1.018/7.30J Ecology 1   **Quiz #2**   **November 5ᵗʰ, 2009**

Please put your name on every page! Space is provided for your answers; if you need more room, use the back of the **same** page. This exam is worth 100 points, with an additional 6 points of bonus problems. You have 80 minutes to work on it and the value of each question is roughly proportional to the amount of time you should spend answering it. The test will begin at 11:05am and promptly end at 12:25pm.

<p style="text-align:center">**Mean = 83.4, Standard Deviation = 11.0**</p>

1. (25 points)

a) Explain Liebig's Law of the Minimum. Describe and provide an example of how limiting factors can make complex systems easier to understand.
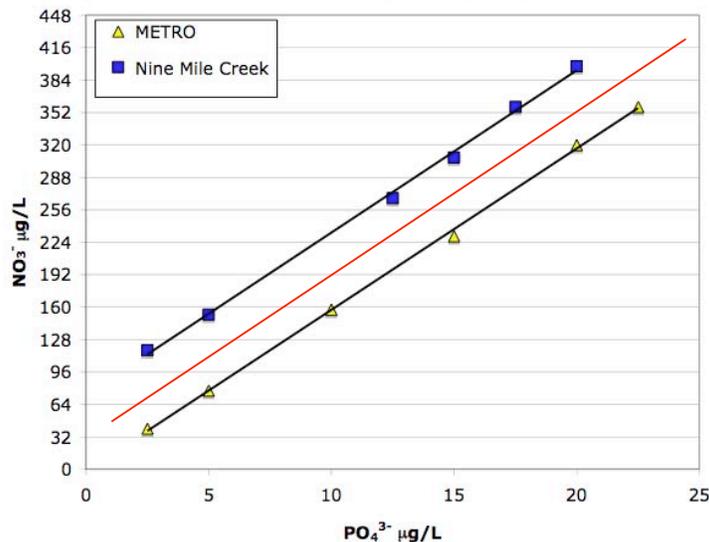
Liebig's Law of the Minimum states that the growth of a plant is dependent on the element that is in least supply relative to the needs of the plant.

Often one nutrient is limiting, which simplifies complex systems because only the cycling of one nutrient needs to be described thoroughly. For example, in high-nutrient low-chlorophyll areas of the ocean, productivity is determined primarily by the flux of iron into the system.

b) Onondaga Lake is located in Syracuse, NY and has experienced extensive cultural eutrophication. Give three potential impacts of cultural eutrophication on the lake ecosystem.

Reduced clarity of water
Reduced oxygen levels
Increased phytoplankton blooms
Reduced fish populations (anoxia)
Change in food web structure

c) Onondaga Lake has two inflows that each contribute 50% by volume: Nine Mile Creek and METRO, Syracuse's primary sewage treatment plant. Jonathan collected samples from Nine Mile Creek and METRO once a week for six weeks during the summer and plotted it for you below. Draw a line that depicts the approximate concentrations of phosphate and nitrate you'd expect to find in Onondaga Lake. Is this lake nitrogen or phosphorous limited?

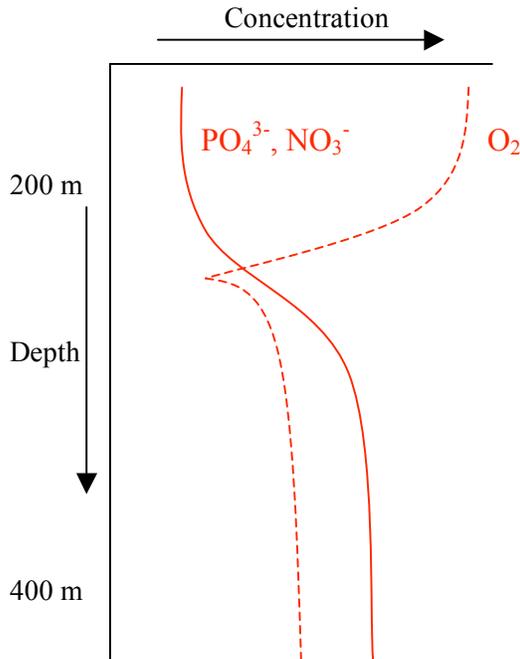Phosphorous limited

d) What source is responsible for the eutrophication and why?

METRO is responsible. Onondaga Lake is phosphorous limited, therefore the contribution of phosphorous by METRO is causing the eutrophication.
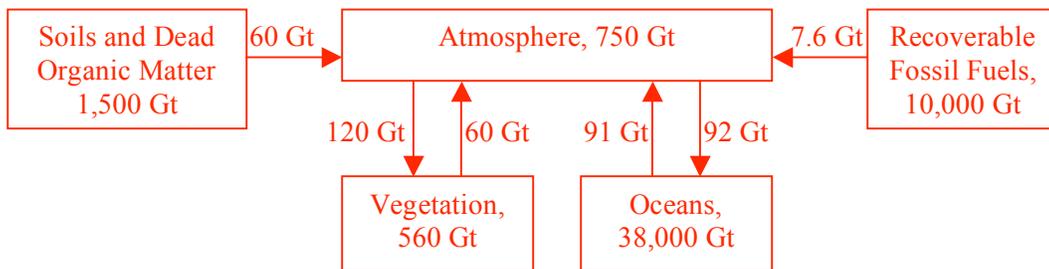
e) Sketch one line showing the nutrient (PO_4^{3-}, NO_3^-) concentration with ocean depth and another showing the concentration of oxygen with ocean depth. Explain the major features of the nutrient and O_2 profiles.

In near-surface well-mixed waters, the atmosphere constantly replenishes oxygen. With depth, respiration of heterotrophs and decomposition of organic matter reduces oxygen concentrations. Oxygen levels continue to decrease until the water becomes so deep that respiration and decomposition no longer occur. Nutrients are consumed at the surface and transported to depth by the biological pump where they are regenerated.

2. (25 points)

a. Sketch the global carbon cycle using boxes and arrows. Identify major reservoirs (boxes) and their sources and sinks (arrows).

b. The figure below shows the latitudinal distribution of the global total (land plus ocean) NPP (solid line), land total NPP (dotted line), and ocean total NPP (dashed line). How does NPP relate to the carbon cycle? What features of the Earth system are responsible for the peaks in NPP at A, B, and C?
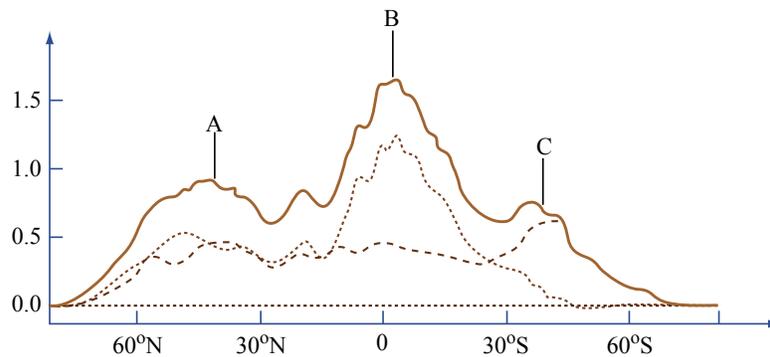

Image by MIT OpenCourseWare.

NPP describes the amount carbon (as CO_2) removed from the atmosphere by photosynthesis.

A – In the Northern Hemisphere, you have production in both the oceans (North Atlantic) and seasonal forests during the spring, summer, and fall.
B – Tropical rainforests are productive ecosystems throughout the year. Oceans also contribute, but the signal is controlled by terrestrial NPP.
C – Productivity in the Southern Ocean dominates at latitudes south of 30°S.

c. Critique the following statement using your knowledge of the carbon cycle and the figure below. *"I don't see any cause for alarm regarding the human contribution of CO_2 to the atmosphere. In ppm, it is only slightly larger than the annual cycle and the concentration of CO_2 has been much higher on Glacial-Interglacial timescales."*
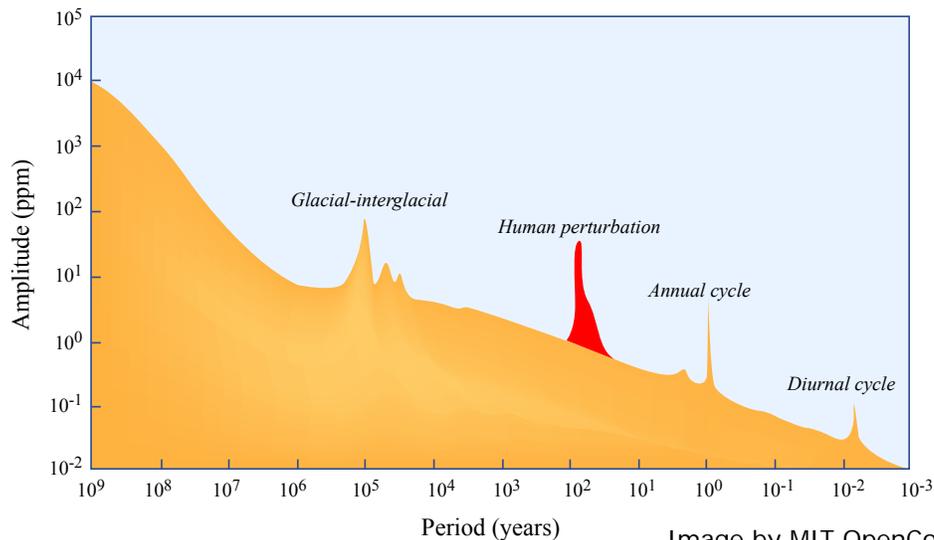

Image by MIT OpenCourseWare.

The amplitude is on a log scale, so "slightly larger" is significant in terms of actual carbon concentrations. Additionally, the annual cycle is the Earth "breathing", so having an effect on that scale is considerable. Dismissing the impact of humans using the argument of higher Glacial-Interglacial fluctuations of CO_2 is flawed for two primary reasons. First, humans would have a difficult time adapting to climate changes similar in magnitude to an Ice Age. Second, humans have had a comparable impact on the concentration of CO_2 in approximately 100 years that Glacial-Interglacial phenomena have had on timescales of 100,000 years.
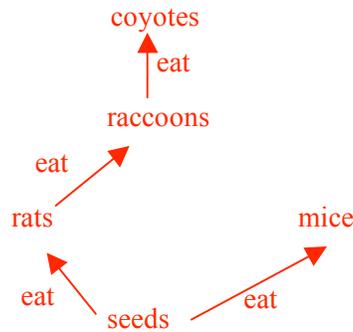
d. Iron ocean fertilization is one geoengineering scheme proposed for removing carbon dioxide from the atmosphere. Briefly describe how, according to this scheme, CO_2 is drawn from the air into the ocean, how CO_2 is partitioned/cycled after it enters the ocean, and how it is ultimately sequestered in the deep ocean.

In high-nutrient low-chlorophyll waters, iron can be used to create phytoplankton blooms, pulling CO_2 out of the atmosphere via the process of photosynthesis. Much of this is regenerated in surface waters and released back to the atmosphere. But some, roughly 1/3 (debated number), of that organic carbon sinks through the mixed layer and thermocline to eventually be sequestered in the deep ocean.

3. (20 points) You have managed to escape the confinements of the immediate Boston and Cambridge surroundings to the Greater Boston Area, a.k.a. Suburbia. You spend some time roaming the woods of Suburbia, observing how four species spend their day (% of time spent on the following activities).

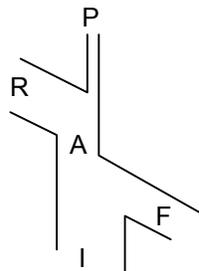|	Rest	Competition	Eating
Rat	30%	15% chasing mice	55% eating seeds
Mouse	30%	25% chasing rats	45% eating seeds
Raccoon	85%	--	15% eating rats
Coyote	80%	--	20% eating raccoons

a) Construct a food web showing the interactions between the species in this system (including seeds).

b) Based on your observational data, what is the trophic level of each species?
Rat: 2, Mouse: 2, Raccoons: 3, Coyotes: 4

c) Below is an energy flow diagram for Ricky the Raccoon. $P = 0.5$ kcal yr^{-1}, $R = 19.5$ kcal yr^{-1}, $I = 35$ kcal yr^{-1}, $F = 15$ kcal yr^{-1}. Calculate the assimilation efficiency.

A.E. = A_n/I_n = (0.5 + 19.5)/35 = 0.571*100 = 57.1%

d) If Ricky becomes a vegetarian will F change? Why?

Yes. You are more efficient at assimilating closer trophic levels, so F will increase.

e) Coyotes are becoming a nuisance for homeowners concerned about their cats. As a result, the homeowners start poisoning coyotes, leading to a significant decline in the coyote population. Make a prediction about what will happen to the population of each species, or state if you cannot predict. Explain your reasoning in one sentence.

Seeds: cannot predict. More mice but fewer rats. Without information about relatively how much both of these consumers eat, it is not possible to know the effect on seeds.

Rats: decrease. Their main predator has increased.

Mice: increase. The decrease in rats means less direct competition by chasing and less competition for seeds.

Raccoons: increase. Their main predator has been reduced.

4. (30 points) Over IAP, Jonathan and Skylar decide to go on a sea monster diving tour of the Caribbean. To their delight, they've come across a pygmy Kraken population. Skylar decides they should use a mark and recapture method to determine the population size. They catch, mark, and release 100 pygmy Krakens. Several weeks later, they catch 100 pygmy Krakens again. 10 of them are marked.

a) Using the data gathered from this method, approximately how many pygmy Krakens are in the population?

$100/N = 10/100$
$N = 100*(100/10) = 1000$ Krakens

b) What are some potential problems with the accuracy of the mark and recapture method?

Biased sampling, removal of marks and emigration, immigration, births, deaths between sampling.

c) Jonathan and Skylar obtain data to construct a life table. Fill in the columns necessary to complete the problems below.

x	n_x	b_x	l_x	L_x	T_x	e_x	$l_x b_x$	$x l_x b_x$
0	500	0	1	300	355	0.71	0	0
1	100	2.5	0.2	52.5	55	0.55	0.5	0.5
2	5	3	0.01	2.5	2.5	0.5	0.03	0.06
3	0	0	0	0	0	0	0	0

x = age or interval
n_x = number of individuals surviving to age x
b_x = per capita births during age interval x to x+1
l_x = proportion of individuals surviving to age x
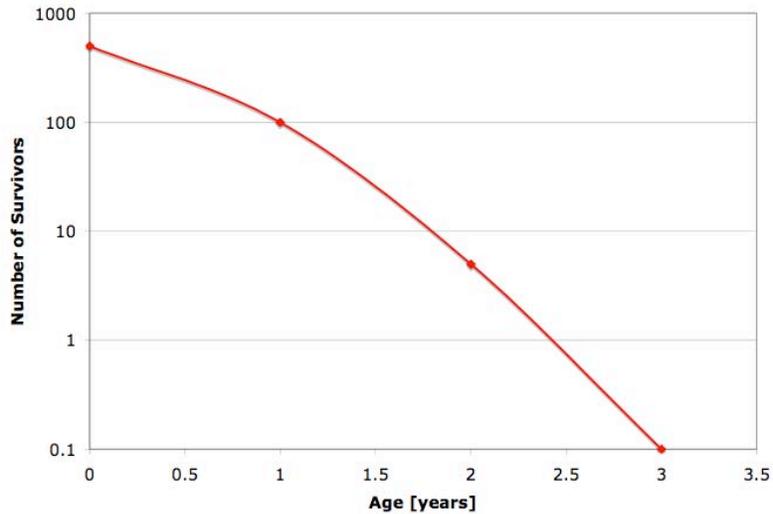L_x = average number of individuals alive during the age interval x to x+1
T_x = total years to be lived by individuals of age x
e_x = mean expectation of life for individuals of age x

d) Jonathan thinks that the life expectancy of a newborn Kraken is 3 years because all of the individuals in the cohort are dead after 3 years. Is he right? Why or why not?
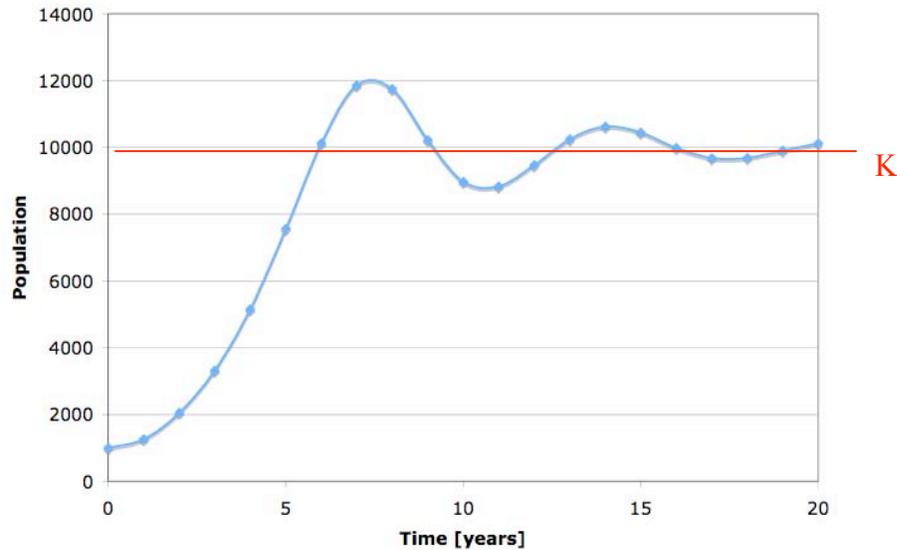
Life expectancy can be thought of more as a probability distribution; while some pygmy Krakens may live 3 years, most don't. The life expectancy for a newborn pygmy Kraken is 0.71 years.

e) Skylar wants to know what the survivorship curve would look like for this species. Please draw the survivorship curve and identify its type. Explain what this means about the species.

A Type II curve indicates that the rate of survivorship is fairly constant at all ages.

The graph below depicts the growth of a Kraken population.

f) Mark the location of the carrying capacity on the "Population" axis (rough estimate). Briefly explain why the population growth curve is shaped like this.

The population grew larger than its carrying capacity (K), which is set by environmental limitations (food, predation, nutrients, habitat space, etc.). The population more or less "crashed" and then eventually stabilized (oscillated) to equilibrium over the course of ~20 years.
r = 0.7; K = 10,000; Lag = 1 year

g) What is the net replacement (R_o)? Explain what this means about the growth of the population.

$R_o = \sum(l_x*b_x) = 0.53$

R_o less than one indicates that each female is replacing herself with less than 1 female, so the population is shrinking.

BONUS (2 points): What is the mean generation time (G) for this population?

$G = \sum(l_x*b_x*x)/R_o = 1.06$ years

BONUS (2 points): What is the "Keeling Curve" and why is it significant?

The Keeling Curve shows atmospheric carbon dioxide concentrations since 1958 measured at Mauna Loa Observatory. It was the first significant evidence of rapidly increasing carbon dioxide levels in the atmosphere.

BONUS (2 points): Explain the meaning of the following Redfield quote: "*It is as though the seas had been created and populated with animals and plants and all of the nitrate and phosphate which the water contains had been derived from the decomposition of this original population.*" In what ways have the biology and chemistry of the sea coevolved?

Sources of phosphorous are primarily derived from inorganic sources. One way that the biology and chemistry of the seas has coevolved is the existence of nitrogen fixers, which are able to pull N_2 from the air thus utilizing more of the phosphorous that is available.

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