Name: __Answer Key_____

1.018/7.30J October 28, 2003
Fundamentals of Ecology

Quiz 2: Secondary Productivity and Biogeochemical Cycles

1. While hiking in a remote mountain kingdom you stumble upon a beautiful glacial lake at the base of awe-inspiring Mount Oikos-logia. Thirsty, you stop for a drink at the shore – a fatal mistake. You are instantly apprehended by the local tribesmen of Academe for violating the sanctity of the lake. They bring you to the outlet of the lake, a waterfall dropping over 200 meters, where Chief Professus offers you a choice: jump or answer the riddles of the lake. If you cannot answer they will toss you off to appease Oikos-logia.

Here is the riddle: The lake is 10m deep, well-mixed and perfectly circular with a radius of 100m. At the inlet 2 cubic meters of water enters every second, containing 4mg NO_3^- L^{-1} in snowmelt from the lightning-prone slopes of Oikos-logia. Every day the tribesmen of Academe remove 20kg of nitrogen from the lake in sustainable fish catches, and according to air measurements made by a wandering MIT graduate student the lake emits 500 moles of N_2O and 1000 moles of N_2 every day. There are no other sources or sinks of N. Chief Professus demands that you tell her 4 things.

(a) What creature/s in the lake could be responsible for the gases and where they might live? (3 pts)

denitrifying bacteria, probably *pseudomonas*, living in anoxic conditions either in mud/sediments or in an oxygen-depleted hypolimnion

(b) What is the steady state mass of N in the lake? (7 pts)

ΣInputs - ΣOutputs + ΣSources - ΣSinks = 0 (you could define outputs and sinks a couple ways and still get the same answer – I'm assuming output to be the outflow)

Fill in the mass balance equation:

$\Sigma Inputs = (4mg_{NO3-}/L)*(1000L/m^3)*(2m^3/s)*(86400s/day)*(10^{-6}kg/mg) =$

$\Sigma Inputs = \boxed{691.2\ kg_{NO3-}/day}$ or 156kg N/day
Outputs = unknown
ΣSources = 0

$\Sigma Sinks = (20kg\ N/day) +$
$(500\ mol\ N_2O/day = 1000\ mol\ N/day)*(14g/mol)*(10^{-3}kg/g) +$
$(1000\ mol\ N_2/day = 2000\ mol\ N/day)*(14g/mol))*(10^{-3}kg/g) =$

$20 + 14 + 28 = \boxed{62\ kg/day}$

Mass balance: $0 = 156kg\ N - x + 0 - 62\ kg/day$
$X = 94kg\ N/day$

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ASSUME That steady state Qin = Qout = $2 m^3/s$ *(86400s/day) = 172800 m^3/day

So 94kg N day^{-1}/ 172800 m^3 day^{-1} = 5.43×10^{-4} kg $_N/m^3$

Since lake is well mixed the C outflow = C in the lake

Volume of the lake: 10m * π * $100m^2$ = V = 314159 m^3
Mass of N in lake = 5.43×10^{-4} kg $_N/m^3$ * 314159 m^3 = **170.6 kg N**

(c) What is the concentration of NO_3^- in the water hurling off the edge of the cliff beneath your feet (where you might soon end up)? (5 pts)

From above we know the concentration in the outflow of the lake is 5.43×10^{-4} kg N/m^3 so:
5.43×10^{-4} kg $_N/m^3$ *(62kg NO_3^-/14kg N)*(1000L/m^3)*(10^6mg/kg) = **2.4mg $_{NO3}$-/L**

Note: This calculation assumes that the N in the lake is mainly present as NO_3^-. While the majority may be present as NO_3^-, this calculation is complicated by the fact that N might also be present as organic N or other forms of N.

(d) What is the mean residence time for water and for N in the lake? Why don't they have the same MRT? (5 pts)

water: MRT = mass/flux = (314159 m^3)/($2m^3$/s) = 1.6×10^5 sec = 1.8 days

N: MRT = mass/flux = (170.6 kg N))/(156kg N/day) = 1.1 days

While N and water enter the system at the same rate, N can leave the system via the waterfall, N_2O, N_2 or as N in fish, while the water only leaves via the waterfall, hence we expect a shorter residence time for N.

2. The Chief is impressed with your solutions to her riddles, so rather than sending you to your death, she promotes you to CEO (Chief Ecological Officer). Apparently, the kingdom is having a few other ecological issues with its forests.

(a) The kingdom is quite large, and contains coniferous forests, deciduous temperate forests and tropical rainforests. Compare the MRT of nitrogen in each of the three kinds of forests, putting them in order of increasing MRT, and explain your reasoning. (5 pts)

rainforest < deciduous temperate < coniferous

Tropical rainforests have very rapid turnover of organic matter, due to year-round warm temperatures.
Deciduous trees lose their leaves annually, promoting more rapid turnover of the leaf biomass.
Coniferous trees hold on to their needles much longer, leading to slower cycling. Also, deciduous leaves are more readily degraded than coniferous needles.

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(b) One of the deciduous forests in the kingdom has recently been clear-cut by bandits from the nearby Timberwolf kingdom. The wandering nitrogen-measuring graduate student has observed that the soil in this clear-cut forest is losing nitrogen in groundwater runoff. Explain why. (4 pts)

The nitrogen in the soil solution is readily taken up by trees, so when the trees are cut down, the mobile N in the soil, rather than being absorbed by trees, can be lost from the ecosystem.

Other factors may influence the availability of N, such as microbial activity, but overall, the lack of trees to take up the N is the biggest reason for N loss.

(c) Nitrate (NO_3^-) and ammonium (NH_4^+) are the two major forms of inorganic nitrogen in the soil. Following clearcutting, one of these two ions is lost much more readily than the other. Which one and why? (4 pts)

NO_3^- is likely to be lost much more readily. Soils tend to have a net negative charge (from the clays and organic matter), expressed as CEC (cation exchange capacity). Thus, while positively-charged NH_4^+ will tend to stick to soils, NO_3^- will not be retained and will likely be lost in groundwater.

(d) The kingdom has recently been fined for releasing N_2O into the atmosphere. The Chief demands to know why anyone would be concerned about N_2O emissions (she thought N_2O was supposed to make everyone laugh). (4 pts)

N_2O is a potent greenhouse gas, with 200 times the heat-trapping capacity of CO_2

(e) What does Oikos-logia mean? (bonus +2)

Oikos = "House" or "Household"
Logia = "study"
The greek root of ecology…

3. Having completed your mission as CEO for Chief Professus, you decide it's time to move on. Along your travels, you encounter a tribe of people living along the coast, very close to sea level. They are, for obvious reasons, concerned about the causes and effects of climate change. Since your reputation as an ecological expert precedes you, the tribe asks you to explain some information they've heard, and to evaluate some approaches the tribespeople have thought of to reduce atmospheric carbon dioxide.

(a) What are the two major fluxes of CO_2 into the atmosphere? What are the three major sinks for these emissions? (6 pts)

Fluxes: fossil fuel emissions, destruction of vegetation
Sinks: ocean, biomass (the "missing" carbon), and the atmosphere (remember a reservoir can be a sink)

(b) CO_2 emissions from the Northern Hemisphere are 6.1 Pg C/yr, and 0.8 Pg C/yr from the Southern Hemisphere. However, the total amount of CO_2 in the atmosphere over the Northern Hemisphere is not much greater than the amount in the atmopsphere over the Southern Hemisphere (376 vs 374 Pg C). Why is there such a big difference in emissions between the two hemispheres? Why is this difference not reflected in the atmospheric concentrations? (4 pts)

Greater emissions in the N. Hemisphere due to greater land mass → more people → more fossil fuel burning.

Atmospheric concentration is close because of interhemispheric mixing and because of greater primary productivity in the N. Hemisphere

(c) In two sentences, evaluate whether the following suggestions will likely decrease atmospheric CO_2 (and if so, on what time scale) and name one negative side effect. (3 pts each)

(we were flexible about the answers for this one; below are just suggested answers)

(i) Increasing the prevalence of heterotrophic methanogenic bacteria. (These organisms convert CO_2 to CH_4 as part of their anaerobic respiration).

Potentially could absorb some CO_2, although by carrying out respiration they may produce more CO_2 than they can absorb.

Even if CO_2 goes down, the production of CH_4 is undesirable because it is a more potent greenhouse gas than CO_2 (25 times stronger).

(ii) Introducing herbivoricides into the open ocean to decrease the populations of zooplankton and in turn decrease predation of phytoplankton.

If more phytoplankton sink to the deep ocean before getting consumed than in the presence of zooplankton, perhaps this could temporarily reduce CO_2 (residence time of deep ocean approximately 350 yrs).

However, this would cause major disruption to entire marine food web and lead to starvation of all higher trophic levels.

(iii) Cutting down trees from tropical rainforests and making wooden houses, furniture and books for poor people around the world. The new trees that replace the harvested trees will drawdown atmospheric CO_2.

This method might lead to some additional sequestration of CO_2. Carbon stored in books, houses or furniture could have residence times on the order of decades to a century or two.

However, cutting down trees could lead to erosion in the forests and loss of nutrients, preventing their regrowth, and leading to lost habitat for forest dwellers.

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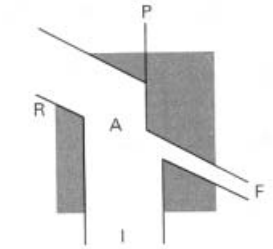
4. After your time with the lowland tribes, let's say you've been selected as a contestant for a new reality show, *Survivor: The Ecological Adventure*. To survive, you will need to demonstrate your knowledge of ecology and food webs.

The following is an example of a detritus food chain:

DUNG ⟶ BEETLE ⟶ LIZARD ⟶ WILD DOG

(a) The three consumers have different assimilation and production efficiencies. Fill in the identity of the following organisms and explain your reasoning. (6 pts)

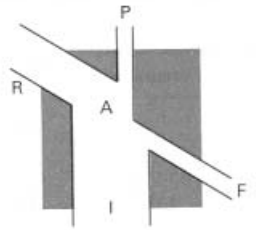
I = amount of energy ingested
A = amount of energy assimilated
P = production of this trophic level
F = amount of energy lost as fecal matter
R = amount of energy respired

(i) 

A/I = 80%
P/A = 2%

organism: ____DOG_____

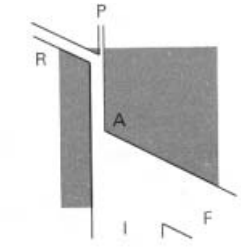
Warm-blooded animals lose much of their assimilated energy to respiration because of their need to maintain constant body temperature. Hence the dog should have the lowest P/A ratio

(ii) 

A/I = 80%
P/A = 30%

organism: _____LIZARD____

The relatively high assimilation efficiency and production efficiency suggest a cold-blooded carnivore. Carnivores have much higher assimilation efficiencies than do detritivores and herbivores.

(iii) 

A/I = 20%
P/A = 40%

organism: _____BEETLE___

The relatively low assimilation efficiency and high production efficiency suggest a cold-blooded non-carnivore. High assimilation efficiencies come from being similar to food.

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(b) Assuming consumption (ingestion) efficiencies of 100%, what is the ecological (or trophic transfer) efficiency of the beetle, lizard and wild dog? (6 pts)

Beetle: Ecological efficiency = $(P/A)*(A/I)*(I/P_{n-1})$. Here $I/P_{n-1}=1$

EE = 0.2 * 0.4 = 0.08

Lizard: EE = 0.8 * 0.3 = 0.24

Wild dog: EE = 0.8 * 0.02 = 0.016

(c) On the most recent episode, you're given the choice between eating beetles or lizards (maybe this sounds more like an episode of Fear Factor), and you have 2 hours to collect your food. In 2 hours, with the same amount of effort, you can collect 1kg of beetles or 0.5 kg of lizards. Taste preferences aside, what information would you need to know in order to decide which meal will give you more energy? Which do you predict would be the better meal? (4 pts)

Need to know your assimilation efficiency for lizards and beetles. If you assimilate more than 2x as much energy from the lizards, then eat lizards. If you assimilate less than twice as much energy from the lizards, eat the beetles.

With so much chitin, which is not digestible by humans, beetles are likely to have far less energy available for assimilation by humans than the lizards have..

(d) Suppose that the wild dogs can't always find enough lizards to feed themselves, so they sometimes resort to eating beetles when they are hungry. If, on average, the dogs get 20% of their energy from beetles, estimate their trophic level. (You can assume dung is Trophic Level 1, although strictly speaking this isn't always true). (4 pts)

80% of the time they are Trophic Level 4
20% of the time they are Trophic Level 3

On average, TL = 0.8*4 + 0.2*3 = 3.8. (Any estimate between 3 and 4 accepted)

(e) Typically, ecological efficiency is higher in aquatic ecosystems than in terrestrial ecosystems. Provide one reason why this might be the case. (4 pts)

More warm-blooded animals in terrestrial systems.
More indigestible biomass (tree trunks, feathers, fur) compared to aquatic organisms
Other answers possible

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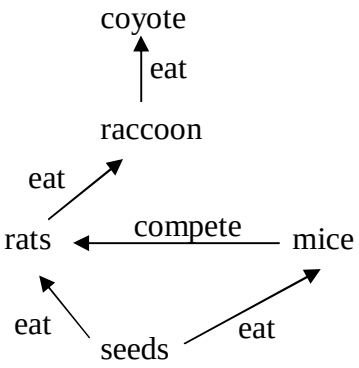
5. Tired from your days on Survivor (you get voted off because everyone else decided you were too smart), you head for a new kingdom, Suburbia. You spend some time roaming the woods of Suburbia, observing how four species spend their time during the day.

Daytime time budget (% of time spent on following activities):

	Rest	**Competition with other species**	**Eating**	**On the prowl for a mate**
Rat	20%	15% chasing mice	55% eating seeds	10%
Mouse	20%	25% getting chased by rats	45% eating seeds	10%
Raccoon	75%	--	15% eating rats	10%
Coyote	75%	--	20% eating raccoons	5%

(a) Construct a diagram showing the interactions between the species in this system (including grass). Label each interaction. (6 pts)



(b) Based on your observational data, what is the trophic level of each species? (4 pts)

rat: 2

mouse: 2

raccoon: 3

coyote: 4

(c) Now, with your handy mass spectrometer that you carry with you in your backpack, you collect some $\delta^{15}N$ data from the biomass of each of the species.

Species	$\delta^{15}N$ (‰)
Seeds	9 ± 0.1
Rat	12.4 ± 0.1
Mouse	12.3 ± 0.1
Raccoon	13.8 ± 0.1
Coyote	17.2 ± 0.1

Does this data change your answer to part (b) at all? If so, in what way? How would your explain this change? If the data don't change your answer, explain how the data supports your answer. (4 pts)

Between trophic levels, $\delta^{15}N$ generally increases by a constant amount. Between seeds and rats, seeds and mice, and raccoons and coyotes, there is a constant increase of 3.4‰, consistent with there being one trophic level difference between these pairs of organisms. Overall, the data support the answer in part (b).

Between the rat and raccoon, the difference is only 1.5‰, suggesting that raccoons are actually not a full trophic level above the rats. This result suggests the raccoon also eats seeds (or some other primary producer), either at night or when you're not looking during the day.

(d) Now, assume that 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 populations of each species, or state if you cannot predict. In one sentence, explain your reasoning. (6 pts)

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.

rat: decrease. their main predator has increased.

mouse: increase. the decrease in rats means less direct competition by chasing, and less competition for seeds

raccoon: increase. their main predator has been reduced.