1.018/7.30J Ecology 1   **Quiz #3**   **November 24th, 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 5 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. ‼
Mean = 75.9, Standard Deviation = 12.3

Useful Equations and Information	
$\dfrac{dS}{dt} = DS_i - DS - rNQ$!	$\dfrac{dN_1}{dt} = r_1 N_1 \left(\dfrac{K_1 - N_1 - \alpha N_2}{K_1} \right)$
$r = \dfrac{r_{max} S}{K_s + S}$!	$\dfrac{dN_2}{dt} = r_2 N_2 \left(\dfrac{K_2 - N_2 - \beta N_1}{K_2} \right)$!
$N = \dfrac{(S_i - S)}{Q}$	$\dfrac{dP}{dt} = \beta PV - qP$!
$D = \dfrac{f}{V}$!	$\dfrac{dV}{dt} = rV - \alpha PV$
$\Delta E'_o = E'_{o(Oxidizing\,Agent)} - E'_{o(Reducing\,Agent)}$	$\dfrac{dN}{dt} = rN \left(1 - \dfrac{N}{K} \right)$

$\Delta G'_o = -nF(\Delta E'_o)$
n = # e⁻ transferred per mol of reductant
F = Faraday constant (96.5 kJ V⁻¹ mol⁻¹)
R = gas constant (8.31 J K⁻¹ mol⁻¹)
Standard reactants: 1 M, 1 atm, 25°C (298 K)
	$SI = 1 - D$

1. True or False (7 points):

___F_The majority of Earth's freshwater is contained lakes and rivers

___T_Global renewable freshwater resources are likely to increase as a result of climate change

___T_Nitrogen cycles more rapidly in the global environment, on average, than phosphorous

___F_The nitrogen cycle has a weak biological component

___F_On an annual basis, the flux of carbon to the atmosphere generated by human activity is larger than the flux of carbon from the atmosphere to terrestrial vegetation.

___T_The oceans store the majority of the Earth's carbon

___F_The largest reservoir of phosphorus on Earth is the atmosphere

2. (15 points) Match each statement with the correct term or terms. Statements with more than one answer are noted. Some terms may be used more than once, some not at all.

1. Exergonic	2. Endergonic	3. Reducing Agent	4. Oxidizing Agent
5. Chemotroph	6. Phototroph	7. Chemolithotroph	8. Nitrogen
9. Water Vapor	10. Carbon Dioxide	11. Oxygen	12. Methane
13. 3.6B years ago	14. 2.5B years ago	15. 2B years ago	16. 1B years ago
17. Assimilation	18. Mineralization	19. Haber-Bosch Process	20. Denitrification
21. Nitrification	22. Nitrogen Fixation	23. Biological Fractionation	24. Redfield Ratio

__14_Great Oxygenation Event

__15_Emergence of macroscopic eukaryotes

__23_Differential use of isotopes of elements by enzymes

___1_A reaction that releases energy

___2_A reaction that absorbs energy

_5,7_An organism that gets its energy from reduction/oxidation reactions (2 answers)

___7_An organism that oxidizes inorganic compounds

9,10,12_Gasses present in significantly greater quantities in Earth's early atmosphere than in the current atmosphere (3 answers)

19,22_Conversion of nitrogen gas to ammonia (2 answers)

__21_Biological oxidation of ammonia to nitrite

__20_Nitrate reduction to N_2 gas

___3_NH_4^+ in: $NH_4^+ + NO_2^- \rightarrow N_2 + 2\ H_2O$

3. (10 points) Answer the following questions using one sentence:

Why do cyanobacteria bloom in lakes that are enriched with phosphorus?
When the phosphorous limitation is removed, nitrogen often becomes limiting and some cyanobacteria are able to fix nitrogen, thus giving them a competitive advantage in nitrogen-limited systems.

Can a lake have a Redfield Ratio of C:N:P of 106:16:1 and still be eutrophic? How?
Yes, adding large quantities of nitrogen and phosphorous to a lake will make it eutrophic, even if added at a ratio of 16:1.

Why is the O_2 minimum in oceans just below the thermocline?
As organic compounds settle out of the mixed layer (which is equilibrated with the O_2 in the atmosphere), they are oxidized and O_2 is consumed at a rate greater than it is produced (if there is light), and these waters are isolated from the atmosphere so there is a net loss.

Why is iron a limiting nutrient in some ocean ecosystems but not in lakes?
Iron is transported to ecosystems by wind-blown dust and cycled from sediment.

List three differences between the biogeochemistry of the clear-cut and control watersheds at Hubbard Brook Experimental Forest.
Increased surface runoff, nitrate output, leaching of cations.

BONUS (2 points): What seminal scientific contribution did researchers at Hubbard Brook make in the 1970s?
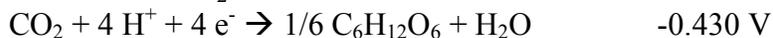Researchers at Hubbard Brook detailed the many negative effects of acid rain on NE forested ecosystems.

4. (8 points) Kate and Emily are devising an evil scheme to take over the world. They want to create a new type of super-organism that will outcompete all others. Additionally, they want their super-organism to produce hydrogen sulfide as a by-product because it is toxic.

Kate finds two half reactions with hydrogen sulfide as a product:
SO_4^{2-} + 10 H^+ + 8 e⁻ → H_2S + 4 H_2O -0.210 V
S + 2 H^+ + 2 e⁻ → H_2S -0.243 V
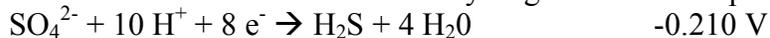
Emily wants to couple one of the above reactions with either:
2 H^+ + 2 e⁻ → H_2 -0.414 V
CO_2 + 4 H^+ + 4 e⁻ → 1/6 $C_6H_{12}O_6$ + H_2O -0.430 V

Pick which reaction is most energetically favorable (show work).

SO_4^{2-} & H_2: $\Delta G_o{}' = -8F * (-0.210 + 0.414) = -1.63F$

SO_4^{2-} & $C_6H_{12}O_6$: $\Delta G_o{}' = -8F * (-0.210 + 0.430) = -1.76F = -169.8$ kJ V^{-1} mol^{-1}

S & H_2: $\Delta G_o{}' = -2F * (-0.243 + 0.414) = -0.34F$

S & $C_6H_{12}O_6$: $\Delta G_o{}' = -4F * (-0.243 + 0.430) = -0.75F$

5. (15 points) You have developed a pilot scale algal production system designed to study how you might maximize the production of lipids by algae for use in biofuels. You have learned that if you grow the cells in a nitrogen-limited chemostat, they are likely to produce more lipids per cell, so you decide to set this system up. You have three different culture media available to you, with the following compositions:

	Concentration µg/L		
	A	B	C
Nitrogen	32	32	60
Phosphorus	2	4	3
Iron	0.05	0.04	0.005

NOTE: In the answers below, be sure to include units. Also show your reasoning. The actual answer is not as important as how you arrived at it.

a) Which medium would you use to set up your chemostat? Why?

Medium B, N:P ratio is around 8:1

b) You have an old broken down pump, and it can only pump media into the chemostat at one speed: 200 L per day. What volume of culture would you set up if you wanted your cells to grow at a specific growth rate, r, of 0.8 day $^{-1}$?

r = D in steady state, and D = f/V

V=f/D

$V = 200L$ day^{-1}/0.8 day^{-1} = 250 L

c) At this growth rate, and with the media you selected, you find that there are 10^5 cells per L in your culture. How much nitrogen is there in each cell?

$Q = (S_i – S)/N$ and S is negligible, so $Q = S_i/N$

$Q = (32$ µg/L$)/(10^5$ cells/L$) = 3.2$ x 10^{-4} µg/cell

d) Your boss is not satisfied with the yield from your chemostat. How would you increase it?

Increase all nutrients in S_i. The system must remain nitrogen-limited.

$N = S_i/Q$

e) Your boss still isn't satisfied. She buys you a pump that actually has variable speeds.
How would you determine the maximum pumping rate you could use to produce the most
amount of biomass per unit time?

Dial up the speed and bring the culture to steady state at each incremental speed until you
reach one that washes the cells out. The max steady state production of cells would be at
the dilution rate, D, that is right below r_{max}. Or determine r_{max} in batch culture and set the
dilution rate right below it.

6. (15 points) In the summer of 2010, Skylar decides to return to Chesapeake Bay to
participate in a study of salt marshes. In the first part of the study, Skylar is asked to
examine the profiles of two different marine inlets of the salt marshes (shown below). I_o
is the incident light intensity at the surface of the water.
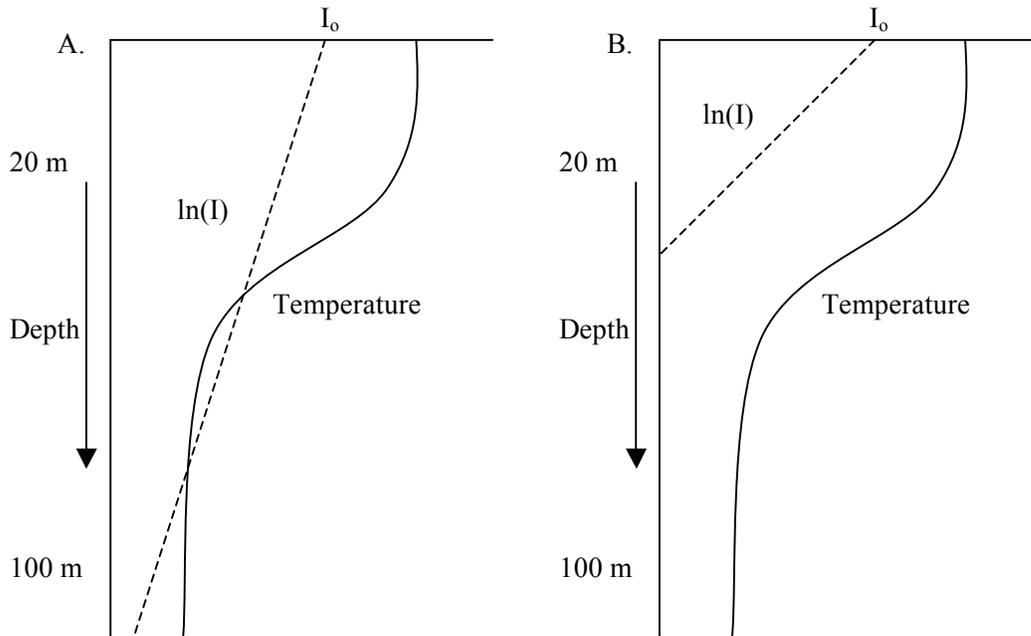

a) Which marine site would have the most net primary productivity and why?
A will have the most NPP. In A, since light penetrates below the mixing depth,
phytoplankton will be actively photosynthesizing throughout the whole mixed layer and
will have positive NPP. In B, phytoplankton will spend some of their time below the
compensation depth, so they will spend some of their time respiring only, hence their
overall NPP will be lower. In other words, the GPP/R ratio will be higher in A, meaning
NPP will be greater.

b) The next part of the study involves looking at the marsh itself. It is assumed in this
problem that the only source of primary productivity in marshes is a marsh grass called
Spartina. You determine that for a patch of marshland the Gross Primary Productivity
(GPP) is 400 g C m^{-2} day^{-1}, the NPP is 325 g C m^{-2} day^{-1}, and the NCP is 200 g C m^{-2}
day^{-1}. What is the respiration rate of autotrophs and heterotrophs in this system?
NPP = GPP – R_A
NCP = NPP – R_H

Skylar participates in a survey to determine the food web of the marshland. She draws the following food web that includes a turtle, a snail, Spartina, a blue crab, and a striped bass:
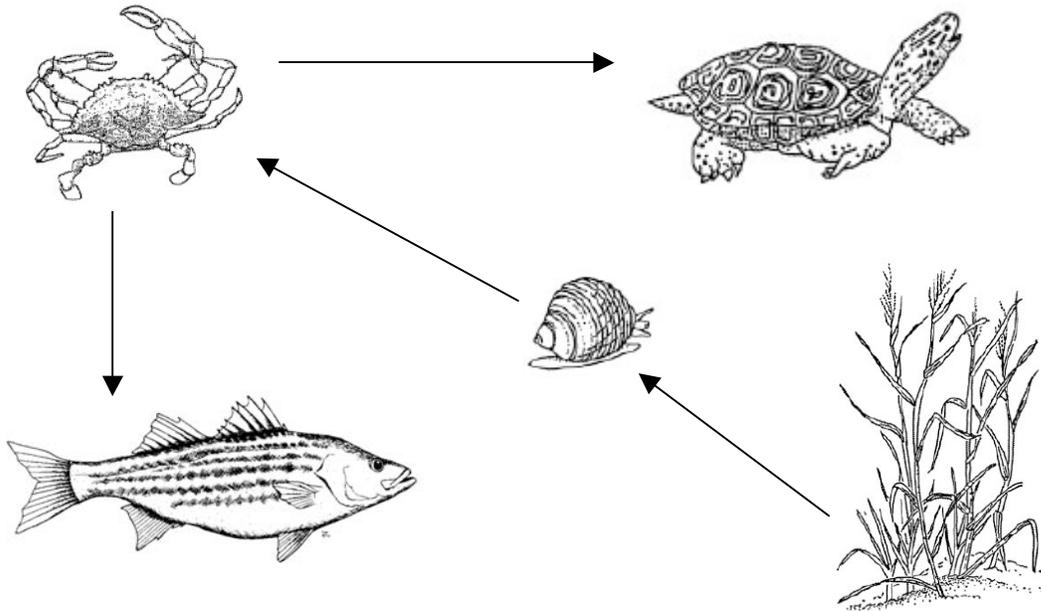
c) Assume the exploitation efficiency between all trophic levels is 10%. How many g C of Spartina is required to produce 1200 g C of striped bass?
P = 1200 g C/ (0.1)(0.1)(0.1)

d) Define what a keystone predator is in a sentence or two. Which of the above species is the keystone specie of this system? What would happen to the other species if it were removed?
A keystone predator is one that has a controlling effect on an ecosystem; its removal would have a larger effect than predicted by numbers alone.

Blue crab, the species is keeping the periwinkle in check. Since there are no other competing herbivores in this system, periwinkle would eat all the Spartina, habitat would be gone. Striped Bass population would disappear, same with turtles.

e) Skylar does some behavioral observations of striped bass in the system. She finds that their diet consists of 60% blue crab and 40% of a herbivorous crab. Calculate the striped bass' exact trophic level.
TL = 0.4*2 + 0.6*3

f) List two methods taught in class to determine the mean trophic level of fish.
Gut content analysis, stable isotope analysis

g) Juncus is a species of marsh grass that is found in the high marsh (farther from the ocean). It is not nearly as nitrogen and water limited as Spartina, but grows slower than Spartina. How does Spartina impact Juncus' fundamental niche? Why does Juncus

survive in the high marsh? What would happen to Juncus' area of cover if Spartina were removed from the system?

Spartina competes with Juncus for physical space. Because Spartina can grow fast, it takes up space quickly. However Juncus does not require as many nutrients and water to grow so its able to survive in the high marsh. If Juncus did not have to compete with Spartina it would be able to cover more of the marsh.

7. (10 points)

The size of the human population on Earth has increased dramatically in the past 200 years. This has been described as a period of "demographic transition". Some countries have already finished going through the transition, while others have not.

a) On the axes below, sketch the changes in birth rate (b_x), death rate (d_x), and relative population size (N) over the course of a demographic transition in a population. Indicate on the time axis of the graph where you might find a country like France, and where you might find a country like Liberia.
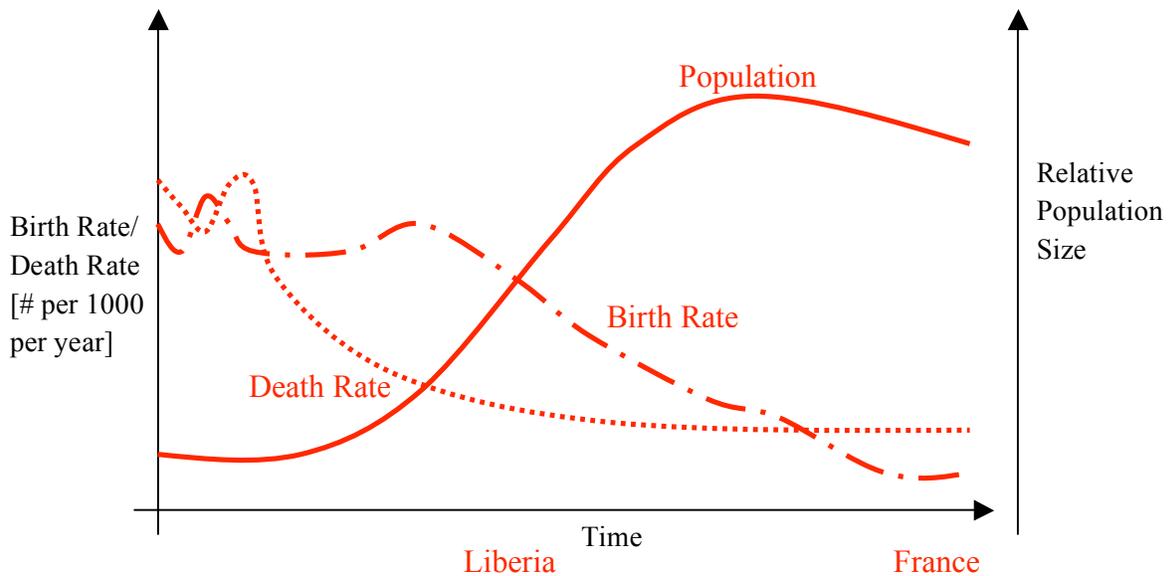

b) Explain the underlying causes of the features on your figure.

When the birth and death rates are high and similar, the population is fairly stable and relatively small. As agricultural, medicine, and technology (the ability to create/use energy) improve; the death rate is reduced while the birth rate stays constant. This results in a population explosion. Decreases in death rates continue and eventually level off. Birth rates also decrease, reflecting socioeconomic changes. Eventually the death rate surpasses the birth rate and population begins to contract.

8. (15 points) Skylar and Jonathan have had enough of the precipitation in New England and decide to go to the Kalahari Desert. They stumble across two kinds of scorpions: red and black. Skylar and Jonathan decide to study the competition between the two species. They determine that the carrying capacity (K_1) of red scorpions is 100 and that the

carrying capacity (K_2) of black scorpions is 150. Jonathan calculates that the impact of the black scorpion on the red scorpion (α) is 2 and the impact of the red scorpion on the black scorpion (β) is 3.

a) The initial population sizes are 25 red scorpions and 50 black scorpions. Graph the isoclines for each species and plot the initial population sizes. Predict the short-term dynamics of each population. Predict the final outcome of interspecific competition.
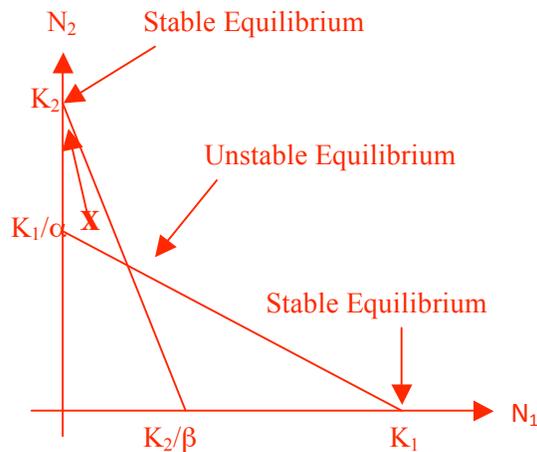
The isoclines define an unstable equilibrium. From the initial densities, the black scorpions will increase and the red scorpions will decrease in the short run. Eventually, the red scorpions will be driven to extinction; the black scorpions will be out at their carrying capacity (150).

b) Skylar does her own calculations and determines that Jonathan's calculation of the carrying capacity (K_1) of red scorpions is wrong, but that the rest of his calculations are correct. What are the relationships between carrying capacities needed for red scorpions to win in competition? Write your answer in terms of K_1, K_2, α, and β.
$K_2 < K_1 \beta$ AND $K_2 \alpha < K_1$

c) What are the relationships between carrying capacities needed for red scorpions to coexist with black scorpions? Write your answer in terms of K_1, K_2, α, and β.
$K_2 \alpha < K_1$ AND $K_2 > K_1 \beta$

d) Define the Intermediate Disturbance Hypothesis.
The intermediate disturbance hypothesis states that at moderate levels of disturbance the biodiversity is highest, because one species is not able to totally dominate (as would in low disturbance) nor do all go extinct (as in high disturbance).

e) Below is the figure from Connell (1978) demonstrating the intermediate disturbance hypothesis:
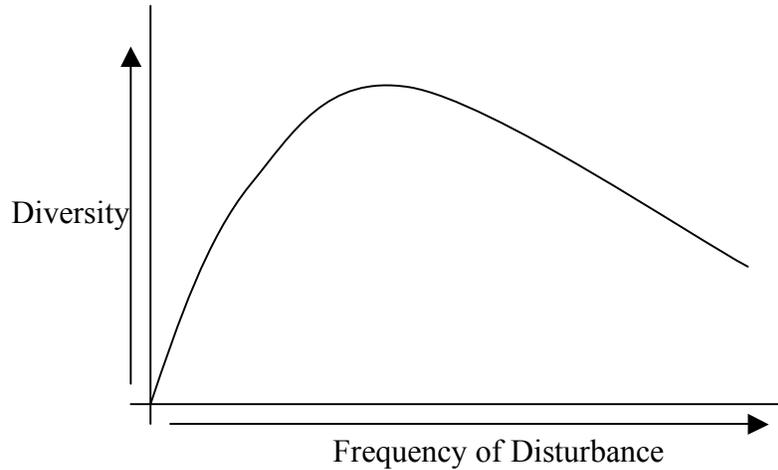
Jonathan and Skylar determine that according to their isoclines, red scorpions win out in competition. Explain to your TAs how this hypothesis might explain why we see the red and black scorpions coexisting in the Kalahari Desert.

Here, moderate disturbance may allow black scorpions to survive because it perhaps reduces' the red scorpion's population often enough.

9. (5 Points) Name and describe one additional component included in the "Sterman Model" that is lacking in the Malthusian human population growth model.

Variable carrying capacity. In the Malthusian Model the carrying capacity is fixed, while in Sterman's model technology, use of resources, and waste generated all affect the carrying capacity.

BONUS (3 points): List the three necessary (but not sufficient) principles of sustainability outlined by Prof. Sterman.

Can't use renewable resources faster than they are regenerated; can't produce wastes faster than they are rendered harmless; can't use nonrenewables over the long haul at all.

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