Laboratory 12: Dissolved Oxygen and Aquatic Primary Productivity

*describe the physiological importance of carbon and oxygen in an ecosystem
*understand the physical and biological factors that affect the solubility of dissolved gases in aquatic ecosystems
*describe a technique for measuring dissolved oxygen
*define primary productivity
*describe the relationship between dissolved oxygen and the process of photosynthesis and respiration as they affect primary productivity in an ecosystem
*design an experiment to measure primary productivity in an aquatic ecosystem
*understand the effect of light and nutrients on photosynthesis

Oxygen is critical to the maintenance of the life processes of nearly all organisms. In the aquatic environment, it must be in solution in a free state before it is available for use by organisms. Its concentration and distribution are directly dependent on the chemical and physical factors of the water, and are greatly affected by biological processes. The atmosphere is about 20% O_2; the water contains only 0.5-1% dissolved oxygen (DO). Measurement of oxygen in an aquatic environment is a very important indicator of water quality.

Salinity and temperature have great effects on DO; both seem to decrease the available oxygen as they increase. Respiration and photosynthesis rates are also important.

The fertility of any body of water depends on the productivity of the green plants there: the primary productivity of an ecosystem is the rate at which sunlight is stored by plants in the form of organic materials (rate of photosynthesis). The rate of oxygen production in this process can be used to calculate the fixation rate [1 ml O_2 = 0.536 mg of carbon]. One method of measuring O_2 production is the light and dark bottle method. DO concentrations of samples are measured and compared after incubation in light and darkness; the difference between the bottle is the total oxygen productivity = gross productivity.

The Winkler method is often used to measure DO.

a. add alkaline iodide and manganous sulfate to water sample
b. manganous hydroxide is produced/ when acidified, is converted to tetravalent manganese compound by available O_2
c. compound reacts with iodide to release iodine, coloring the water yellow
d. titration with sodium thiosulfate will finally render solution colorless (amount = amount of dissolved O_2)

Using BOD bottles (biological oxygen demand), you can take initial DO reading: one over 24-hour period with light, one over same period with dark, and in bottles with nitrogen and phosphorus added ("enriched").

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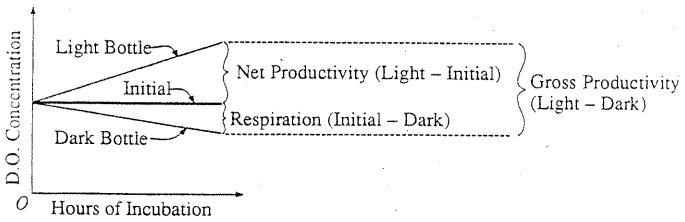


Class Averages for different Light Intensities using a *Chorella* culture

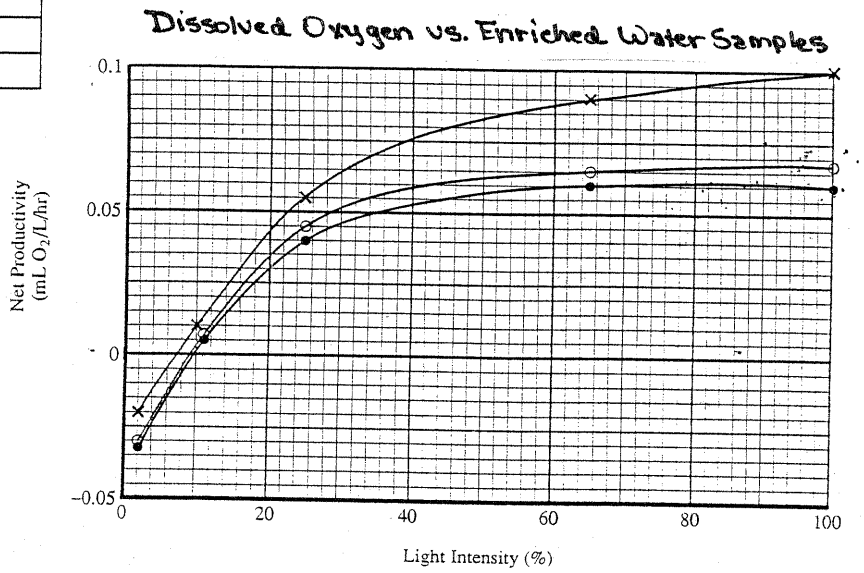
% Light	Gross*			Net*		
	N	P	—	N	P	—
100	0.19	0.16	0.15	0.10	0.07	0.06
65	0.18	0.15	0.15	0.09	0.06	0.06
25	0.14	0.13	0.13	0.06	0.04	0.04
10	0.10	0.10	0.10	0.01	0.01	0.01
2	0.07	0.06	0.06	-0.02	-0.03	-0.03

*$mL0_2/L/hr$

Respiration*
0.09

DO Concentration Data Sheet — Class Sample

Temperature	Mean DO (mg/L)	%DO Saturation
5°c	9.3	>0
20°c	8.9	95
30°c	8.5	110



Lab 12
Dissolved Oxygen

Question 3
2001

A biologist measured dissolved oxygen in the top 30 centimeters of a moderately eutrophic (mesotrophic) lake in the temperate zone. The day was bright and sunny, and the wind was calm. The results of the observations are presented below.

Hour	[O2]
6:00 A.M.	0.9 mg/L
8:00 A.M.	1.7 mg/L
10:00 A.M.	3.1 mg/L
12:00 noon	4.9 mg/L
2:00 P.M.	6.8 mg/L
4:00P.M.	8.1 mg/L
6:00 P.M.	7.9 mg/L
8:00 P.M.	6.2 mg/L
10:00 P.M.	4.0 mg/L
12:00 midnight	2.4 mg/L

(a) Using the graph paper provided, **plot** the results that were obtained. Then, using the same set of axes, draw and label an additional line/curve representing the results that you would predict had the day been heavily overcast.

(b) **Explain** the biological processes that are operating in the lake to produce the observed data. **Explain** also how these processes would account for your prediction of results for a heavily overcast day.

(c) **Describe** how the introduction of high levels of nutrients such as nitrates and phosphates into the lake would affect subsequent observations. **Explain** your prediction.

The Grading Standards for Question 3:

*(a) Using the graph paper provided, **plot** the results that were obtained. Then, using the same set of axes, draw and label an additional line/curve representing the results that you would predict had the day been heavily overcast.* (4 points possible)

(1) Proper orientation of graph (independent variable on x-axis)

(1) Graph (all must be present):
- Uniform spacing of units
- Correct labeling of axes:
  - proper numbering (a minor error acceptable)
  - X-axis label: "Time"/ "Hour"/AM, PM labels/a conversion to integers requires unit label as well
  - Y-axis: oxygen label and mg/L Unit

(1) Correct plot of data points
-no connecting line necessary
-No point if more than one data point is misplotted
-No point if there is a solid extrapolation line beyond the 6:00 AM data point to the origin or beyond the 12 midnight data point

(1) Drawing the cloudy day prediction Line/Curve (all must be present):
- Distinguish between the two curves with a legend or direct labeling of one curve
- Position completely under the bright-day curve (may touch toward the tails)
- There must be some curve to the line (no flat lines)

(b) ***Explain*** *the biological processes that are operating in the lake to produce the observed data.* ***Explain*** *also how these processes would account for your prediction of results for a heavily overcast day.* (5 points possible)

(1) Photosynthesis: production of O_2 correlated with light changes (i.e. explains changes in shape of bright-day curve). The student must link photosynthesis to increase in light to increase in O_2 production. The student must use the term "photosynthesis" or an excellent replacement such as the chemical equation for the process.

(1) Respiration: consumption of O_2. Must link respiration to decrease in O_2. The student must use the term "respiration" or an excellent replacement such as the chemical equation for the process or the name of another process such as "decomposition."

(1) Description of the interaction of the above: photosynthetic rate changes while respiration rate remains relatively constant.

(1) Overcast prediction curve explanation:
- Reduced light leads to decreased photosynthetic O_2 production, etc.
- No point given if there is no prediction line/curve on the graph.

(1) Elaboration point (1 max) for any one of the above. Examples of elaboration may include, but are not limited to
- Water split/photolysis to produce O_2 in the light phase, etc.
- Balanced equation for photosynthesis or respiration (unless used as a substitute for the term above)
- Description of "light phase" processes (photosystem II, etc)
- Gross vs. net productivity

(c) ***Describe*** *how the introduction of high levels of nutrients such as nitrates and phosphates into the lake would affect subsequent observations.* ***Explain*** *your prediction. (3 points possible)*

(1) Describe (predict) a change in lake conditions such as (must be related to the question):
- increased/decreased O_2
- increased/decreased biomass or numbers of organisms
- increased/decreased CO_2
- long-term or short-term changes
- no change

(1) Explanation of the prediction above
- may include toxic effects due to significant changes in pH, altered osmolarity, etc.

(1) Elaboration on the explanation of the prediction above or long term ecological consequences to lake.

3. A biologist measured dissolved oxygen in the top 30 centimeters of a moderately eutrophic (mesotrophic) lake in the temperate zone. The day was bright and sunny, and the wind was calm. The results of the observations are presented below.

30, (10 pts)

Hour	$[O_2]$
6:00 A.M.	0.9 mg/L
8:00 A.M.	1.7 mg/L
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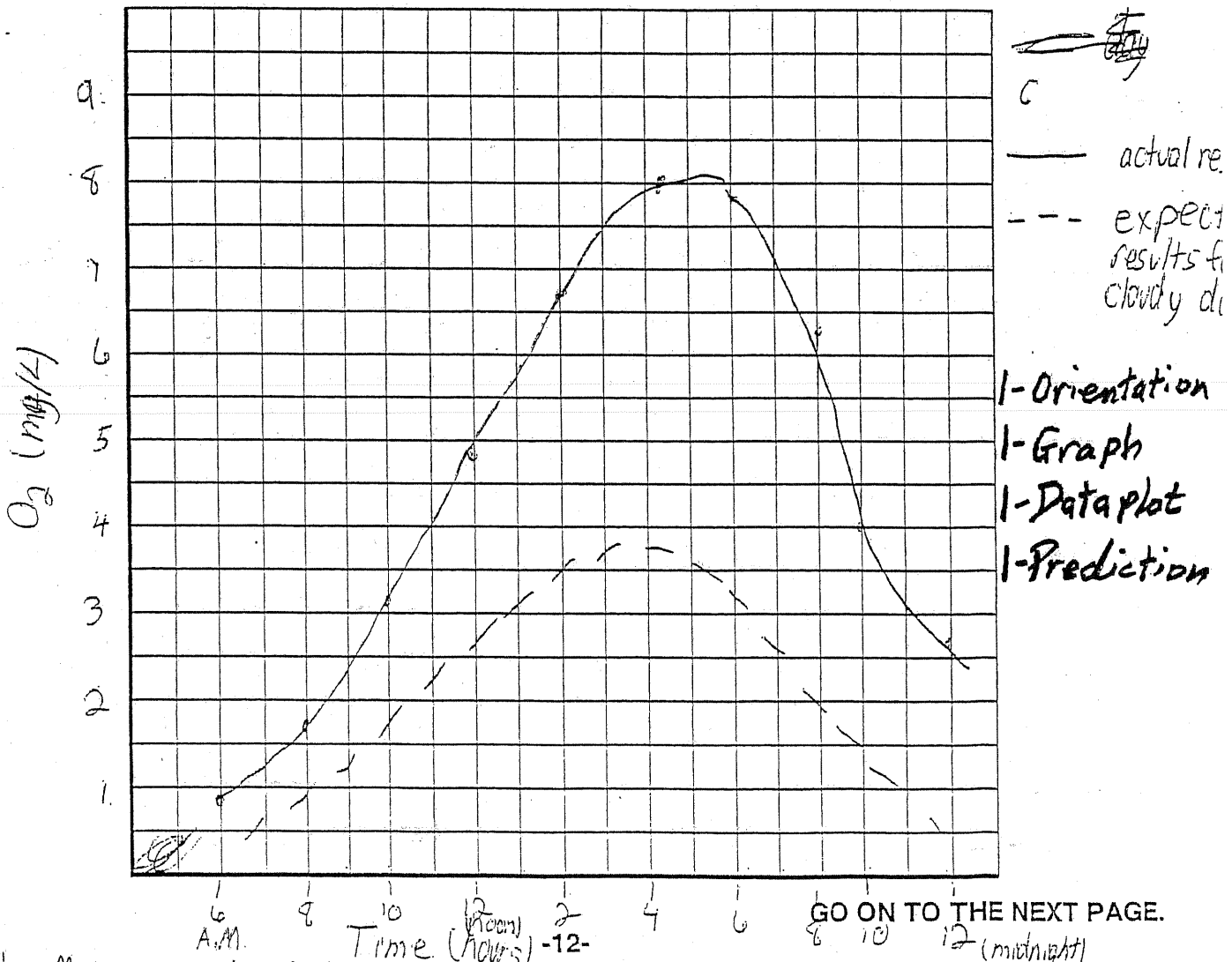

Graph 1. Measurement of Dissolved O_2

3Q2

ADDITIONAL PAGE FOR ANSWERING QUESTION 3

B. ~~In the morning~~ In the morning dissolved O_2 levels are low. At mid-day the levels peak, and then later in the day the levels lower. One reason for the dO_2 levels is the amount of sunlight reaching the lake. As the day continues, more sunlight reaches the plants in the lake. Because sunlight is used to initiate photosynthesis, more photosynthesis occurs with more sunlight. The sunlight helps excite the electrons in photosystems I & II which aid in the production of ATP and NADPH which are used to produce glucose and as a waste product O_2. The more sunlight the more photosynthesis, the more O_2 is given off as a waste product. The O_2 levels are also lower at night because the pl animals in the lake still have to perform cellular respiration which causes the O_2 levels to drop because O_2 is needed. ① Photosynthesis ① Resp. ① photo. also slows down or stops because there is no light which is needed for the process. The O_2 levels would be lower on an overcast day because there is not as much sunlight reaching the plants, thus causing less photosynthetic activity thus producing less O_2. ① Explanation of curve Also the animals & plants continue cellular respiration. Since plants don't photosynthesize as much, there is not an equal production and consumption of O_2 causing O_2 levels to be lower than normal. ① Interaction

GO ON TO THE NEXT PAGE.

3Q3

ADDITIONAL PAGE FOR ANSWERING QUESTION 3

C. If high levels of nutrients such as nitrates and phosphates were added then the lake would have higher levels of O_2. (1) Prediction This is because the nitrates would become part of the nitrogen cycle. It has been shown increased levels of nitrogen increase plant fertility. This may be because the nitrogen ~~are~~ is used in the productions of DNA and nucleotides such as NADPH. Since NADPH is an energy molecule and there is more energy w/the nitrogen, the plant has more energy to make food. The added phosphate will also help because it too is part of the NADPH ~~and~~ nucleotide. Phosphate can also be used in another energy molecule ATP. Phosphate will help provide more energy. Nitrogen & phosphate are both macronutrients meaning they are required in large amounts for plants.

(1) Explanation + possible elaboration

(10)

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