PRAIRIE & PLOT
PRIMARY PRODUCTIVITY

Reference: Molnar, W. Laboratory Investigations for AP Environmental Science. 2005

Introduction:

Net primary productivity (NPP) is defined as the amount of carbon from the atmosphere that gets added to green plants per unit of time. It is a rate, the quantity of new vegetable matter added per day, per week or per year. Net prmary producitivity is calculated as the total gain of biomass form photosynthesis minus the losses due to plant respiration. It is this net gain that is available to other organisms as food. The higher the NPP is in a region, the higher the overall biomass and diversity.

You will measure NPP by comparing the changes in dry mass of plant growth over the course of one week. Data will be collected from at least two places – planted rye grass and the prairie and/or the bioretention system. You will follow the clipped plant procedure which measures the net primary productivity as an increase in dry weight over a one week period.

Prelab Preparation

1. Fill the trays with potting soil to near the top.
2. Plant the seeds so that the seeds are no more than 0.5 cm apart.
3. Cover the seeds with a thin layer of the potting soil.
4. Water the trays enough to ensure that the soil is saturated but with no standing water.
5. Place the trays to expose them to sunlight or under artificial lights designed for plants.
6. Continue to water the seeds when necessary as they sprout and grow
7. It will take two to three weeks for the plants to be large enough to start the experiment

Procedure – Clipped Grass Procedure

1. Harvest 15 plants, all from the same area in the tray, by cutting the plants 0.5 cm above the soil.
2. In the section of the tray from which you took your samples, count the number of plants in a 5 cm by 5 cm area. Record the count in your data table.
3. Place the clippings in an open container with the bottom covered with paper towels.
4. Allow the clippings to dry for one week
5. After the plants are dry, weigh and record the mass. This is the starting dry mass.
6. Allow the remaining grass to grow in the tray for one more week.
7. Harvest an additional 15 grass plants by clipping the plants 0.5 cm above the soil. Repeat the drying and weighing procedure. Record this as the final dry mass.
8. Find the difference in dry mass. This number is in grams of carbon per 15 plants. Scale this value up by using the number of plants growing in 25 cm^2. Then convert units of cm^2 to m^2 and also the number of days between samples into years.
9. Calculate and graph the net primary productivity in units of grams of carbon per square meter per year.

Data

Area Investigated	Starting Dry Mass	Final Dry Mass	Number of Plants in 25 cm^2	Number of plant per m^2

Graph

POND PRIMARY PRODUCTIVITY

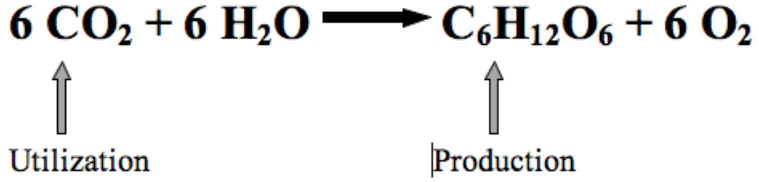
Introduction

The productivity in aquatic ecosystems is more complex. Aquatic plants and photosynthetic protists depend on dissolved oxygen and in some cases dissolved carbon dioxide in order to assimilate carbon through photosynthesis. The amount of dissolved gases there are in aquatic ecosystems is dependent on salinity (high [salt] holds less gas), altitude (higher altitudes hold less gas), and especially water temperature (higher temperatures hold less gas). Biological processes, such as photosynthesis and respiration, can also affect DO concentration. Photosynthesis usually increases the DO concentration in water. Aerobic respiration requires oxygen and will usually decrease DO concentration. The measurement of the DO concentration of a body of water is often used to determine whether the biological activities requiring oxygen are occurring and consequently, it is an important indicator of pollution.

The **primary productivity** of an ecosystem is defined as the **rate** at which organic materials (carbon-containing compounds) are stored. Organisms possessing photosynthetic pigments utilize sunlight to create new organic compounds from simple inorganic substances. Aquatic plants and photosynthetic protists obtain carbon for carbohydrate synthesis from the CO_2 in the water or air according this equation:

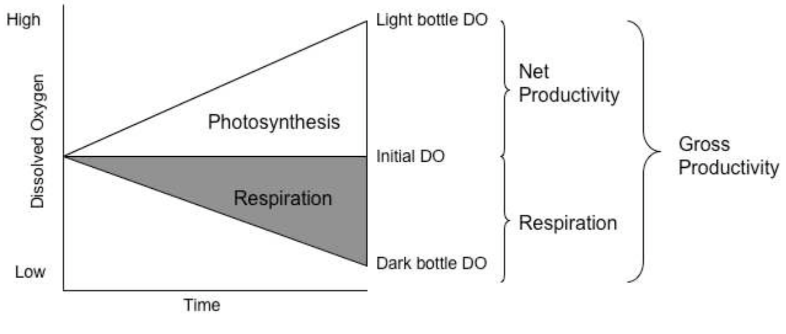
$$6CO_2 + 6H_2O \text{ ----> } C_6H_{12}O_6 + 6O_2$$

To measure primary productivity one can determine the rate of carbon dioxide utilization, the rate of organic compound formation, or the rate of oxygen production. The measure of oxygen production over time is the most convenient means of calculating primary productivity. For each milliliter of oxygen produced, approximately 0.536 milligrams of carbon has been assimilated.



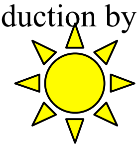
$$6\ CO_2 + 6\ H_2O \longrightarrow C_6H_{12}O_6 + 6\ O_2$$

One method of measuring the rate of oxygen production is the **light and dark bottle method**. In this method, the DO concentrations of samples of ocean, lake, pond, or river water can be measured and compared before and after incubation in light and darkness. The difference between the measurements of DO in the initial and dark bottles is an indication of the amount of oxygen that is being consumed by respiration. In the bottles exposed to light, the biological processes of photosynthesis *and* respiration are occurring; therefore, the change over time in DO concentration from the initial concentration is a measure of **net productivity.** The DO difference over time between the light bottle and the dark bottle is the total oxygen production and estimates gross productivity.



LIGHT/DARK Bottle Method

Production by Photosynthesis:

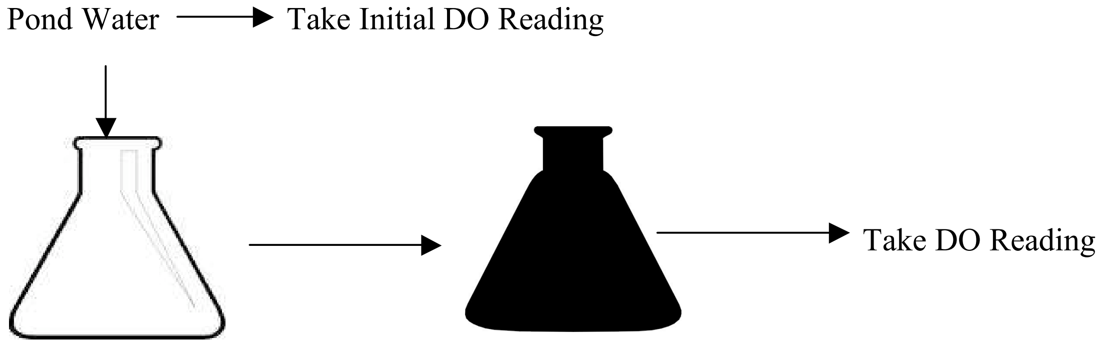


$$6\ CO_2 + 6\ H_2O \longrightarrow C_6H_{12}O_6 + 6\ O_2$$

Usage by Respiration:

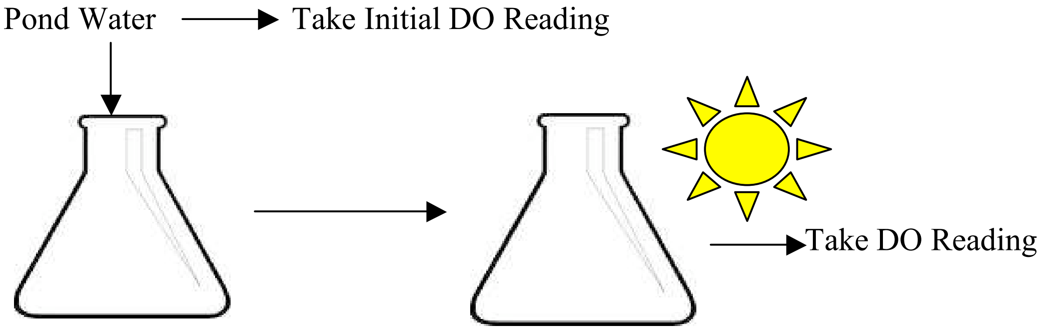
$$C_6H_{12}O_6 + 6\ O_2 \longrightarrow 6\ CO_2 + 6\ H_2O$$

Respiration Measured



-- Initial DO minus Dark Bottle DO

Net Productivity



-- Light Bottle DO minus Initial DO

Gross Productivity

-- Light Bottle DO minus Dark Bottle DO

A Model of Productivity as a Function of Pond Depth

Procedure

1. Obtain seven water sampling bottles, (these are also called BOD bottles for "biological oxygen demand"). Fill all the bottles with the pond water. You may be asked to add a specific weight of aquatic plants or algae to each bottle. Be careful not to leave an air bubble at the top of the bottle.
2. Label the cap of each bottle: I for initial, D for dark, 100%, 65%, 25%, 10%, and 2%.
3. Determine the DO for the Initial bottle now and record on the next table. This is the amount of DO that the water has to start with (a baseline).
4. Cover the Dark Bottle with aluminum foil so that no light can enter. In this bottle no photosynthesis can occur, so the only thing that will change DO will be the process of respiration by *all* of the organisms present.
5. The attenuation of natural light that occurs due to depth in a body of water will be simulated by using window screens. Wrap screen layers around the bottles in the following pattern:

100% light	no screens
65%	1 screen
25%	3 screens
10%	5 screens
2%	8 screens

The bottles will lie on their sides under the lights, so remember to cover the bottom of the bottles to prevent light from entering there. Use rubber bands to keep the screens in place. Slip a piece of paper with your name under each rubber band.

6. Leave the bottles on their sides under the bank of lights in the lab. Be sure to turn the bottles so that their labels are down and do not prevent light from getting to the contents. Leave overnight under constant illumination.

Productivity of Screen-Wrapped Samples

7. Determine the DO in all the bottles that have been under the lights. Record the Dark bottle DO in the table on the next page. Calculate the respiration rate using the formula (Initial - Dark). Record the values for the other bottles in the table. Complete the calculations in the table. The Gross Productivity is (Light Bottle - Dark Bottle) and the Net Productivity is (Light Bottle - Initial Bottle). The screened bottles will be used as the 'light bottles'. The calculations will be based on the time period that we allowed our bottles to sit under the light. Share your data with the class and record class average values. Record as mg O_2/L/day.
8. Graph both the net and gross productivities as a function of light intensity. The two kinds of productivity may be plotted on the same graph. Use proper graphing techniques.

Table 1. Light Intensity/ DO Data

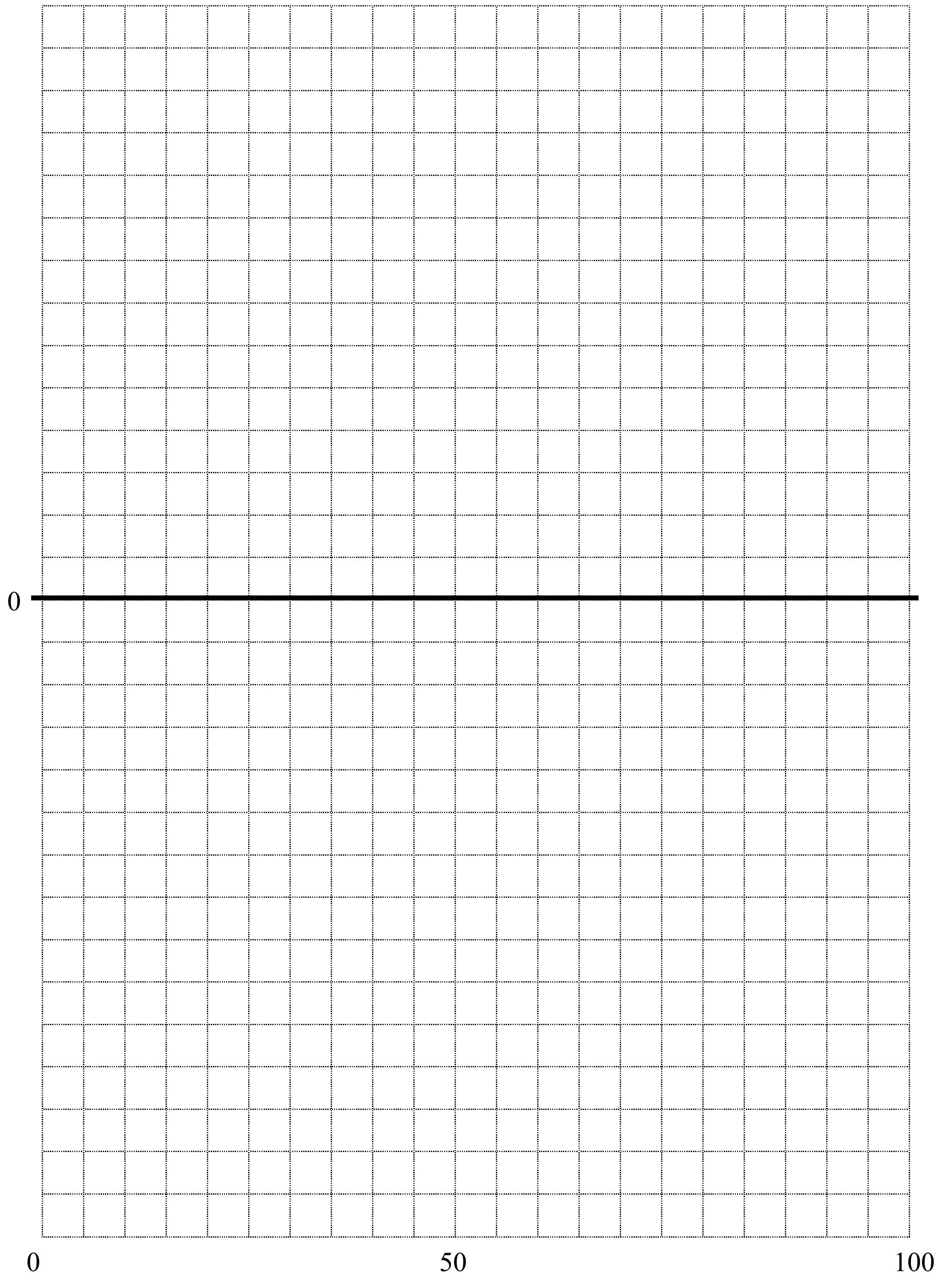
Condition	Pond Water	Pond Water + Producer
Initial Bottles		
Dark Bottles		
100% Light Bottles (no screens)		
65% Light Bottles (1 screen)		
25% Light Bottles (3 screens)		
10% Light Bottles (5 screens)		
2% Light Bottles (8 screens)		

Table 2. Gross & Primary Productivity Data using DO

**note then conversion you are going to have to do to figure grams of carbon per cubic meters per year.

Condition	Net Productivity in g of Carbon / m^3 / year		Gross Productivity in g of Carbon / m^3 / year	
	Pond Water	Pond Water + Producer	Pond Water	Pond Water + Producer
100% Light Bottles (no screens)				
65% Light Bottles (1 screen)				
25% Light Bottles (3 screens)				
10% Light Bottles (5 screens)				
2% Light Bottles (8 screens)				

Graph. The effect of light intensity on gross and net productivities in pond water measured in g of carbon per m^3 per year.



Light Intensity (%)

Key

= Gross Productivity w/o Producer

= Gross Productivity w/ Producer

= Net Productivity w/o Producer

= Net Productivity w/ Producer

Questions & Analysis

1. What is the definition of net primary productivity? Why is this rate such an important piece of information for ecologists?

2. Why are the results expressed as ‘net productivity’ instead of ‘gross productivity?

3. Suppose the rye grass plants continued to grow at the same rate over a six-month growing season. What would be the net productivity for a field that is 1 km^2?

4. In the St. Louis area much of our climax hardwood forests has been replaced and is being replaced with large, single-family homes and townhouse complexes. Based on the outcome of this investigation, explain one reason why the deer herds have drastically increased.

5. What is the relationship between oxygen production and assimilation of carbon?

6. Refer to your graph of pond productivity and light intensity. At what light intensity do you expect there to be:

no gross productivity ________________ no net productivity _________________

What about the pond sample “spiked” with a producer?

no gross productivity ________________ no net productivity _________________

7. Based on our findings what relationship would you expect for primary productivity and depth that a water sample was taken?

8. Compare the net primary productivities of all the ecosystems we studied. What accounts for the differences?

9. Compare the data we obtained with that found in the textbook on p. 182. Does our data correlate with that found in the graph? Explain.

10. Look at the graphs on p. 182. Why does the open ocean have such low net primary productivity?

11. Look at the graphs on p. 182. Generalize the locations on Earth that have low net primary productivity and high net primary productivity.

12. Complete the activity below.

Productivity and Respiration in Three Ecosystems (kilocalories/m^2/year)

Productivity & Respiration	**Alfalfa Field**	**Short-Grass Prairie**	**Deciduous Forest**
Gross Primary Productivity	24,000	5,230	27,976
Plant Respiration	9,200	1,778	18,200
Net Primary Productivity			
Consumer Respiration	800	2,379	9,172
Net Ecosystem Productivity	14000		
Net Ecosystem Respiration	10,000		
Productivity to Respiration Ratio	2.4 to 1		

12a. What would a productivity to respiration ratio of 1 mean?

12b. The forest and prairie ecosystems are unmanaged, whereas the alfalfa field is managed for agricultural purposes. On the basis of the data in the completed table, what are two differences between agricultural and unmanaged ecosystems?

12c. What source(s) of respiration has been omitted from the table? If this (these) factor(s) were taken into account, how would the P/R ratio be affected?