NAME: ________________________ **Section: _______** **RHS AP Environmental Science**

Ecology Packet #5: Ecological Calculations

Pamela J. Shlachtman
Miami Palmetto High School
Miami, Florida

One of the four free-response questions on the AP Environmental Science Exam is a data set question. Students are required to perform mathematical calculations in order to obtain answers to some parts of these questions. Often, students skip this portion of the question, do not show their work, or have difficulty using scientific notation. Additionally, students have demonstrated that they are not familiar with the metric system and/or common metric prefixes. These sets of ecological calculations focus on these areas. Sets one, two, and three are meant to be done without using a calculator.

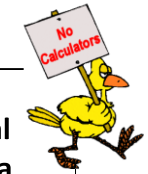
Activity 1: Ecological Footprint

In our quest to attain a sustainable planet, a question that is often asked is, "How many people can the planet support?" It can be argued that the earth has already reached its carrying capacity. Evidence to support that conclusion would include increasing degradation of the planet's air and water quality along with a decrease in arable land. Population size, affluence, and technology are contributing factors to the human population's impact on the planet (Miller 2008). However, environmental impacts are not created equally; the developing countries represent about 82 percent of the world's population, yet they consume only about 25 percent of the world's resources. The United States, at about 4.6 percent of the world's population, consumes about 25 percent of the world's resources.

The idea of a human ecological footprint was first proposed by Wackernagel and Rees in 1996. The definition they proposed for an ecological footprint is "the amount of productive land and water surface to support all the needs of a person." In the United States the average size of an American's footprint is 9.7 hectares, while in India the average value is 0.8 hectares. Although this assignment utilizes averages values for ecological footprints, students can visit many different Web sites to calculate their ecological footprint. This exercise will help students understand the magnitude of the U.S. footprint, and it will allow them to predict the impact on the planet if the majority of the world had a similar footprint.

Use this information to assist you for Activity 1:

Hectare = 10,000 m^2
1 km^2 = 1,000,000 m^2
Earth's Land area = 150,000,000 km^2
Earth's Water Area = 361,100,000 km^2
Earth's Total Area = 511,100,000 km^2



Activity 1: Ecological Footprint Activity — Student Sheet

Country	Population (thousands)	Ecological Footprint (hectares/person)	Ecological Footprint (km^2/person)	Total Area of Ecological Footprint per Country (km^2)	% of the Earth's Land Area	% of the Earth's Land Area	% of the Earth's Total Surface Area
United States	301,140	9.7					
Canada	33,390	8.8					
China	1,322,000	1.6					
Japan	127,433	4.8					
Indonesia	234,694	1.1					
India	1,130,000	0.8					
Pakistan	164,742	0.6					

* Population data was obtained from www.census.gov

1. Complete the table by converting hectares per person into km^2 per person. ***DO NOT USE A CALCULATOR FOR THE FIRST PROBLEM IN THIS ACTIVITY – YOU MUST SHOW WORK TO RECEIVE CREDIT!*** EXAMPLE: Show your work here for the United States. Show how you set up the problem with words and numbers and calculate without a calculator. You do not have to do this for EACH country, and you may use a calculator for every country thereafter!

United States Ecological Footprint (km^2/person) =

2. Calculate the total area (ecological footprint) required by each country (again, show proper equation and solve without calculator for U.S., use same formula and calculator for all other countries):

Total area of ecological footprint per country (UNITED STATES) =

3. Calculate the percentage of the planet needed to sustain each country's population. Show work for U.S. (no calculators for U.S.!)

United States - % of the Earth's Land Area =

United States - % of the Earth's Ocean Area =

United States - % of the Earth's Total Area =

4. If everyone in China and India had the same ecological footprint (km^2/person) as the United States, would the earth be able to sustain its population? How much of the planet would it take to support those countries?

INDIA: CHINA:

Show all work:

Write a sentence or two to describe how you solved this problem (#4):

5. The current population (mid-2007) of the world is about 6.7 billion people. At its current rate of growth, the population should reach 13.4 billion people in about 60 years. If everyone on the planet has an ecological footprint equivalent to that of the United States**, how many earths will be required to support the population at that rate of consumption**?

Write a sentence or two to describe how you solved this problem (#5):

ACTIVITY 2: Net Primary Productivity in Ecosystems

Net Primary Productivity in Ecosystems
Gross primary productivity (GPP) can be described as the rate at which plants convert solar energy into chemical energy (organic compounds). Net primary productivity is the organic compounds left over for consumers. NPP = GPP – R.   R represents the energy that is used in carrying out respiration. Various ecosystems have different NPP. In this exercise, students will compare the NPP of different ecosystems and rank those ecosystems based on their average global NPP.

STUDENT ACTIVITY:

1) Complete the table on the next page by calculating the global NPP for each of the ecosystems listed. ***Calculators may not be used for this assignment. Please show all your work, including units. Display all answers using scientific notation.***

2) After you complete the table, rank the ecosystems from MOST productive to least productive based on global GPP. Then rank them AGAIN from least productive to most productive based on global NPP. Are these rankings identical? If not, please explain why, below:

Rankings:

Explanation:

TABLE 1: NET PRIMARY PRODUCTION OF SELECTED ECOSYSTEMS

Ecosystem	Area (million km²)	Mean NPP per unit area (g/m²/yr)	Global NPP (billion metric tons/yr)	Global NPP (metric tons/yr)
Algal beds and reefs	0.6	2,500		
Boreal forest	12.0	800		
Continental shelf	26.6	360		
Cultivated land	14.0	650		
Desert shrub	18.0	90		
Estuaries	1.4	1,500		
Extreme desert, rock, sand, and ice	24.0	3		
Lake and stream	2.0	250		
Open ocean	332.0	125		
Savannah	15.0	900		
Swamp and marsh	2.0	2,000		
Temperate deciduous forest	7.0	1,200		
Temperate evergreen forest	5.0	1,300		
Temperate grassland	9.0	600		
Tropical rainforest	17.0	2,200		
Tundra and alpine meadow	8.0	140		

Activity 3: Energy Flow through Ecosystems/Pyramids of Energy/ Biomagnification

Methods of investigating energy flow through an ecosystem include examining a pyramid of numbers, of energy, or of biomass. Due to respiration and the second law of thermodynamics, 100 percent of the energy is never passed from one trophic level to the next. The amount of usable energy passed, as biomass, from one level to the next is dependent on the efficiency of the organisms. The idea of trophic levels and energy flow through those levels was first proposed by Lindemann in 1942. The average ecological efficiency between trophic levels is about 10 percent, but it can vary from 2 percent to 40 percent, while plants have a photosynthetic efficiency of 1 to 3 percent.
In this activity, students will calculate the amount of energy passed from one trophic level to the next based on the ecological efficiencies of the organisms. Additionally, students will examine the concept of biomagnification.

ACTIVITY:

The information in the following table represents the energy flow in a hypothetical spring in Florida. Unfortunately, the spring experienced a DDT spill. The concentration of DDT found in the organisms at each trophic level is also given in the table below. Use the information in the table to answer the questions (1-3) below.

TABLE 1: ENERGY FLOW AND DDT CONCENTRATIONS FOR THE OKEECHOBEE SPRING IN OKEECHOBEE, FLORIDA

Trophic level	**Productivity (kcal/m²/yr)**	**DDT Present (ppm)([1])**
Producers	9,000	0.04
Primary Consumers (herbivores)	1,500	0.23
Secondary Consumers (carnivores)	120	2.07
Tertiary Consumers (top carnivores)	12	13.8

1.Calculate the efficiency of energy transfer from:
   a) Producers to primary consumers
   b) Primary consumers to secondary consumers
   c) Secondary consumers to tertiary consumers
2. What percent of the energy from the producers is transferred to the tertiary consumers?
3. The concentration of DDT in the water was 1.0 X 10-8 mg/L. a) How many times more concentrated is the DDT in the producers as compared to the water? b) Calculate the ratios of DDT between trophic levels, as it accumulates
from producers to primary consumers, primary consumers to secondary consumers, and secondary consumers to tertiary consumers

TABLE 1: ENERGY FLOW AND DDT CONCENTRATIONS FOR THE OKEECHOBEE SPRING IN OKEECHOBEE, FLORIDA

Trophic level	Energy Available (kcal/m²/yr)	Ecological Efficiency	DDT Present (ppm)(1)	Increases in DDT
Producers	9,000		0.04	
Primary Consumers (herbivores)	1,500		0.23	
Secondary Consumers (carnivores)	120		2.07	
Tertiary Consumers (top carnivores)	12		13.8	
Per cent of energy from producers to tertiary consumers Increase from producers to tertiary consumers	Answers:			

WORK:

1a.	2.	3a
1.b		3b (i)
1c.		(ii)
		(iii)