1.5) NET PRIMARY PRODUCTIVITY AND BIOLOGICAL OXYGEN DEMAND

Objective: In this activity you will estimate net primary productivity in pond samples by comparing dissolved oxygen dynamics in light and dark bottles. You will also determine over time the effect of phytoplankton on BOD. **Video instructions:** https://vimeo.com/70477473

Introduction: Anyone who has managed a retail business knows that sales revenue is not the same as net profit. This is analogous to the difference between gross and net primary productivity by producers. Just like animals and other consumers, plants and algae also participate in cellular respiration and thereby consume a significant portion of the oxygen, adenosine triphosphate (ATP), and sugar they produce through photosynthesis. This is the cost of doing business.

Because algae usually produce surplus amounts of oxygen, it seems logical that bodies of water with thick densities of phytoplankton should also have higher levels of dissolved oxygen. In fact, during warmer months the opposite is true because much of the oxygen produced by algae does not stay in the water.

The dissolved oxygen "reserve" that remains in the water as the result of photosynthesis during daylight hours is particularly critical in the summer. This is because warm water holds less oxygen, and higher temperatures also increase the BOD of most aquatic organisms. At night, only respiration takes place; and under hypereutrophic conditions, algae can become the single largest consumer of oxygen.

In the absence of adequate aeration or water exchange, oxygen levels may fall to less than 1 ppm before dawn, resulting in an "algae crash" that kills nearly all of the aquatic life in the affected area. Algae crashes are not limited to small bodies of water such as ponds and lakes. Every summer, large "anoxic zones" in many coastal waters such as the Chesapeake Bay and the Gulf of Mexico spread out for hundreds of square miles. This destroys valuable habitat for commercially important species like crabs and oysters.

Part A: Net Primary Productivity

1) Fill two flasks to the brim with green water and then seal the top of each flask with a stopper to remove all exposure to the air. If you are using *Elodea* or *Spirogyra* as a substitute for green water (Fig. 2), use an electronic balance to make sure biomass is divided equally between both flasks. Try to get between 3-4 grams algae per flask. The mass of *Spirogyra* is obtained by picking up the algae and letting the water drip out for about 5-10 seconds (no squeezing!).
2) Fill and seal a second pair with tap water. This will serve as your control.
3) Wrap one flask from each group in aluminum foil or dark paper so that absolutely no light enters the flask. Place each wrapped flask in a clear beaker with water so that any heat that is absorbed by the water in the beaker passes to the wrapped flask (Fig. 1). This helps ensure that the light and dark flasks have the same temperature.
4) Measure temperature and dissolved oxygen at time 0. Place the flasks in front of the fluorescent lamp (Fig.1) and measure again after 30 and 60 minutes. If some water is lost while testing for oxygen, add more of your original water sample so that there is no air space when you seal your flask. Record your data into a table (Tables A-1 and A-2).
5) Use the formulas below to calculate net and gross primary productivity for the 60- minute time intervals:
    a. light flask (O_2 gain):

        O_2 ppm at 60 minutes – O_2 ppm at 0 minutes = net 1° productivity

    b. dark flask (O_2 loss):

        O_2 ppm at 0 minutes – O_2 ppm at 60 minutes = total respiration

    c. light and dark flasks (O_2 gain + O_2 loss):

        net 1° productivity + total respiration = total 1° productivity

6) Use the data from Table A-1 to make a graph with two lines (one for the light flask and another for the dark flask) and place the independent variable (time) on the x-axis and the dependent variable (oxygen) on the y-axis:

Table A-1: Green Water Dissolved Oxygen Dynamics

	O_2 ppm at 0 min.	O_2 ppm at 30 min.	O_2 ppm at 60 min.	60 min. calculations
Light flask: 1^o productivity				
Dark flask: Total respiration				
Light and dark: Total 1^o productivity	N/A	N/A	N/A	

Table A-2: Tap Water Dissolved Oxygen Dynamics

	O_2 ppm at 0 min.	O_2 ppm at 30 min.	O_2 ppm at 60 min.	60 min. calculations
Light flask: 1^o productivity				
Dark flask: total respiration				
Light and dark flasks: Total 1^o productivity	N/A	N/A	N/A	

Fig. 1

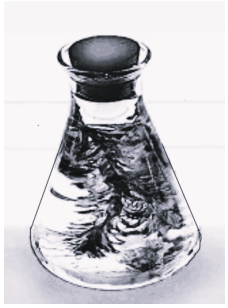

Fig. 2

Part B: Effect of Temperature on BOD

1) Fill 9 bottles to the brim with green water from either an algae culture or a hypereutrophic pond, taking care not to allow any air into the bottles. If you are using *Elodea* or *Spirogyra* as a substitute for green water (Fig. 2), use an electronic balance to make sure biomass is divided equally between both flasks. Try to get between 3-4 grams algae per flask. The mass of *Spirogyra* is obtained by picking up the algae and letting the water drip out for about 5-10 seconds (no squeezing!).
2) Using the same technique of keeping out the air, fill another 3 bottles (12 total) with tap water. These last three bottles will serve as your control.
3) Wrap bottles in aluminum foil so that no light can penetrate (this is not necessary for samples placed in a dark drawer or a refrigerator.)
4) Record dissolved oxygen at time 0 (Tables B-1 and B-2).

5) Place 3 of the bottles containing green water (9 total) into each of the three different environments: refrigerator, dark drawer, and warm-water bath (30-35 °C). Place 1 bottle of tap water into each of these three different environments (a total of 3 bottles). You will end up with a total of 4 bottles in each environment (3 of which are green water and 1 of which is tap water).
6) After 1 hour, 2 hours, and 24 hours, remove a bottle of pond water from each environment and take a temperature and oxygen reading and record them into a table (Table B-1).
7) For the tap water, take readings only after 24 hours and record them in a separate table (Table B-2).
8) Use the data from Table B-1 to make a graph with three lines representing the three different temperatures and place the independent variable (time) on the x-axis and the dependent variable (oxygen) on the y-axis:

Table B-1: Effect of Temperature on Dissolved Oxygen in Green Water

Treatment	Storage temperature	O_2 ppm at 0 hours	O_2 ppm at 1 hour	O_2 ppm at 2 hours	O_2 ppm at 24 hours
Refrigerator					
Room					
Warm bath					

Table B-2: Effect of Temperature on Dissolved Oxygen in Tap Water

Treatment	Storage temperature	O_2 ppm at 0 hours	O_2 ppm at 24 hours
Refrigerator			
Room			
Warm bath			

Questions:

1. Comparing green water versus tap water; what is the relationship between turbidity caused by algae and net primary productivity?

2. Given that plants and algae usually produce more oxygen than they consume, why do hypereutrophic ponds often suffer from oxygen deficits?

3. On what time of the day do oxygen levels reach their lowest point in outdoor ponds? Why is this so?

4. What is the effect of temperature on BOD?

5. What is the BOD of pond water vs. that of tap water? What is responsible for this difference?

6. Taking into account day length and average temperature, during which month is oxygen depletion most likely to take place, December or August? Why is this so?

7. Suppose you are the manager of 40 commercial fish ponds, but you have only enough time to measure oxygen in half of these ponds. Since all ponds are outdoors, the temperatures are relatively uniform. The only differences between the ponds are their turbidity and biomass of fish. What criteria would you use to decide which ponds will or will not be measured for oxygen? *Hint: Which ponds do you think are most at risk of running out of oxygen?*

Assignment Checklist:

1. Did you answer all the questions?
2. Did you graph the data for green water from Parts A and B?
3. Do both graphs have titles, axis labels, and captions?
4. Are the graphs hand-drawn?