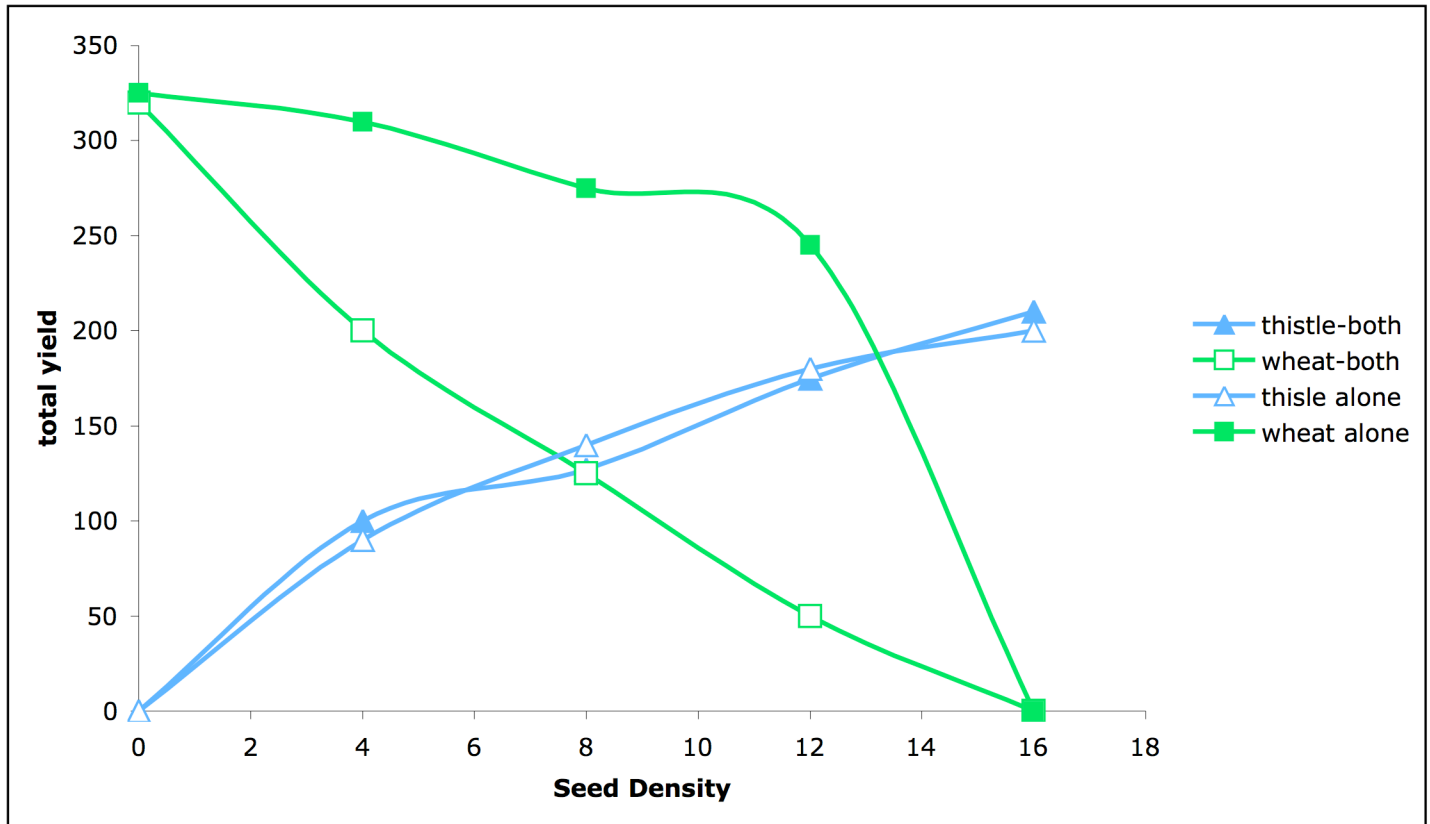
**Grown Alone:**

| Thistle      |                 | Wheat        |             |
|--------------|-----------------|--------------|-------------|
| Seed density | Final yield (g) | Seed density | Final yield |
| 4            | 90              | 4            | 245         |
| 8            | 140             | 8            | 275         |
| 12           | 180             | 12           | 310         |
| 16           | 200             | 16           | 325         |
| 32           | 310             | 32           | 350         |

**Grown Together:**

| Initial seed density |       | Final yield |           |
|----------------------|-------|-------------|-----------|
| Thistle              | Wheat | Thistle (g) | Wheat (g) |
| 16                   | 0     | 210         | 0         |
| 12                   | 4     | 175         | 50        |
| 8                    | 8     | 127         | 125       |
| 4                    | 12    | 100         | 200       |
| 0                    | 16    | 0           | 320       |

(a) Plot the data on the graph below. Make sure to provide a legend!



For each of the questions below, give an answer, and justify it based on the data.

(b) What is the evidence for interspecific competition between the species?

*Interspecific species is when species have an effect on each other's growth. In this case, when grown together, the thistle plant produces a final yield similar to what it would produce when grown alone. The wheat plant, however has a lower final yield per seed density when grown in the presence of the thistle plant.*

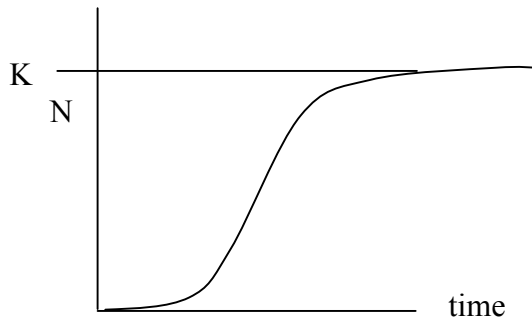
(c) Is the competition reducing the fitness of both species? Why or why not?

*The fitness of only the wheat plant is being reduced. The final yield of the thistle plant is not affected by the presence of the wheat plant. However, the final yield of the wheat plant is reduced when grown in the presence of the thistle plant, so its fitness must be reduced by the competition.*

(d) Which species has **more intense** intraspecific competition? What is the evidence?

*Intraspecific competition is when one species competes with itself for growth. To determine if there is intraspecific competition, you must compare the amount of growth you expect in the absence of intraspecific competition and how much is actually observed to grow. In the absence of intraspecific competition, you would expect that the total yield of the plant would increase proportionally as the seed density increases. Neither the thistle plant nor the wheat plant grow proportionally with seed density, so both display intraspecific competition. The growth rate of the wheat plant, however, is slower than that of the thistle plant (the slope of the growth curve after the initial planting is less) so it shows more intense intraspecific competition.*

5. A population is found to grow according to the logistic equation, as indicated by the following growth curve:



(a) How does the logistic equation differ from the exponential equation for describing the growth of a population?

*The logistic equation takes into consideration the limits of the environment to sustain the growth of the population. The exponential equation assumes limitless growth conditions.*

(b) On the graph above, indicate K, the carrying capacity, on the Y axis. Explain what the carrying capacity is.

*The carrying capacity is the maximum number of individuals of a particular species that an environment can support.*

(c) For this population, what is the growth rate,  $r$ , when  $dN/dt = 50$  and  $N = 50$ ?

$$\begin{aligned} 1/N \times dN/dt &= r \\ 1/50 \times 50 &= 1 \text{ } t^{-1} \end{aligned}$$

(d) If the carrying capacity,  $K$ , of this population is 100, what is  $r_m$ ?

$$(1/N)(dN/dt) = r_m((K-N)/K)$$

$$(1/50)(50) = r_m((100-50)/100)$$

$$r_m = 2 \text{ } t^{-1}$$

(e) How do  $r$  and  $r_m$  differ?

*$r$  is the rate of growth at any given time.  $r_m$  is the rate of growth only during exponential conditions.*

(f) What is the doubling time of the population when  $N = 50$ ?

$$\begin{aligned} T_d &= \ln 2 / r \\ 0.69 / 1 &= 0.69 \text{ } t^{-1} \end{aligned}$$

(g) What is the doubling time when  $N=2$

$$\begin{aligned} \text{must determine a new } r: \\ r &= dN/dt * 1/N = r_m(K-N/K) \\ r &= 2(100-2/100) \\ r &= 1.96 \end{aligned}$$

$$T_d = 0.69 / 1.96 = 0.35 \text{ } t^{-1}$$

6. You are determining the evolutionary relationships between the microorganisms found in a sample of dirt outside Building 54.

(a) **Explain** why an evolutionary tree based on comparisons of DNA sequence is more accurate than an evolutionary tree based on phenotypic comparison.

*studying by phenotype is less reliable for at least two reasons: 1. interpretation of phenotype is dependent on the person doing the comparison, so it involves human error 2. a particular phenotype might not have the same function for different species (e.g wings on a penguin don't have the same effect as wings on a sparrow).*

(b) Below are several genes that you could use for your DNA sequence comparison. Indicate which gene you think would be most appropriate by **circling** that gene. For **each** gene **explain** why you did or did not choose that gene.

A gene that encodes for:

a protein that binds origins of replication (not DNA polymerase)

*the DNA sequence of origins is not conserved between species, thus the proteins that bind these sequences might not be well conserved.*

an enzyme involved in photosynthesis

*not all microorganisms do photosynthesis, so you might miss some microorganisms in your sample*

an enzyme involved in glycolysis

*All organisms perform glycolysis, which is a highly conserved process.*

an enzyme involved in mRNA splicing

*the microorganisms found in your soil sample will most likely be prokaryotes and therefore will not have introns and splicing.*

a protein that binds to promoters (not RNA polymerase)

*similar to origins, promoters are not conserved.*

(c) You have determined the sequence for a segment of your particular gene for each of the microorganisms in your sample. Determine the evolutionary distance between each of the sequences:

#1 ACCACTAGCA

#2 ACCAGTAGCA

#3 AGGAGTTCCA

#4 TCCACGAGCA

|       |       |
|-------|-------|
| 1 → 2 | 0 . 1 |
| 1 → 3 | 0 . 5 |
| 1 → 4 | 0 . 2 |
| 2 → 3 | 0 . 4 |
| 2 → 4 | 0 . 3 |
| 3 → 4 | 0 . 7 |

(d) From another sample, you determine the following evolutionary distances. Based on these distances, create a phylogenetic tree.

*You have to draw the tree based on the relative relationships as best you can because the evolutionary distances will never add up exactly as they are generally approximations. Additionally, this tree should not have any "nodes" because none of the organisms is extinct (i.e. – none of the organisms is an ancestor).*

|       |         |
|-------|---------|
| 1 → 2 | 0 . 1 2 |
| 1 → 3 | 0 . 1   |
| 1 → 4 | 0 . 2   |
| 2 → 3 | 0 . 2 4 |
| 2 → 4 | 0 . 3 8 |
| 3 → 4 | 0 . 2 6 |

