1.018/7.30J Fall 2003
Fundamentals of Ecology

Problem Set 2: Secondary Productivity and Biogeochemical Cycles
due October 21, 2003

Please staple your problem sets together.
Put your answers in numerical order.
Be as clear and concise as possible.

1. World production of nitrogen fertilizer is approximately 90 million metric tons/year (measured as metric tons of nitrogen in fixed from). By comparison, natural nitrogen fixation (by N-fixing soil microorganisms) in non-agricultural terrestrial ecosystems is approximately150 million metric tons N/year.

(a). If agriculture accounts for 15% of global terrestrial NPP, and if the chemical composition of plant organic matter follows the Redfield Ratio, how much nitrogen do crop plants require each year? At most, what percentage of this nitrogen requirement can by met by supplying manufactured fertilizers? You can assume that all fertilizer produced within a given year is used within that year.

(b). Name two major sources of N that make up the discrepancy between the amount of N that the crops require and the amount of N supplied by manufactured fertilizers.

(c). In reality, a significant portion of the fertilizer that is applied to agricultural areas does not end up fertilizing crop plants, but actually runs off into surface water (a major cause of eutrophication) or blows into nearby terrestrial ecosystems. Assume that one-third of the fertilizer added to agricultural areas ends up fertilizing non-agricultural terrestrial ecosystems. If all of this additional nitrogen is converted into additional biomass, how much carbon will be sequestered this way? What percentage of global terrestrial NPP does this represent? What does your result suggest about our ability to increase C uptake by terrestrial ecosystems by fertilizing forests and grasslands?

2. There is much interest in reducing SO_2 emissions into the atmosphere because SO_2, along with NO_2, is a key contributor to acid precipitation. In addition, elevated concentrations of SO_2 can cause damage to plants and acts as a respiratory irritant in humans. A major source of SO_2 emissions into the atmosphere is coal burning.

Total amount of coal burned in the world annually: 3.1×10^{12} kg
Average sulfur content of coal (by weight): 2.5%

(a). Assuming that all of the sulfur in coal is converted into SO_2, how much SO_2 is released into the atmosphere annually from coal burning? (In reality, not all of this SO_2 will be released into the atmosphere because many coal-burning plants use scrubbers and other control technologies to limit their SO_2 emissions.)

(b). Estimate the volume of the troposphere. Over one year, if all of the SO_2 released from coal burning stays in the troposphere, what would be the expected concentration of SO_2 in the troposphere (in units of moles SO_2 m^{-3})?

(c). How does this compare to measured average global concentrations of 1.3×10^{-8} mol m^{-3} (0.3 ppb by volume)? Explain the discrepancy.

(d). The eruption of Mt. Pinatubo in the Philippines in 1991 was estimated to release approximately 7 x 10^{12} g S. How many such volcanic eruptions are equivalent to annual sulfur emissions from coal burning?

3. A stable pollutant is dumped into a lake at the rate of 0.16 g day^{-1}. The lake volume is 4×10^7 m^3, and the average water flow through rate is 8×10^4 m^3 day^{-1}. Assume that the pollutant is uniformly mixed in the lake, and is not taken up by any organisms.

(a). What steady state concentration will the pollutant reach in the lake?

(b). After steady state is reached, what is the pollutant's residence time in the lake?

(c). Suppose that a team of biologists discovers an endangered species of fish living in the lake that is very sensitive to the pollutant. The biologists succeed in getting all of the pollution diverted from the lake. The pollutant concentration needs to be brought down to 1/10 the steady state concentration in order to be considered "safe." After the pollutant input is stopped, how long will it take for the concentration of the pollutant to reach the "safe" level?

4. You are the manager of a fishing fleet that has exclusive rights to fish in the Mediterranean Sea. Your fleet has been harvesting 20×10^5 tons km^{-2} yr^{-1} of fish. Your inventory of fish caught and their characteristics yields the following data: (catch data are given in metric tons wet weight fish)

Species	**Catch (tons km^{-2} $yr^{-1} \times 10^6$)**	**Trophic level**	**Assimilation efficiency A_n/I_n**	**Production efficiency P_n/A_n**	**Consumption efficiency I_n/P_{n-1}**	**Ecological efficiency P_n/P_{n-1}**
tuna	3	4	0.80	0.30	0.50	(i)
anchovies	10	3	0.70	0.30	0.60	(ii)
zooplankton	7	2	0.30	0.50	0.70	(iii)
phytoplankton	--	1	--	--	--	--

Ecological Efficiency (aka Trophic Level Transfer Efficiency or Trophic Efficiency):

$= P_n / P_{n-1} = (A_n / I_n) * (P_n / A_n) * (I_n / P_{n-1})$ = exploitation x assimilation x production efficiency

a. What is the Ecological Efficiency between trophic levels
(i) 3 and 4; (ii) 2 and 3; and (iii) 1 and 2

b. Why is the assimilation efficiency higher for anchovies and tuna than for zooplankton?

c. What is the Total Net Primary Productivity Required (PPR) to produce the fish you harvest annually? Assume that 9g of fish wet weight is equivalent to 1 g C. Explain your reasoning and show your work. (You may want to re-read the Pauly and Christensen (1995) article).

d. The picture to the right shows the relative sizes of the productivity and biomass of each of four trophic levels (adapted from Lecture 7, the Cod Lecture). How can the size of the biomass in Trophic Level 2 be larger than that of Trophic Level 1?