# Lab 7 – Identify factors that control primary production in the western temperate Atlantic Ocean

Name: Section number \_\_\_\_\_\_\_\_\_\_\_\_\_

Complete the lab and use this form as your answer sheet. Type answers in the Text boxes which will expand as you type in them.

# Lab 7.1 - How does the abundance of phytoplankton vary over the course of a year?

1. Describe the trends and patterns you see in the concentration of chlorophyll over the course of the year. Pay particular attention to the following: During which months does chlorophyll tend to be higher? Intermediate? Lower? During which months does chlorophyll tend to increase? Decrease?

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1. Assume the following seasons:

Winter = December, January, February; Spring = March, April, May

Summer = June, July, August; Fall = September, October, November

Order the seasons from highest to lowest expected phytoplankton abundance.

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1. Based on what you know about photosynthetic primary production, which factors might affect chlorophyll concentrations? Formulate some preliminary ideas here that you will be able to explore in more detail in the next activity.

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1. Right whales feed on copepods (zooplankton), which in turn feed on phytoplankton. Would the abundance of zooplankton in this area be expected to vary seasonally as well? Would the abundance be highest and lowest in the same months as phytoplankton? Why or why not?

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# Lab 7.2 - What is the relationship between Chlorophyll and other abiotic variables?

1. Examine each variable and fill in the table below (for chlorophyll, you can consult your answers from Activity 7.1, Questions 1 & 2). For each variable, indicate the following information:
2. Approximate minimum and maximum values for the season
3. Magnitude of the variable compared to other seasons (e.g., is it high, low, intermediate, etc.)
4. Change in the variable over the season (e.g., does it increase, decrease, remain about the same, etc.)

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|  | **Winter** | **Spring** | **Summer** | **Fall** |
| **Chlorophyll (from Activity 7.1)** | a. | a. | a. | a. |
| b. | b. | b. | b. |
| c. | c. | c. | c. |
| **Irradiance** | a. | a. | a. | a. |
| b. | b. | b. | b. |
| c. | c. | c. | c. |
| **Nitrate** | a. | a. | a. | a. |
| b. | b. | b. | b. |
| c. | c. | c. | c. |
| **Temperature** | a. | a. | a. | a. |
| b. | b. | b. | b. |
| c. | c. | c. | c. |

1. Phytoplankton need sunlight for photosynthesis. Therefore, you might expect to see higher chlorophyll concentrations when irradiance is higher, and lower chlorophyll concentrations when irradiance is lower.
2. Looking at the different seasons, did you find a positive relationship between irradiance and chlorophyll? Justify your answer by listing examples of the values and trends of irradiance and chlorophyll within each season.

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1. What does your answer to Question 2a tell you about the impact of irradiance on the pattern of chlorophyll throughout the year? Is irradiance the only factor affecting chlorophyll concentration? Justify your answer.

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1. Phytoplankton need nutrients for growth. Therefore, you might expect to see higher chlorophyll concentrations when nutrients, including nitrate, are higher.
2. Looking at the different seasons, did you find a positive relationship between nitrate and chlorophyll? Justify your answer by listing examples of the values and trends of nitrate and chlorophyll within each season.

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1. What does your answer to Question 3a tell you about the impact of nitrate on the pattern of chlorophyll throughout the year? Is nitrate the only factor affecting chlorophyll concentration? Justify your answer.

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1. Many biological rates, including growth, are positively correlated with temperature (warmer temperatures lead to higher rates). Therefore, you might expect to see higher chlorophyll concentrations at warmer temperatures, when phytoplankton might grow faster.
2. Looking at the different seasons, did you find a positive relationship between temperature and chlorophyll? Justify your answer by listing examples of the values and trends of temperature and chlorophyll within each season.

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1. Does your answer to Question 4a indicate that the positive effect of temperature on growth rates is responsible for changes in chlorophyll throughout the year? Justify your answer.

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1. The effect of temperature on phytoplankton abundance is much more complex than the direct effect on biological rates. This is due to temperature’s effect on water density and thus the three-dimensional physical structure of the ocean environment. Temperature differences between surface and deeper water affect the stratification and mixing of the water column (for more information on density stratification, see background information to this lab activity, additional information provided by your instructor, and Lab 5).
2. The temperature plotted in the graph is the surface temperature at this location. Assuming that the water temperature at deeper depths generally remains cool throughout the year, what does the surface temperature tell you about the potential degree of stratification during the different seasons? During which season is this location likely the most stratified? During which season is it likely the most mixed (least stratified)? Explain your reasoning.

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1. Stratification and mixing affect the availability of nutrients, including nitrate, in the surface water (see background information at the beginning of lab activity 7.2 or additional materials provided by your instructor). Based on your answer to Question 5a above, during which season would you expect high nitrate concentrations at the surface? During which season would you expect low nitrate concentrations? Does this agree with what you found in the graph? Justify your answer and list actual values from the graph or table.

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1. Take a closer look at the nitrate concentration at the beginning of April: over the course of a few days, it drops sharply. Nitrate then remains fairly low throughout April despite the colder surface water temperatures indicating some degree of mixing. What might most likely be responsible for this drop in nitrate and the continued low nitrate values despite mixing?

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1. The area around the Coastal Pioneer Array recently has been identified as a high-use area for the North Atlantic Right Whales, especially during certain times of the year. During which season(s) would you expect the whales to spend time near the array, and why? In your explanation, include a detailed discussion of a) the factors leading to seasonal variability of phytoplankton abundance (from activity 7.2), b) the effect this has on the availability of food for the whales (from introduction to Lab 7 and activity 7.1), and c) how these factors informed your choice of season.

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# Lab 7.3 – Can you make predictions for patterns of variation for other years?

1. Because of the lack of nitrate data for much of the time period examined here, you were unable to check your nitrate prediction. As frustrating as this might be, scientists do not always have access to all necessary data. However, by carefully examining the available data and applying scientific knowledge, reasonable predictions can still be made. Explain your thinking behind your prediction of nitrate concentration over the four years. When did you predict nitrate to be high, low, intermediate, increasing, decreasing, etc... ? Why did you predict nitrate concentration to vary in this manner? Use your prior knowledge of the relationships between irradiance, temperature, nitrate, and chlorophyll concentration from Activity 7.2 to explain and justify your prediction.

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1. Consider your prediction for chlorophyll and compare it to the actual chlorophyll values. For either 2017 or 2018 (choose one), how well did your prediction match the actual values? Note any similarities and differences with respect to magnitude of chlorophyll values throughout the year, timing of spring and fall blooms, and anything else you notice.

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1. Discuss some possible explanations for any discrepancies between the predicted and actual chlorophyll patterns. In your explanation, consider other factors that might influence the amount of chlorophyll and timing of blooms, and might cause them to vary from year to year.

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1. Use the complete data set spanning all four years to explain how the combination of irradiance, temperature, and nitrate results in the seasonal patterns of chlorophyll concentrations:

* In all four years, chlorophyll concentrations were lowest during the summer. Explain why that is the case, using evidence from the four-year irradiance, temperature, and nitrate graphs, and concepts from Activity 7.2.
* Chlorophyll concentrations also were generally low during the winter of all four years. Explain why that is the case, again using evidence from the four-year irradiance, temperature, and nitrate graphs, and concepts from Activity 7.2.
* In all four years, chlorophyll concentrations peaked during the spring and again in the fall. Explain what happens during those seasons to result in increased chlorophyll concentrations. Use evidence from the four-year irradiance, temperature, and nitrate graphs, of irradiance, nitrate, and temperature patterns, and concepts from Activity 7.2 to support your explanation.

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1. Over the next few decades, surface water temperature is predicted to increase. Discuss the changes in magnitude of chlorophyll concentrations and timing of blooms that are expected to occur due to this warming, and explain why you expect those changes to occur.

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1. How might these shifts in magnitude and timing of phytoplankton blooms affect the migration patterns of North Atlantic Right Whales? Explain your reasoning.

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