From the Mountains to the Estuary:
From the Schoolyard to the Bay

Meaningful Watershed Experiences for High School Students

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PEREC POTOMAC ENVIRONMENTAL RESEARCH & EDUCATION CENTER

With grant support from the
NOAA Bay Watershed Education Training (B-WET) Program

In partnership with:

Data from the Field

Dissolved Oxygen in Aquatic Systems: Photosynthesis and Respiration

Student Exercise Using Continuous Monitoring Data

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Overview

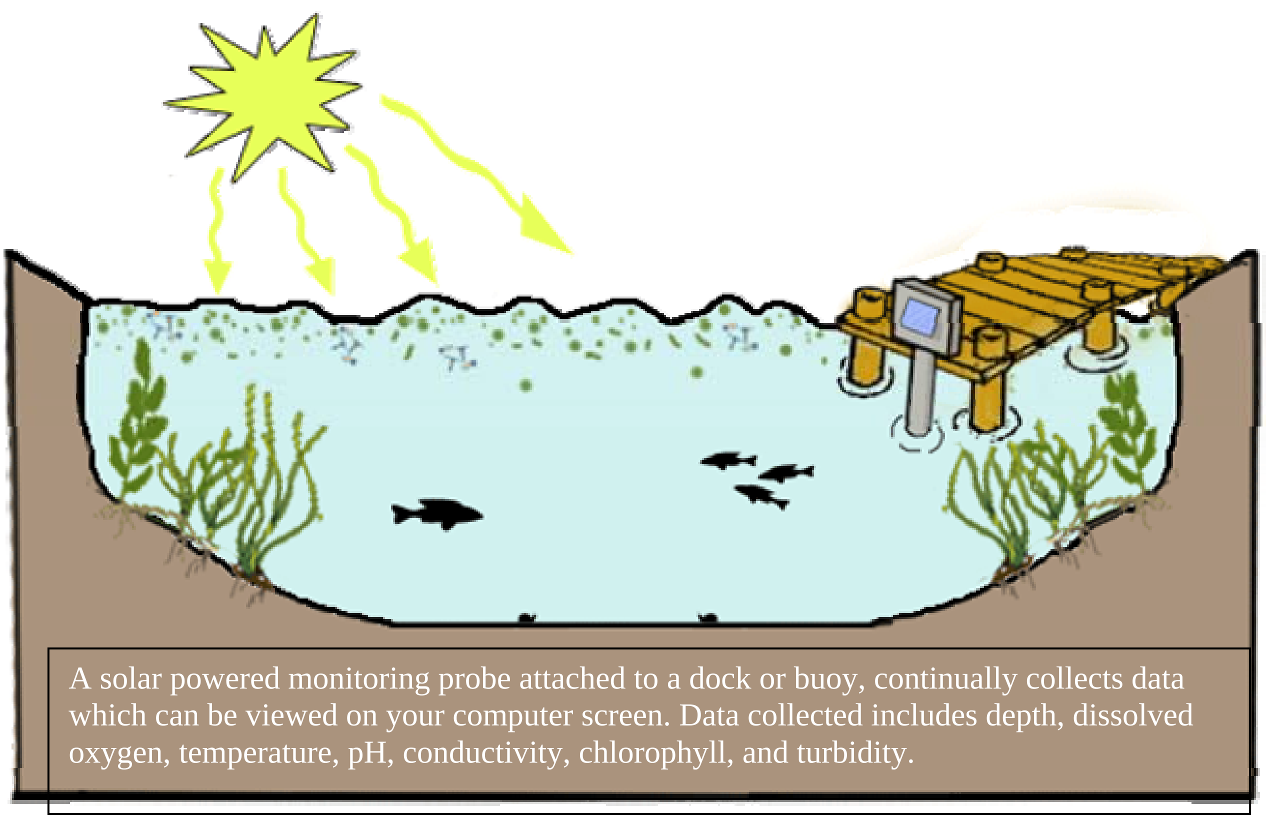
Students investigate the processes of **photosynthesis** and cellular **respiration** and their role in determining dissolved oxygen concentrations in aquatic systems. They will access and download light data from a weather station and dissolved oxygen data from a water quality monitoring site. Students will choose a one week period with at least one very sunny day and one cloudier day based on light data from the weather station. They will download this week of light data. Then they will download dissolved oxygen data from the continuous water quality monitor for that week. They examine changes in dissolved oxygen during the day (when photosynthesis is active) and night (when only respiration is active) to test the hypothesis that: if oxygen is produced by photosynthesis and consumed by respiration, then dissolved oxygen will be highest during the day when PAR is high and lowest during the night when PAR is low. And the amount of photosynthesis (as indicated by DO change) will be greater on a sunny day than on a cloudy day. Students will determine maximum, minimum and net change in dissolved oxygen on a daily basis and create graphs from this data.

Materials Needed

Computer with internet access.
Belmont parameter sheets
Weather data and dissolved oxygen data at: http://perec.gmu.edu

Setting the Stage:

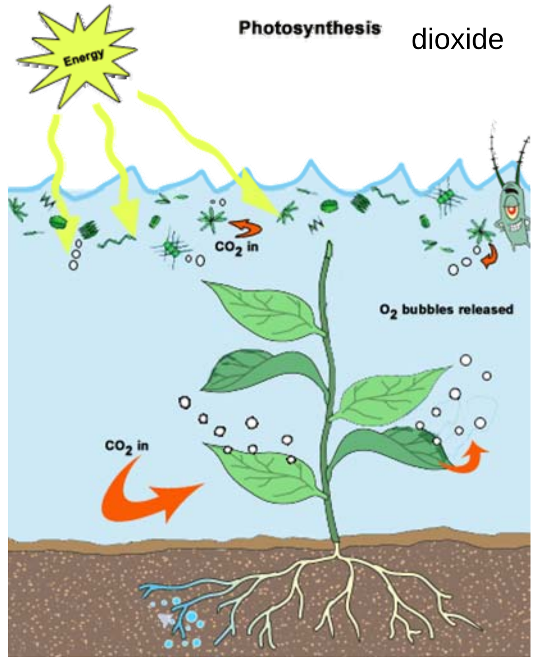
To better understand water quality in and around the Chesapeake Bay, scientists frequently look at data collected from probes attached to buoys or docks that sample water every fifteen minutes. Weather data is also collected continuously. By examining continuous monitoring data scientists and anyone with a computer can to see how weather and water quality parameters, change throughout the day and night as well as monthly and yearly.



A solar powered monitoring probe attached to a dock or buoy, continually collects data which can be viewed on your computer screen. Data collected includes depth, dissolved oxygen, temperature, pH, conductivity, chlorophyll, and turbidity.

Basics:

Photosynthesis is the basic process by which carbon dioxide is converted into biomass by plants and algae (phytoplankton).
In the process dissolved oxygen is produced. The basic equation for photosynthesis is:



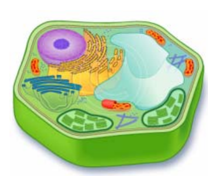
$$CO_2 + H_20 + light \rightarrow (CH_2O) + \ O_2$$

OR *carbon dioxide* + *water* + *light* YIELDS *carbohydrate* + *oxygen*

The process of photosynthesis provides a way for plants and algae to store the sun's energy in the form of chemical bonds of carbohydrate. From the carbohydrate base, other essential **biochemicals** such as proteins, fats, and nucleic acids can be produced and then use by the plant for growth, maintenance and reproduction.

In aquatic systems, when oxygen is released by plants and algae, it increases the concentration of dissolved oxygen in the water. The three requirements of photosynthesis are carbon dioxide, water and light. Since carbon dioxide and water are rarely limited in aquatic systems, the amount of oxygen produced is typically a function of light availability.

The process of **cellular respiration** provides a way for all organisms (plants, animals, fungi and microbes) to access the energy stored in carbohydrates. This energy is used to power the growth and cellular processes of all living things. The basic equation for respiration is:



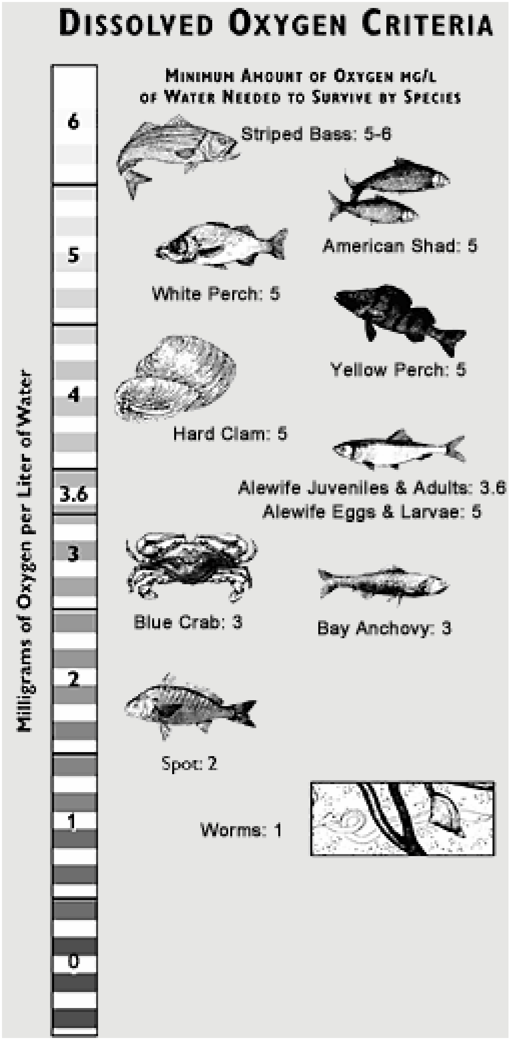
$$CH_2O + O_2 \ \rightarrow CO_2 + \ H_2O + energy$$

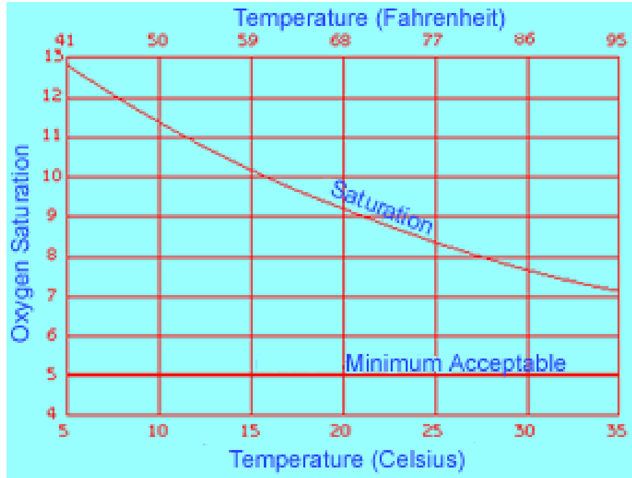
OR carbohydrate + dissolved oxygen YIELDS carbon dioxide + water + energy (ATP)

For every atom of carbon in carbohydrate that is respired, one molecule of molecular oxygen is consumed. In aquatic systems, the oxygen is removed from the water and decreases the concentration of dissolved oxygen in the water. Respiration occurs at a more or less constant rate both day and night in aquatic systems.

Molecular oxygen is very abundant in air composing about 20% of its volume and mass. However, molecular oxygen is much less abundant in water. Water can be saturated by bubbling it with air for an extended period. When this is done, we achieve 100% saturation with respect to air. This saturation value is a function of temperature, but is roughly 10 mg/L.

The amount of dissolved oxygen that the water can hold depends on the temperature and salinity of the water. Cold water can hold more dissolved oxygen than warm water and fresh water can hold more dissolved oxygen than salt water. Thus, the warmer and saltier the water, the less dissolved oxygen it can hold. The maximum amount of dissolved oxygen that the water can hold is called the saturation value. Dissolved oxygen measurements are given as a percent of saturation (%) or in units of milligrams per liter (mg/l).





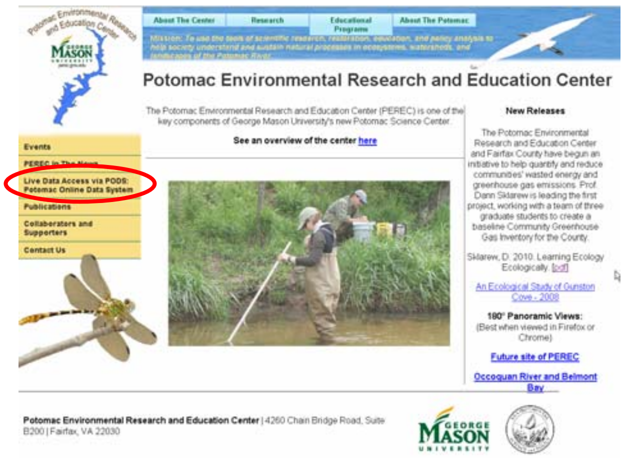
Above 5 mg/l

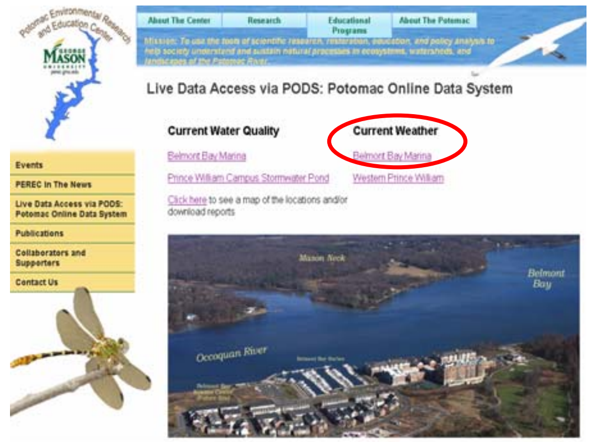
dissolved O_2, most aquatic organism can survive. Anoxia occurs when almost all the dissolved oxygen is used up, below 0.5 mg/l. Very few organisms can survive anoxic conditions which during warm summer months on the Chesapeake Bay.

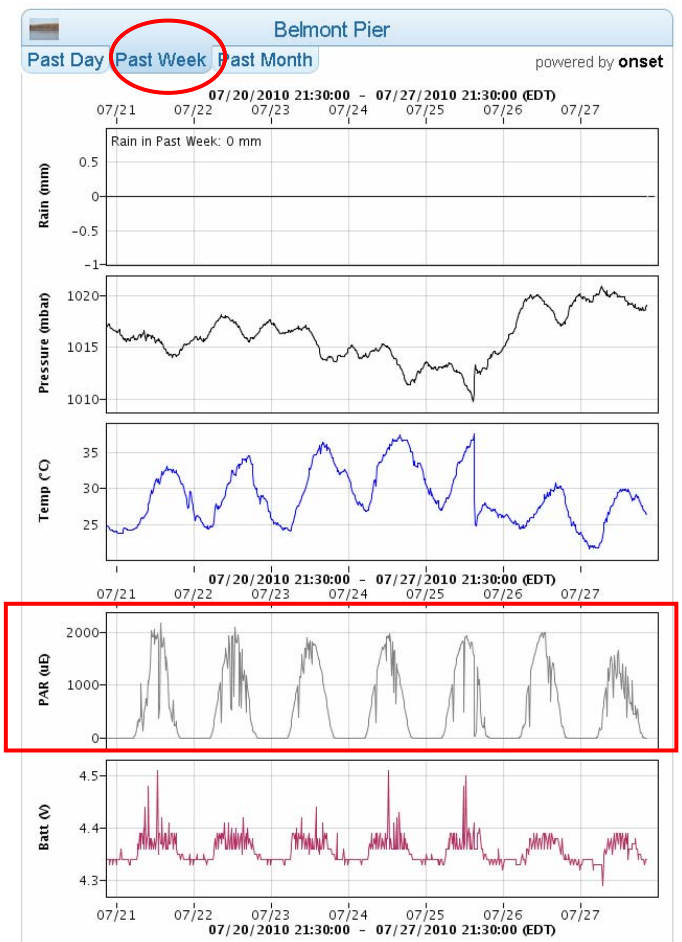
While other factors may be important in some cases, the dissolved oxygen in an aquatic system is often directly related to the processes of photosynthesis and respiration. In this lab we will test the hypothesis that dissolved oxygen in an aquatic ecosystem is controlled by the processes of photosynthesis and respiration.

Engage:

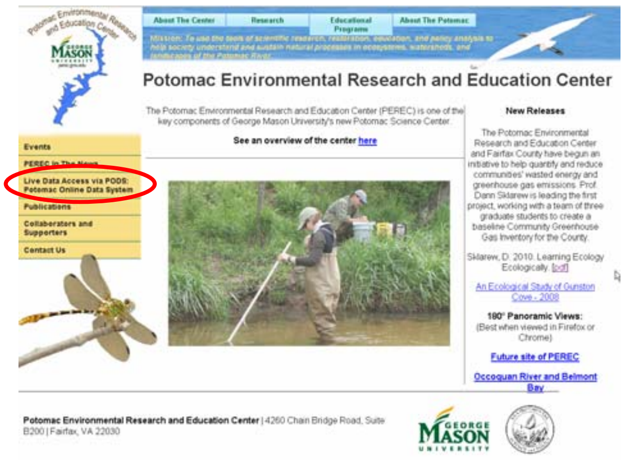
1. Access a computer which has internet access and EXCEL.
2. Log onto the PEREC website http://perec.gmu.edu/ and click on the left panel: **Live Data Access via PODS Potomac Online Data System**
3. Click on **Current Weather Belmont Bay Marina**

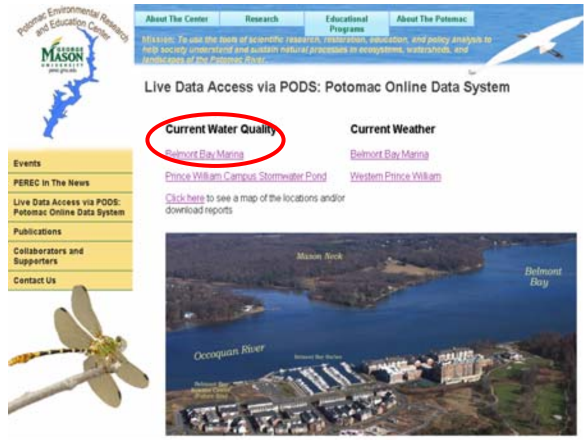




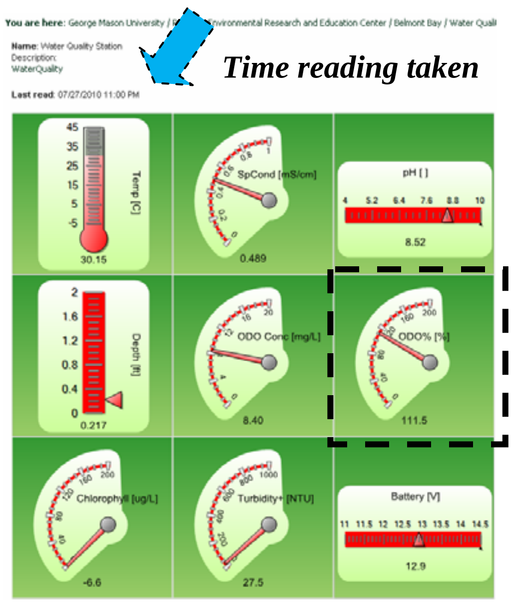


4. Click on the tab for **Past Week** and examine the graph of PAR. PAR is the amount of Photosynthetically Active Radiation, or light energy that can be used by aquatic plants and algae. Write down the dates you are examining data from _____ to _______.
5. What do you notice about the graph? At about what time does PAR peak? Are all days in that week similar in terms of peak value?
6. For each date, determine the approximate maximum PAR value from the graph and record in Table 1.
7. Students will compare this PAR data to a graph of Dissolved Oxygen data collected during the same week period.
8. Log onto the PEREC website http://perec.gmu.edu/ and click on the left panel: **Live Data Access via PODS Potomac Online Data System**
9. Click on **Current Water Quality Belmont Bay Marina**. This link will take you directly to data collected every 15 minutes from the data probe attached to the Belmont Marina dock.





10. Examine the **ODO mg/l gauge**. What is the amount of dissolved oxygen in the water? _________mg/l. Is this amount high enough to support life in Belmont Bay? ______________



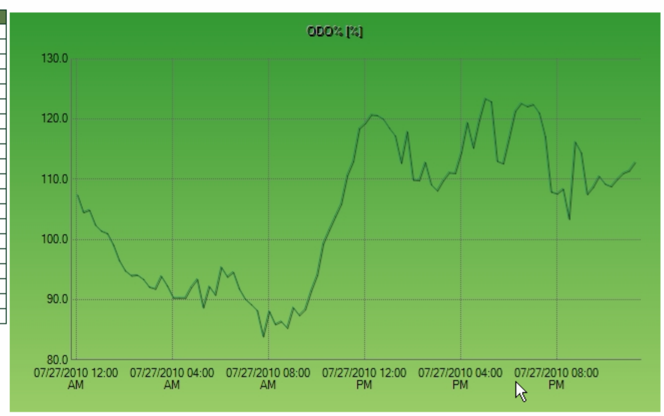
11. Examine **ODO % dissolved oxygen**. What is the current percent saturation of Dissolved Oxygen? _______________. What time of day was the most current reading taken? ___________.

12. Click on the **ODO % gauge**. A table containing Local Time and Value and a graph will show up. This graph is for the last day.

Parameter: ODO% [%]
Start Date: 7/27/2010 End Date: 7/28/2010 **Submit**

Local Time	Value
07/27/2010 11:15 PM	112.9
07/27/2010 11:00 PM	111.5
07/27/2010 10:45 PM	111.1
07/27/2010 10:30 PM	110.1
07/27/2010 10:15 PM	108.9
07/27/2010 10:00 PM	109.3
07/27/2010 09:45 PM	110.6
07/27/2010 09:30 PM	108.8
07/27/2010 09:15 PM	107.6
07/27/2010 09:00 PM	114.5
07/27/2010 08:45 PM	116.3
07/27/2010 08:30 PM	103.5
07/27/2010 08:15 PM	108.5
07/27/2010 08:00 PM	107.7
07/27/2010 07:45 PM	108.0
07/27/2010 07:30 PM	117.2
07/27/2010 07:15 PM	121.1
07/27/2010 07:00 PM	122.5
07/27/2010 06:45 PM	122.2
07/27/2010 06:30 PM	122.7

Previous Next



15. Graph the DO data for the two days on a common time axis (24 hr).
16. Compute the difference between maximum and minimum DO for each day.
17. Test the hypothesis by examining:
18. –Graphs

A. During what time of the day is the percent saturation of Dissolved Oxygen the highest? When is it the lowest?

B. Using the dates you wrote down in step 4 above, type them into the boxes marked **Start Date** and **End Date** and click **Submit.**

15. You will get a new graph (on the right side of the screen) showing the full week's data. For each day you get an approximate minimum and maximum dissolved oxygen value. To get accurate maximum and minimum values as well as the time of occurrence of these, you can scroll through the data table on the left side of the screen using the "Previous" and "Next" buttons at the bottom of the table. For each day record Max ODO% value and time and Min ODO% value and time.

Parameter: ODO% [%]
Start Date: 7/23/2010 End Date: 7/30/2010 **Submit**

Local Time	Value
07/29/2010 11:45 PM	110.5
07/29/2010 11:30 PM	108.3
07/29/2010 11:15 PM	105.9
07/29/2010 11:00 PM	102.7
07/29/2010 10:45 PM	96.2
07/29/2010 10:30 PM	99.6
07/29/2010 10:15 PM	103.4
07/29/2010 10:00 PM	104.5
07/29/2010 09:45 PM	106.7
07/29/2010 09:30 PM	109.1
07/29/2010 09:15 PM	116.6
07/29/2010 09:00 PM	117.4
07/29/2010 08:45 PM	119.4
07/29/2010 08:30 PM	117.7
07/29/2010 08:15 PM	118.3
07/29/2010 08:00 PM	121.2
07/29/2010 07:45 PM	120.5
07/29/2010 07:30 PM	121.6
07/29/2010 07:15 PM	122.6
07/29/2010 07:00 PM	117.3

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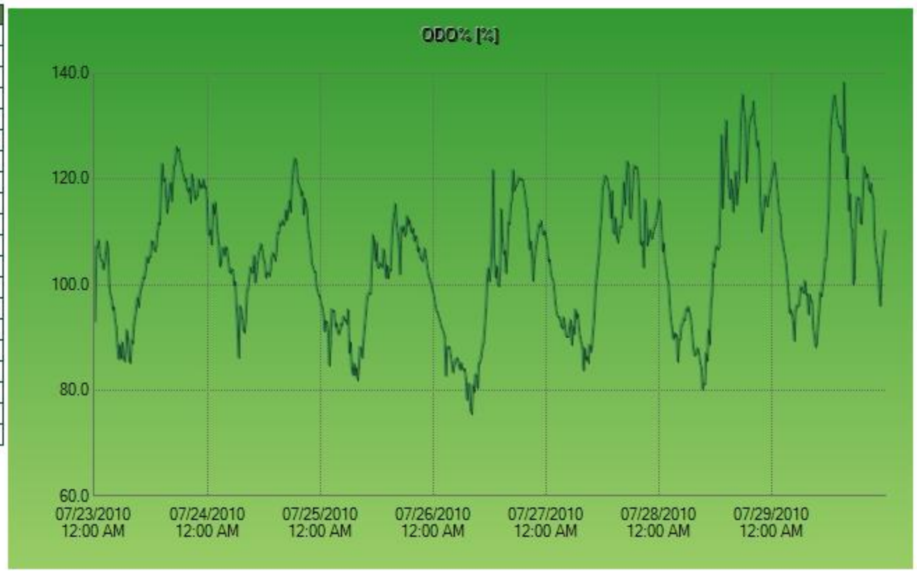
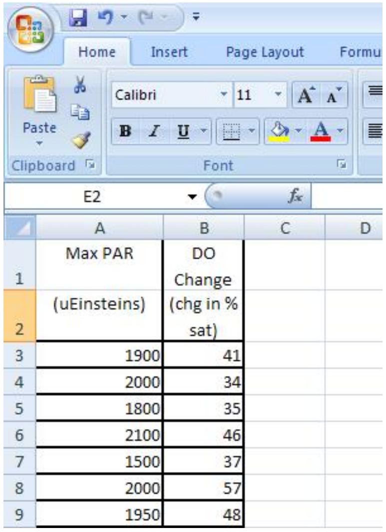


16. Calculate the DO Change for each day by subtracting the Min DO from the Max DO on each day.

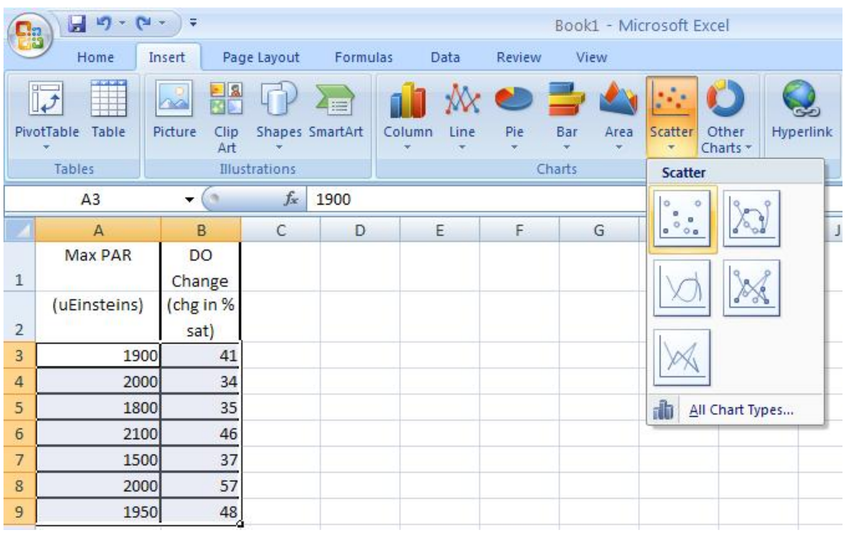
17. Hypothesis 1 states that DO will undergo a diel (24 hour) cycle based on photosynthesis occurring during the day leading to maximum DO in the late afternoon and respiration dominating at night leading to a minimum DO in the early morning hours. Is this what you found?

18. Hypothesis 2 states that the amount of DO change will be proportional to the maximum PAR value on a given day. We will test this by constructing a scatterplot with PAR on the x-axis and DO change on the y-axis. If there is a relationship, a trend should be apparent with points tending to increase from left to right on the graph.

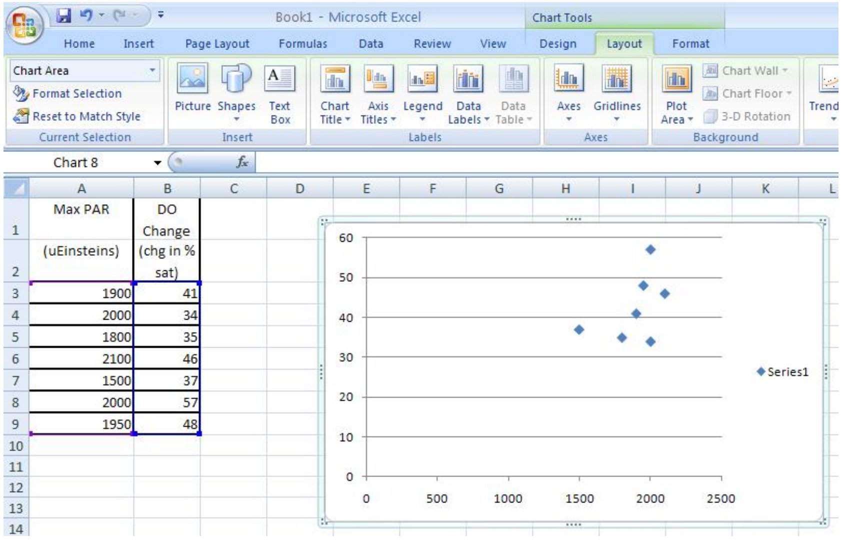
19. Open a blank sheet in Excel. Then copy and paste the Max PAR and DO Change columns from Table 1 into Excel.



20. Highlight the data in both columns. Click the Insert tab at the top of the page. Click Scatter and then the highlighted scatter plot shown in the screenshot below.



21. A scatter plot showing the data will appear on the screen. Max PAR should be on the x-axis and DO Change on the y-axis. However, these will not be labeled so you will have to label these axes and also give the plot an appropriate title. This can be done by clicking the Layout tab under Chart Tools and choosing Chart Title and Axis Titles.



Report

1. Table 1 showing Solar radiation (PAR) and DO Minimum, Maximum, Difference table for each day 2.
2. Graph showing relationship between Maximum PAR and %ODO Difference
3. Answer questions:
   - -Does the data support your hypothesis?
   - -Critique of test of hypothesis
   - -Possible alternative explanations for the data
   - -Other ways to test the hypothesis
   - -What might happen if we had a lot of cloudy days in a row?

Extension

Retest for another set of paired dates at different time of year
Retest for another set of paired dates at different site (VECOS, Eyes on the Bay, CBIBS)
Set up an in lab (more controlled?) test using Labware and aquariums with defined species
Elodea & Photosynthesis Lab

Dissolved Oxygen criteria image: http://www.chesapeakebay.net/do.htm

Vocabulary

Biomass: the amount of living matter in a given habitat, expressed either as the weight of organisms per unit area or as the volume of organisms per unit volume of habitat. Aerial productivity of algae biomass is reported as grams per square meter, tons per acre, tonnes per hectare. Volumetric productivity of algae biomass is commonly reported as grams per liter.

Cellular respiration is carried out by every cell in both plants and animals and is essential for daily living. It is the process by which food is broken down by the body's cells to produce energy, in the form of ATP molecules. In plants and algae, some of this ATP energy is used during photosynthesis to produce sugar. These sugars are in turn broken down during cellular respiration, continuing the cycle that is essential for growth. Dissolved oxygen is used to make ATP energy.

Name:_____________________________

Table 1.

Date	**Max PAR (uEinsteins)**	**Min DO (% saturation)**	**Time of Min DO**	**Max DO (% saturation)**	**Time of Max DO**	**DO Change (chg in % sat)**