



Schools on Board Lab/Fieldwork Activity Example

(As it appears in the Student Handbook!)

Tracking down phytoplankton biomass in the water column HYPOTHESIS DRIVEN LAB ACTIVITY

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Lab Instructor: Karine Lacoste Subgroup: 3. Light, Nutrients, Primary and Export Production in Ice-Free Waters

This lab will take place: In the conference room

Time required to complete this lab:

Investigation: 1½hr (see field activity)

Breakdown for a 1½hr lab:

10-15 minutes to describe and demo activity;

45 min. for the students to put into graph the data they collected in the fieldwork activity as well as other data from other time periods or areas, also to look at results from nutrients.

Student output: 30 min. compare and interpret results of data worked on

PREPARATION

A general reading on phytoplankton (see attached document).

*This lab activity needs to be done after the fieldwork activity. Results will have come from the fluorometer readings that the students will have done prior to the lab activity. In the event of problems related to filtration or fluorometer readings, dataset from previous sampling on board the ship will be provided to the students for them to analyse.

BACKGROUND

Planktonic production estimates for the arctic continental shelves are scarce, due to the difficulties associated with access to these areas. Furthermore, the mechanisms related to the inter-annual variability of primary production with regard to natural physical and/or biological forcing are not well known. The lab activity done during the Schools on Board programme intends to describe the water column distribution of the size-fractionated phytoplankton community of Franklin Bay during the month of February and compare it to other time periods of the CASES project. Although the CASES project will cover a much larger area over a longer time frame, the results of this lab activity will contribute in answering some of the objectives of the primary production subgroup of the CASES project which are:

- (1) to determine the biomass and the production of pico-, nano- and microphytoplanktonic cells in the photic zone over the Mackenzie Shelf, and in the Cape Bathurst polynya and Franklin Bay areas.
- (2) to evaluate the relative contribution of phytoplankton to the total primary production in these areas,
- (3) to assess the effects of the bio-optical factors on the vertical attenuation of the ultraviolet component of the solar spectrum in the water column, and

RESULTS (Student Output)

Sheets for making graphs will be provided

DISCUSSION/CONCLUSION

Is there a chlorophyll maximum at this station for this period of the year? What can you say about this chlorophyll profile of the water column?

How does this data set compare to the other data sets that you analysed? What is similar? What is different?

How could you explain those similarities and dissimilarities?

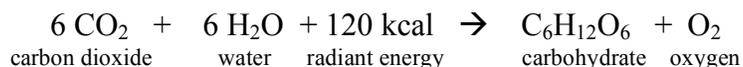
PREPARATION DOCUMENT

Plankton, a word derived from the Greek term "planktos" which means to wander, are bacteria, plants, and animals which drift passively in the water because their swimming ability is limited or non-existent. Many can swim actively, but they are so small that they usually cannot move faster than the waters are flowing. Plant members of the plankton are termed phytoplankton (phyto=plant) while the zooplankton (zoo=animal) are the animal plankton. Phytoplankton are microscopic plants that contain chlorophyll and hence obtain energy for growth by photosynthesis. Zooplankton are small herbivorous or carnivorous animals that feed on phytoplankton or on other zooplankton. Phytoplankton live near the surface in the *photic zone* where there is enough light for photosynthesis (<100 m approx.), while zooplankton are present in the photic zone as well as in much greater depths.

One simple way in which oceanographers describe planktonic organisms, whether plants, animals, or bacteria, is to classify them by size. Three groupings are commonly used. Those having diameters between 20 and 200 micrometer (μm) are called microplankton; we find in this group phytoplankton cells called diatoms and dinoflagellates. (A human hair is about $100\mu\text{m}$ in diameter.). Plankters less than $20\mu\text{m}$ in diameter but larger than $2\mu\text{m}$ are called nanoplankton; this group has phytoplankton organisms such as coccoliths and silicaflagellates. The smallest category of plankton is the ultraplankton which are smaller than $2\mu\text{m}$ and include bacteria and cyanobacteria.

Diatoms are the most common and most important group of phytoplankton found in arctic waters. They are single-celled algae and have hard external skeletons made of silica, in either a pillbox or rod-like shape. Some species have sticky threads or long spines protruding from their bodies and form long chains of individual cells, especially in nutrient-rich waters. The second most abundant phytoplankton are dinoflagellates. Dinoflagellates come in a variety of shapes and forms but are usually recognizable because of their paired, whip-like flagella which renders them capable of movement. Some have rigid cell walls made of cellulose, while others do not. Coccolithophores, another major group of flagellated phytoplankters, are distinguished by their coatings of tiny calcareous plates. Finally, a group of bacteria – the cyanobacteria (having blue-green pigments) – include some of the smallest types of phytoplankton as well as some of the largest. Some cyanobacteria play a very important role as nitrogen fixers in the ocean.

Phytoplankton cells contain *chlorophyll* or some other light-absorbing pigment which allows them to synthesize organic matter, using energy from sunlight and nutrients dissolved in the water. These pigments capture energy from sunlight, and the marine plant then uses that energy to combine dissolved carbon dioxide with water, forming carbohydrates, which are energy-rich compounds consisting of carbon, hydrogen, and oxygen.



The availability of light controls plant growth and phytoplankton distributions in the ocean. Light is absorbed as it passes through water. The clearest open-ocean water is most transparent (absorbs the least amount of light) in the blue-green range of colors. As concentrations of particules and dissolved organic matter increase, the color of the light that penetrates deepest into the water shifts from yellowish green in coastal ocean waters to red in the most turbid estuarine waters. Thus, as light gets dimmer with increasing depth, its color also changes. This change in color affects plant production because each plant pigment is most efficient with a specific color of light. The combination of pigments found in any type of phytoplankton will determine its *optimal depth distribution*.

The chlorophyll content per volume of seawater gives a direct reading of the total *biomass* of plants present. The determination the chlorophyll *a* pigment, using the fluorimetric method, represents the most common method of assessing the production of phytoplankton in the sea. Color sensors on satellites also measure chlorophyll concentrations, however only of surface waters, and consecutive satellite images show how these concentrations change with season. Such measurements can be averaged and combined to provide maps of the global distribution of marine plant growth.

Primary production is affected by several factors. Here is a list of the most important ones:

1. Light: Phytoplankton production is closely coupled to sunlight as a source of radiant energy for photosynthesis. There are four aspects of light which are mostly important when studying phytoplankton productivity: (1) the intensity of incident sunlight; (2) changes in light on passing from air into water; (3) changes in light with increasing water depths; and (4) the utilization of radiant energy by phytoplankton cells.
2. Nutrients: In addition to light, marine plants need a number of nutrients for adequate growth and reproduction, the most critical being nitrogen, phosphorus, and silicon.
 - a) Nitrogen (as nitrate (NO_3), nitrite (NO_2), and Ammonia (NH_3)) is the chief limiting element to primary production growth in estuarine and oceanic waters. Nitrogen is particularly important in the formation of proteins.
 - b) Phosphorus plays a role in energy transfers and in the formation of cells membranes and genetic materials. Phytoplankton takes up phosphorus primarily in the form of phosphate (PO_4). Zooplankton grazing and excretion account for rapid regeneration of phosphates in *pelagic waters*. The amount of phosphate in seawater is rarely limiting which makes nitrogen shortage rather than phosphorus limitation more deemed to be responsible for halting the growth of phytoplankton populations in marine ecosystems. Nitrogen and phosphorus undergo seasonal cycles usually accumulating and peaking in the winter, subsiding rapidly in the spring, remaining low in the summer, and rising again in the late fall. As phytoplankton populations increase in the spring, they assimilate nutrients which then become depleted. In winter, phytoplankton populations decline, and the nutrients attain maximum levels.
 - c) Silicon (Si), when present in very low amounts, represses metabolic activity of the cell and can limit phytoplankton productivity. However, it also represents an essential element for the skeleton growth of diatoms.

Some of these elements are often scarce in seawater, and this scarcity limits production for many organisms, even when there is enough sunlight. Scarcity of any one nutrient can limit production, but in many ecosystems two or more nutrients are co-limiting. As plants die and decompose in the surface zone, about 95 percent of the nutrients contained in their tissues is released into surface waters by decomposition and quickly taken up by growing plants. The remaining 5 percent is released below the surface zone, because some of the tissues and shells sink before decomposing. Because there is usually too little light for photosynthesis at these lower depths, nutrients released in the *aphotic zone* accumulate there. These deep-sea nutrients move along with sub-surface currents and are returned much later to surface waters.

3. Hydrographic components exert a major influence on primary productivity in the ocean as well. Currents and upwelling create mixing of the water column and help deep-sea waters to return to the

surface of the sea. They therefore both effect light and nutrients conditions by limiting or enhancing phytoplankton productivity.

4. Zooplankton grazing: Of all biological factors, grazing by herbivorous zooplankton most significantly limits phytoplankton production. Whereas some phytoplankton losses in the ocean arise via sinking below the photic zone, the vast majority of cells disappear by zooplankton grazing. Grazing intensity by these herbivores varies both in space and time. Selective feeding by zooplankton potentially governs the composition of the phytoplankton community. When grazing is intense and phytoplankton abundance decreases below a critical level, zooplankton abundance likewise wanes after a lag period.

Coastal waters and estuaries typically are much more productive than the open ocean. These habitats are shallower which allows light to sometimes penetrate the entire water column and nutrients levels to be much higher than in open-ocean areas therefore creating an excellent environment for plant growth. When these favourable conditions are present, there is usually a rapid increase in phytoplankton abundance and biomass; such a rapid increase is called a bloom. When a bloom occurs, the number of phytoplankton cells can double in a day or two. The bloom ends when one of two things happen. Either the growing phytoplankton populations use up the available nutrients which they require for photosynthesis, or the herbivores eat the phytoplankters, greatly reducing their numbers. In seasonal plankton cycles, phytoplankton blooms are often superseded by a peak in zooplankton abundance.

Definition of key words:

Aphotic zone: part of the water column where there is not enough light for photosynthesis.

Biomass: amount by weight of plant (or animal) matter per volume of seawater (g/m^3 or mg/l).

Chlorophyll: green pigment of plants and bacteria which is necessary for photosynthesis.

Optimal depth distribution: depth at which productivity is most favored.

Pelagic waters: part of the water column where most organisms live

Photic zone: part of the water column where there is sufficient light radiation to allow photosynthesis.

Primary production: rate at which new organic material is synthesized from inorganic substances (primarily carbon, nitrogen, and phosphorus) using radiant light as a source of energy for photosynthesis. Primary production is measured as grams of carbon produced in one square meter of water per day ($\text{g C}/\text{m}^2/\text{d}$).

Text inspired from the following references:

- Gross, M.G., Gross, E.R, and Maybaum, H.L. (1996). Oceanography: A view of Earth 7th Ed. Prentice Hall Inc., Upper Saddle River, NJ
- Kennish, M.J. (1989). Practical handbook of marine science 2nd Ed. CRC Press, Inc. Boca Raton, FL
- Meadows, P.S. and Campbell, J.I. (1978). An introduction to marine science 2nd Ed. Tertiary level Biology, London, Eng.