FLUOROMETER

Related lesson plan

Examining Marine Green Algal Cells

What is this sensor?

Fluorometers are commonly used in oceanography to measure chlorophyll-*a*, the pigment that the microscopic marine plants and plant-like organisms (called phytoplankton) use to produce food. By measuring chlorophyll in the water, researchers can get an idea of the health and productivity of the upper layers of the ocean.

A fluorometer is a device that measures the fluorescence or light emitted by different fluorescing objects. Fluorescence occurs when one wavelength of light hits and excites electrons in a material, and the electrons in that object instantaneously emit (fluoresce) light of a different wavelength. For example, an object exposed to blue light, may fluoresce (emit light) in the red end of the spectrum. All fluorescent objects have their own “signature” meaning that they excite and emit only certain types of light. A common example is white objects under “black” (ultraviolet) light. In normal daylight, white objects appear white, but under black light, they appear to glow, or fluoresce. Not every fluorescent object needs black light to glow; many objects fluoresce under regular white light. For example, familiar fluorescent objects would be the ink from highlighters or fluorescent clothing. These objects fluoresce under normal light, which is why they appear to “glow” as we look at them.

How does a fluorometer work?

Fluorescence occurs when electrons in an object are excited at one wavelength of light and then immediately emit light (fluoresce) at a different wavelength. All fluorescent objects have their own “signature” of fluorescence, meaning that they will absorb a certain wavelength and emit at a different, but predictable wavelength of light. For example, when chlorophyll is exposed to blue light, it fluoresces with a red wavelength of light. So, the instruments used by researchers typically illuminate at excitation wavelengths and read emission wavelengths that are specific to the compounds they are interested in, e.g., chlorophyll-*a*. So a “chlorophyll fluorometer” can tell them how much chlorophyll is in their sample. When a lot of fluorescent material such as the chlorophyll in phytoplankton is present in the water, the sensor will pick up a lot of red light.

How is chlorophyll from a fluorometer measured?

(μg/l) or (ppb)

On the Ocean Networks Canada observatories, the fluorometers use a small blue LED light to excite any chlorophyll present in the water. Chlorophyll fluorescence is then converted to chlorophyll concentration and is expressed as micrograms per litre, written as (μg/l). It can also be written as parts per billion (ppb) which is an identical measurement to (μg/l) in liquid solutions. This number is reflective of the number of parts or grams of chlorophyll that are fluorescing in a defined volume of water (the concentration). For example, if the fluorometer gives a reading of 35, this means that the fluorometer is detecting 35µg/l of fluorescence. It's important to note, that the fluorometer detects the amount light returning to it, not the number of objects that are glowing; therefore the number 35 does not mean that there are 35 glowing objects, but simply that there is 35µg of fluorescing material in the sample. In general, the concentration of chlorophyll increases with the total amount of phytoplankton in the water. However, the chlorophyll fluorescence in some cells may have slightly more or less fluorescence which means that the relationship between chlorophyll fluorescence and the amount of phytoplankton may not always be the same. Thus, researchers can compare the concentration of chlorophyll over time, and get a good idea of seasonal changes of phytoplankton mass in the water.

What is the normal range for these data? What variables influence it?

General quick reference:

Seasonally dependent. 0 (winter), 50+ (spring bloom).

Detailed explanation

Chlorophyll is the pigment that allows plants to use light energy and carbon dioxide to make sugars for food. Like land plants, ocean plants and phytoplankton need the right combinations of light and nutrients to grow. Also like land plants, phytoplankton tend to grow faster and in larger amounts (blooms) during different seasons, primarily in the spring and fall because conditions are most favourable, though some phytoplankton may be present all year. Seasonal patterns of phytoplankton growth vary with latitude, or the distance from the equator. In temperate locations phytoplankton may "bloom" (a large sudden growth) when conditions are perfect, namely in the spring and fall. In the high arctic, phytoplankton may not be able to grow until there is both enough sunlight per day and until the seasonal retreat of sea ice occurs in the summer. In tropical waters, phytoplankton grow all year, as nutrient conditions do not favour fast-growing species, thus these locations do not have a 'bloom' like we would observe in temperate seas.

Phytoplankton can also be affected by predation as they are the base of the ocean food chain and subject to grazing by zooplankton (tiny planktonic animals). As phytoplankton levels increase so do their predators which are an important source of food for fish and seabirds. In the tropics, fish and seabirds may be present in consistent numbers all year. In temperate or arctic regions, fish or seabirds may arrive for blooms only to leave when food levels fall below the level needed to support them.

Chlorophyll data may vary or show patterns based on a number of variables such as:

- **Water temperature:** Phytoplankton will generally grow faster with warmer conditions. However, different phytoplankton species can usually only tolerate certain temperature ranges and will not grow if the water is too hot or too cold. As phytoplankton can only grow in the sunlit zone, the importance of temperature is related more to latitude than depth.

- **Depth:** Phytoplankton require sunlight to grow, and growth only occurs in the sunlit zone. It is possible for phytoplankton to become mixed into deeper layers, but they will not grow in these layers, and may die if they cannot return to the sunlight layers in time.
- **Nutrient availability:** Phytoplankton in the oceans, like land plants, need particular elements such as carbon, nitrogen, and phosphorous in large amounts (macronutrients) to grow properly. Some important species also require silica and all species need some nutrients such as iron in very small quantities (micronutrients). The availability of these nutrients is often seasonal.
- **Fluorescent wavelengths:** Chlorophyll is synthesized by phytoplankton cells to create food. However, when a cell dies or is chewed apart the chlorophyll is released into the water and starts to break down. The first breakdown form of chlorophyll still fluoresces just like chlorophyll and fluorometers cannot tell the difference. The only way that researchers have of distinguishing between the two forms is to collect cells, remove the chlorophyll and measure it in the lab.
- **Predation:** Phytoplankton are at the base of most marine food webs, and are preyed upon by zooplankton and other microscopic animals.
- **Light:** Like most plants, phytoplankton need light to synthesize their food. Light may be restricted by season, or due to other factors such as sea ice cover or even cloudiness.

Chlorophyll is used to help determine how much phytoplankton (or primary) production is taking place in the ocean. Seasonal blooms and patterns in time can help researchers determine the health of a body of water, and to anticipate some changes and impacts. For example, an unusual bloom may indicate a change in the chemistry of a body of water—or other changes, such as hypoxia—are likely to occur. It's important to note that although the fluorometer measures chlorophyll, it is not the chlorophyll that is important to the ocean, it's the primary producers (phytoplankton) that influence the body of water. Factors and variables affecting primary production are listed below, in alphabetical order. Bear in mind, many of these factors interact, and trends and variations in chlorophyll fluorescence can often be attributed to more than one single factor or variable.

Depth

Chlorophyll is produced by primary producers, which require sunlight to survive and create food. All primary production occurs within the first 200 or so metres of the ocean. Beyond this depth, there is not enough light for phytoplankton to grow. Occasionally, phytoplankton may become mixed deeper due to tidal, wind, or wave action, but the phytoplankton cannot survive at this depth.

In the data, you will notice that fluorometers are placed in shallow, rather than deep, locations.

Light

The availability of sunlight is crucial to the production of phytoplankton and chlorophyll. Sunlight may be restricted due to latitude, season, and weather patterns. Equally, depending on latitude, sunlight may be restricted due to ice cover for much of the year. Without regular access to sunlight, phytoplankton are not able to grow. It is not uncommon for phytoplankton to “bloom” in large numbers in the spring and fall due to the long daylight hours. Occasionally, smaller blooms may occur in periods of continued sunlight as well. Equally, it is not abnormal to notice a decrease in chlorophyll in the early morning (as phytoplankton have not been able to photosynthesize at night) with the highest concentrations in the late afternoon (after the phytoplankton have been photosynthesizing all day).

In the data, you may notice an increase in phytoplankton growth that can be related to seasonal changes in light (i.e. longer days) or due to sea-ice melt allowing sunlight to reach the water.

Nutrient availability

Like other plants and animals, phytoplankton require other nutrients—such as nitrogen and phosphorus in large quantities, and iron, zinc and manganese in very small quantities—to complete photosynthesis and grow properly. Nutrient availability is often a limiting factor in phytoplankton growth, so an overabundance of nutrients can cause unseasonable or unsustainable phytoplankton blooms. Agricultural runoff, sewage, and other pollution can cause *eutrophication* or an excess of nutrients, which in turn can cause a nuisance phytoplankton bloom. A large phytoplankton bloom in an area that does not normally support a large phytoplankton population may indicate a change in nutrient status, possibly caused by pollution.

As nutrients are not measured alone, you may notice a spike in chlorophyll that cannot be reasonably related to any other factors such as temperature, light, or depth. This may indicate an influx of nutrients that may need to be confirmed through other evidence such as time of the year.

Predation

As phytoplankton are the basis of many marine food webs, they are subject to significant predation. Most predation occurs at night as zooplankton use the cover of darkness to protect themselves from their predators as they feed.

Ideas for classroom explorations

This section is intended to inspire you and your students to explore different ways of accessing, recording, and interpreting data. These suggestions can be used "as is", or can be freely modified to suit your needs. They can also be used to generate discussion and ideas, or as potential staring points for projects.

- Record the oxygen, temperature, and chlorophyll on a daily basis. Watch for seasonal trends to appear. Inquire, are meteorological changes reflected in the water data at the same time, or is there a delay?
- Monitor oxygen levels, chlorophyll, and meteorological conditions. What is their relationship over time? Can your data help you make further predictions?
- Compare oxygen and temperature readings after specific meteorological events. For example, do the data change during or after a heavy rain or periods of intense sunlight?
- Compare local readings to those in other locations. Will one predict or precede the trend of another? What other factors may account for the change in your data?
- Monitor chlorophyll levels and predict when the bloom will begin, peak, or end. Compare your prediction to actual data.

Ideas for projects

This section contains suggestions for long-term projects you and your students may be interested in investigating using the data. These projects may require support from multiple data sources, experts in the field, or additional experimentation.

- Compare the data and inquire about relationships among other seasonal trends. For example, during fish migrations is there a trend in the data? In successful spawning or hunting years, are there differences observed from unsuccessful spawning or hunting years?
- Compare data from several years. Can a seasonal or annual trend be determined? Can this trend be attributed to something using additional data, anecdotal evidence, or both?
- Compare multiple stations using the same variables.
- Explore how chlorophyll and oxygen levels change over an hourly basis. Do we see biological responses to these changes as well?
- How do tides appear to be impacting your readings? Are their correlations among tidal movements and the data you see?
- Investigate problem-solving solutions to human-caused phytoplankton blooms. For example, a phytoplankton bloom may be caused by farm run-off (i.e., nutrients from fertilizers are causing a bloom). What measures could be put in place or invented to correct or prevent the problem?
- Explore which phytoplankton species are responsible for your local bloom. Compare, are they the same ones found in other areas?
- Design the ultimate species of phytoplankton. Which features do you consider to be desirable? For example is the “ultimate” phytoplankton the one that best feeds fish, sequesters the most carbon from the atmosphere, or sinks fastest (pulling carbon into the deep ocean) the most efficiently? Which features would it need for success?

Common misconceptions or difficult concept elements

This section contains suggestions for long-term projects you and your students may be interested in investigating using the data. These projects may require support from multiple data sources, experts in the field, or additional experimentation.

- *Fluorometer* is a generic term for an instrument that detects fluorescence. The instrument can be used by a number of different fields in science. At Ocean Networks Canada, they are primarily used to detect chlorophyll.
- *Fluorescence* is the emission of light of a specific part of the light spectrum. This means that a fluorometer will detect any light reflected in a same or similar wavelength (or part of the spectrum) as the returning light.
- A fluorometer does not create a "count" of objects. Instead it measures the amount of fluorescence that returns to it. This means that the measurement is based on the strength of the returning light, not the number of plankters in the sample.
- Chlorophyll is an organic compound and can take a while to break down, so a phytoplankton bloom may be finished, but still appear in the water for a short time.