Biology Background Info

Primary Productivity in the Marine Environment

Microscopic plant-like organisms called phytoplankton are essential to the marine ecosystem. Not only are they responsible for ~50% of the oxygen you breathe and an important carbon sink, but they also form the foundation of most marine food webs (Sverdrup and Kudela, 2017). As primary producers, phytoplankton are able to create their own food by converting energy from sunlight into sugars. They generate the energy-rich organic material that is available for consumption by all the other organisms. In fact, our charismatic megafauna - such as whales - could not exist without phytoplankton!

The rate at which sunlight is stored by phytoplankton as organic matter, also known as primary productivity, is driven by the process of photosynthesis:

$$6CO_2 + 6H_2O \xrightarrow[\text{nutrients}]{\text{light}} C_6H_{12}O_6 + 6O_2$$

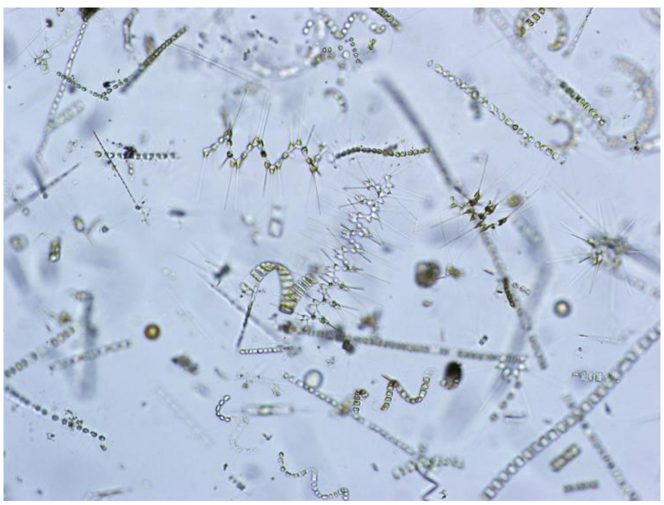


Figure 1. An assemblage of diatoms, one of the most abundant and diverse groups of phytoplankton. Photo credit: Ocean Research College Academy

When rates of productivity are high, plankton biomass can accumulate in the form of a “bloom” (Figure 1). How can we tell when a bloom is occurring? All phytoplankton contain a green or brown pigment called chlorophyll *a* that helps them capture energy from the sun, so scientists can essentially use the color of the ocean to estimate the amount of plankton in the water. In other words, chlorophyll *a* is considered to be an excellent proxy for phytoplankton biomass. We can also monitor some of the drivers of productivity to predict when conditions might be right for a phytoplankton bloom.

Drivers of Primary Productivity

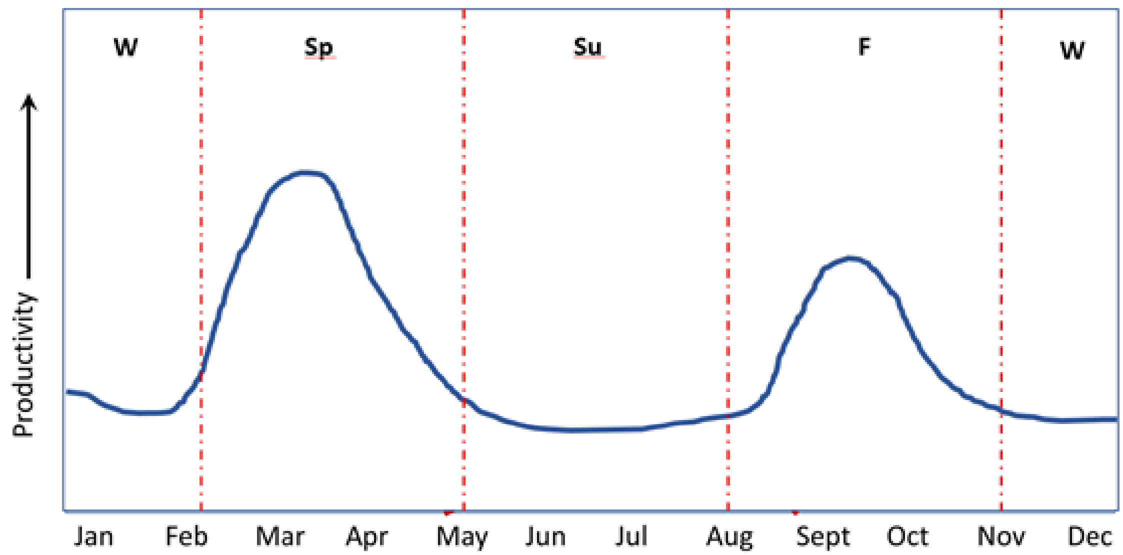
There are many factors that can influence spatio-temporal patterns (patterns by location and time) in marine primary production, but the most important factors are *sunlight* and *nutrients*. Because of the light requirements, all photosynthesis happens in surface waters where sunlight can penetrate (i.e., the photic zone). The duration and intensity of sunlight also varies with latitude and season.

Nutrients, such as nitrogen and phosphorus, are also essential to phytoplankton growth. In the open ocean, nutrients accumulate in deeper waters and are brought to the surface through upwelling and mixing of the water column. In coastal areas, nutrients can also be added to the ecosystem through coastal runoff and river systems. *Take a moment to brainstorm some of the sources and pathways of nutrient delivery in your local ecosystem.*

Seasonal Patterns of Productivity

Like land plants, the photosynthesizers of marine ecosystems also experience seasons and variations in productivity throughout the year. In mid-latitudes, a typical annual pattern involves a large spring plankton bloom, a smaller bloom in the fall, and periods of low productivity during the summer and winter months (see callout box). This pattern is driven by the fluctuating dance of nutrient and light availability throughout the year. However, these patterns can be further complicated in coastal areas or inland seas due to additional nutrient inputs such as rivers, stormwater runoff, and anthropogenic wastewater.

Typical Mid-Latitude Productivity Patterns



- **Winter:** In mid-latitude winters, heavy winds and winter storms contribute to mixing of the water column, allowing nutrients that have accumulated at depth to be brought to surface waters. Despite the availability of nutrients, however, primary productivity is typically low due to lack of light and the mixing of phytoplankton below the photic zone.
- **Spring:** As sunlight becomes more available and more direct in the spring, phytoplankton take advantage of all those nutrients hanging out in the surface waters, and the spring bloom is triggered.
- **Summer:** With summer comes a more stratified or layered water column due to the warming of surface waters. This limits mixing, so nutrients in the surface waters are not easily replenished after being used up by the spring bloom. Furthermore, populations of zooplankton act as a “top-down” control and may limit phytoplankton growth through consumption.
- **Fall:** As winds pick up and temperatures cool in the fall, the stratified water column breaks down and nutrients are again mixed to the surface layers, including nutrients from previous blooms that had sunk to the bottom. A second bloom occurs, but is smaller than the spring bloom as a result of reduced light availability.

Image inspired by figure from Roger Williams University

About the Study Area

The data you are about to explore were collected in Possession Sound, WA. Possession Sound is located within the inland waters of Washington State and British Columbia, also known as the Salish Sea. It is a rich estuarine ecosystem heavily influenced by the Snohomish River. This glacially fed river collects runoff and flows through old-growth forest, rich farmland, and dense urban areas before emptying into Possession Sound. The interactions between the strong river discharge and the tidal influence form a salt-wedge estuary at the river's mouth, leading to high stratification (i.e., layering) of the water column. River discharge patterns can be monitored through the United States Geological Survey in Monroe, WA.

The Ocean Research College Academy (ORCA) has been monitoring the health of the Possession Sound ecosystem since 2005. As part of this monitoring, a conductivity, temperature, and depth (CTD) device deployed near Mukilteo, WA collects data on local water chemistry every 15-30 minutes (Figure 2). Parameters measured include temperature, salinity, pH, dissolved oxygen (DO), turbidity, and chlorophyll. The true depth of the device changes with the rising and falling of the tide, but it is fixed at 2 m from the seafloor. A weather station above the surface also records wind speed and direction. You will have a chance to use data collected from this instrument in the following activity.

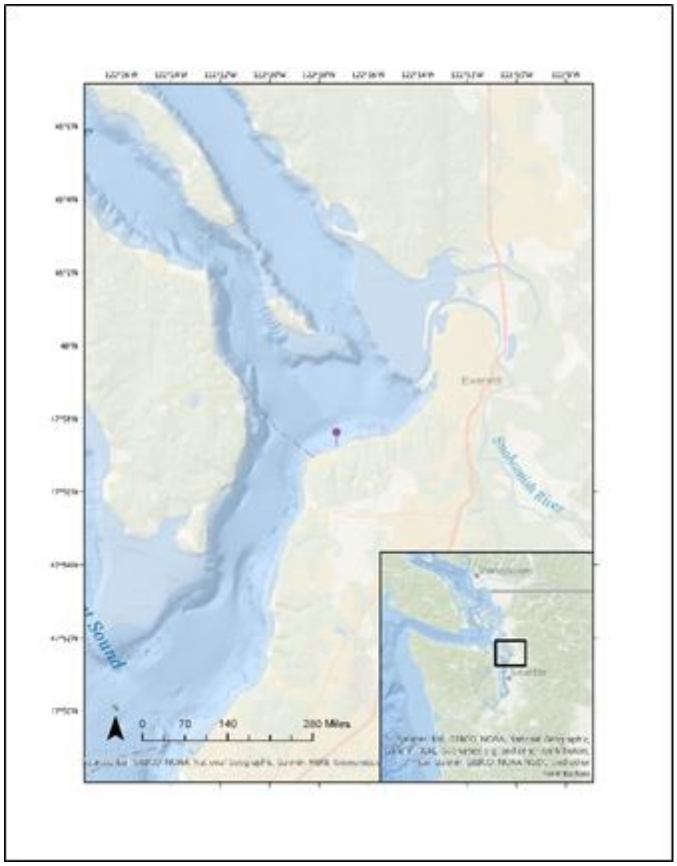


Figure 2. Map of Possession Sound, WA. The location of the CTD is indicated in purple.

Predicting Phytoplankton Blooms

Oceanographers use multiple pieces of evidence to assess the current water conditions and make educated predictions about when phytoplankton blooms might occur. To gain some practice in this, you will observe a full year of CTD data to interpret trends in plankton biomass and primary productivity. Before you begin, spend some time hypothesizing about the following parameters. You will have a chance to submit your answers once you begin the activity:

- How does wind influence the water column and how might that be related to the availability of nutrients?
- How might water temperature be related to the availability of sunlight?
- Based on what you know about photosynthesis, how can dissolved oxygen (DO) be used as an indicator of primary production?

- How might turbidity (a measurement of how clear the water is – low turbidity indicates clearer water) be related to plankton biomass?
- How might a large river system, like the Snohomish River, influence the "typical" mid-latitude patterns in productivity?

After you finish exploring the historical data and feel more confident in your ability to predict a plankton bloom, you can use our live water quality stations to assess whether you think a bloom is occurring NOW!

Resources to Explore These Topics More

Videos:

Plankton & Productivity

Weise, K. (n.d.). Productivity & Plankton - video tutorial. Available from City College of San Francisco. Retrieved from https://fog.ccsf.edu/~kwiese/content/Classes/ProductivityPlankton/ProductivityPlankton.mp4

The Ocean's Green Machines

National Aeronautics and Space Administration (NASA). 2009. NASA | Earth Science Week: The Ocean's Green Machines. Retrieved from https://www.youtube.com/watch?v=H7sACT0Dx0Q&t=1s

Books:

Sverdrup, K. A. & Kudela, R. M. 2017. Investigating Oceanography. New York, NY: McGraw-Hill Education.

Trujillo, A. P. & Thurman, H. V. 2017. Essentials of Oceanography. Boston, MA: Pearson Education, Inc.

Exploring Marine Primary Productivity with Descriptive Statistics and Graphing in Excel
Marina McLeod, Jennifer Olson, Wendy Houston

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