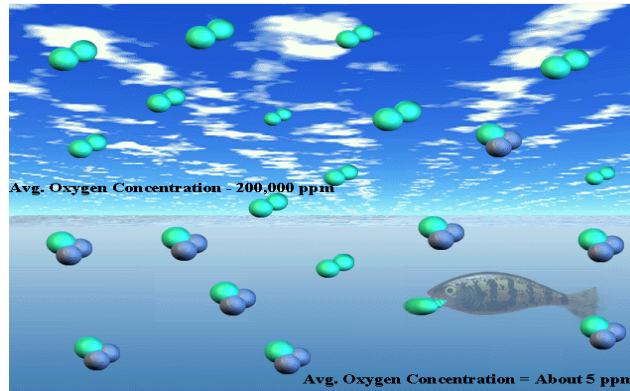


Dissolved Oxygen and Aquatic Primary Productivity



BACKGROUND:

In an aquatic environment, oxygen must be in a solution in a free state (O_2) before it is available for use by organisms (bio-available). Its concentration and distribution in the aquatic environment are directly dependent on chemical and physical factors and are greatly affected by biological processes. In the atmosphere, there is an abundance of oxygen, with about 200 mL of oxygen/1 L air. In an aquatic environment, there are about 5-10 mL O_2 /1 L water. The concentration of the oxygen in aquatic environments is a very important component of water quality.

At 20°C, oxygen diffuses 300,000 times faster in air than water, making the distribution of oxygen in air relatively uniform. Spatial distribution of oxygen in water, on the other hand, can be highly variable, especially in the absence of mixing by currents, winds, and tides.

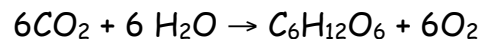
Other chemical and physical factors - such as salinity, pH, and especially temperature- can affect the dissolved oxygen (DO) concentration and distribution. Salinity, usually expressed as parts per thousand (ppt), is the content of dissolved salts in water. Generally, as temperature and salinity increase, the solubility of oxygen in water decreases.

The partial pressure of oxygen in the air above the water affects the amount of DO in the water. Less oxygen is present at higher elevations since the air itself is less dense; therefore the water at high elevations contains less oxygen. At 4,000 meters in elevation (13,000 feet), the amount of dissolved oxygen in water is less than two-thirds what it is at sea level. All of these physical factors, along with oxygen concentration, work together to increase diversity in aquatic habitats.

Oxygen from the atmosphere is mixed into the water through diffusion. However, more oxygen is mixed into the water with the help of winds, rain, waves, and currents. The faster the water moves, the more dissolved oxygen the water will contain since it has more contact time with the air. The process of photosynthesis (underwater plants and algae) occurring in the water affects the number and kinds of animals found there. Healthy streams are saturated with oxygen (90 to 110% saturation) during most of the year.

Biological processes, such as photosynthesis and respiration, can also significantly 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.**

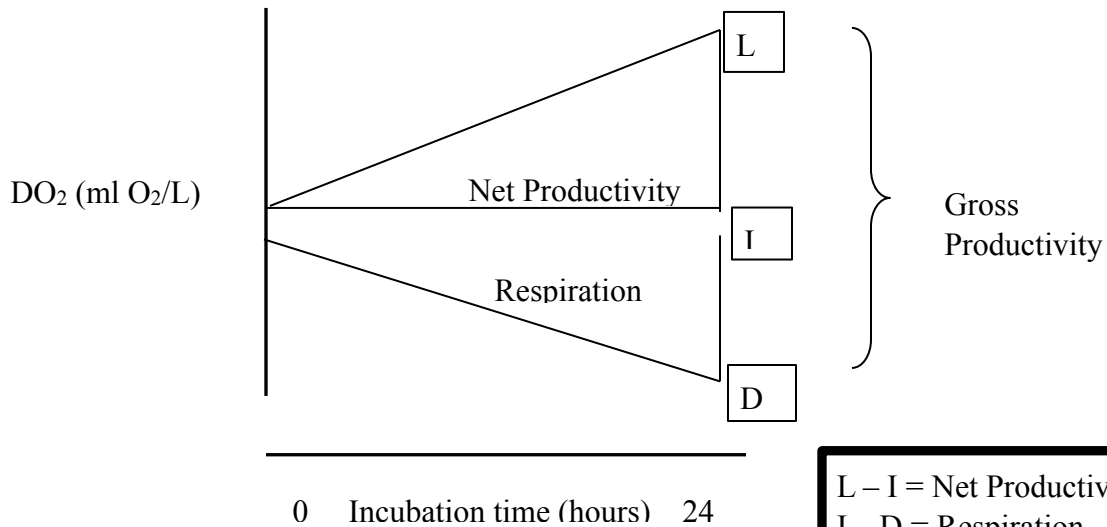
The **primary productivity** of an ecosystem is defined as the **rate** at which organic materials (carbon-containing compounds) are stored. Only those organisms possessing photosynthetic pigments can utilize sunlight to create organic compounds from simple inorganic substances. Green plants obtain carbon for carbohydrate synthesis from the carbon dioxide in the water or the air according to the basic equation for photosynthesis:



The rate of carbon dioxide utilization, the rate of formation of organic compounds, or the rate of oxygen production can be used as a basis for measuring primary productivity. A measure of oxygen production over time provides a means of calculating the amount of carbon that has been bound (taken up by photosynthesis) over a period of time. For each mL of oxygen produced, approximately 0.536 mg of carbon has been assimilated.

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, or river water or samples of laboratory algal cultures are 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 in respiration by organisms in the bottle. In the bottles exposed to light, the biological process of photosynthesis and respiration are occurring; therefore the change over time in DO concentration from the initial concentrations is the measure of **net productivity**. The difference over time between the DO

concentrations in the light bottle and the dark bottle is the total oxygen production and therefore an estimate of gross productivity.



$L - I = \text{Net Productivity}$
 $I - D = \text{Respiration}$
 $L - D = \text{Gross Productivity (or, think of it as } L - I + I - D)$

Dissolved Oxygen and Temperature

1. Fill three of the water sampling bottles with water of the three different temperatures provided.
2. Using the the dissolved oxygen test kits provided, determine the amount of DO per sample.
3. You will be provided with a nomograph for oxygen saturation. Use a straight edge or ruler to determine the percent DO in each of your temperature samples. (To use a nomograph, you line up the edge of a ruler with the temperature of the water on the top scale and the DO on the bottom scale, and read the percent saturation on the middle scale.)

Temperature	Lab Group DO	Class Mean DO	Lab Group % DO saturation	Class Mean % DO Saturation

Graph both the lab group data and class means percent saturation as a function of temperature. Please attach your graph to the end of this lab. Make sure it is properly labeled and neatly done. **(This will be Figure 1 in your lab)**

A Model of Productivity as a Function of Depth in a Lake

1. Obtain seven water-sampling bottles. Fill all of the bottles COMPLETELY with the lake water provided.
2. Using tape, mark the cap of each bottle. Mark as follows: I (for initial), D (for dark), 100%, 65%, 25%, 10%, 2%.
3. Determine the DO for the "Initial" bottle now and record its value. We will also calculate a class mean. 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 things 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 screen. Wrap screen layers around the bottles in the following way: 100% light - no screens; 65% light - 1 screen layer; 25% light -3 screen layers; 10% light -5 screen layers; and 2% light- 8 screen layers. The bottles will be on their sides under the lights, so remember to cover the bottom of the bottles to prevent light from entering there. Use rubber bands or clothes pins to keep the screens in place.
6. Place the bottles on their sides under the bank of lights in the classroom. Tomorrow we will continue...

Day Two

- To complete this experiment, determine the DO in all of the bottles that have been under the lights as well as the dark bottle's DO. Use the "dark" DO in the table below to calculate gross productivity. Calculate the respiration rate using the formula in the table. Record values for other bottles. Complete the calculations to determine the Gross and Net Productivity for each bottle. The calculations will be based on a time period of one day. Determine class means.

Individual Group Data: Productivity of Screen-Wrapped Sample

# of screens	% light	DO	Gross Productivity (light bottle - dark bottle)	Net Productivity (light bottle - initial bottle)
0	100%			
1	65%			
3	25%			
5	10%			
8	2%			

Class Mean Data: Productivity of Screen-Wrapped Sample

# of screens	% light	DO	Gross Productivity (light bottle - dark bottle)	Net Productivity (light bottle - initial bottle)
0	100%			
1	65%			
3	25%			
5	10%			

8	2%			
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Graph both net and gross productivities as a function of light intensity (class means) and attach to lab. **(Figure 2 in your lab)**

You need to turn in the following in your lab notebook:

- Figure 1 (graph of group and class data...% DO saturation as a function of temperature). Please also include a three to four sentence explanation of the trends seen on the graph, i.e. interpret the graph!
- Figure 2 (graph of net and gross productivities as a function of light intensity (use class means, please). Please also include three to four sentence explanations of the trends seen on the graph, i.e. interpret the graph!
- The thirteen questions below. You are expected to work independently on your answers to these questions.
- Your completed data tables

Questions:

1. What are three ways primary productivity can be measured?
2. What is the relationship between oxygen production and assimilation of carbon?
3. From your graph of the temperature data, what is the effect of temperature on the amount of oxygen that water at different temperatures can hold?
4. Refer to your graph of productivity and light intensity...At what light intensity do you expect there to be:
No gross productivity?_____ No net productivity?_____
5. A mammal uses only 1 to 2 percent of its energy in ventilation (breathing air in and out) while a fish must spend about 15 percent of its energy to move water over its gills. Explain this huge difference in their efforts to collect oxygen, i.e., why is it necessary for the fish to invest so much more energy in the "oxygen acquisition" process?
6. Would you expect the DO in water taken from a stream entering a lake to be higher or lower than the DO taken from the lake itself? Explain.
7. Would you expect the DO concentrations of water samples taken from a lake at 7:00 a.m. to be higher or lower than samples taken at 5:00 p.m.? Explain.

8. What is eutrophication? Explain why allowing nitrogen or phosphorous fertilizers to run into a body of water can negatively affect the life in it.
9. If we know that 7.4 mL of O_2 is produced through photosynthesis, how much carbon would have been assimilated?
10. In general, how would you expect turbidity to affect the productivity of a lake? Why?
11. Propose an alternate experimental design that would have allowed us to assess primary productivity. Think about the components of a good experiment (identify variables, etc.)
12. How does an increase in the rate of the respiration of water dwelling organisms tend to influence the pH of the water they are in? Explain your answer!
13. Why do nuclear power plants occasionally pose a threat to some aquatic life?
(any answer relating to the release of radioactive materials is not acceptable). Hint: how do power plants dissipate energy from nuclear reactions?