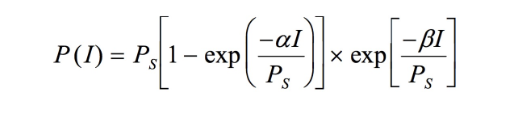
**OC 523: Midterm**

**Question 1**

This research experiment looked at the effects of PAR Irradiance and its effects on primary productivity in the upper ocean. PAR Irradiance is the part of the electromagnetic spectrum that can be utilized for photosynthesis and is fundamental driver for primary producers in ecological systems.

**Question 1A**

Primary productivity is influenced by light, or irradiance, and a number of other factors as shown in Equation 1. This curve shows the importance of light on autotroph productivity, particularly photoautotrophs which rely on sunlight to perform photosynthesis. Figure 1.1 shows how productivity grows linerally as light energy is transferred to the system but then falls off under the presence of too much irradiance.



**Equation 1.1:** Primary Productivity

**Figure 1.1:** The effects of Irradiance levels on Productivity

**Question 1B**

As light photons enter the ocean they are attenuated with depth. The sun is over 90 million miles from earth so it is fascinating to look at Figure 1.2 and realize just how quickly PAR Irradiance drops as you descend into the ocean. The figure shows that by about 100 meters down the ocean will be very dark with little light available for photosynthesis.

Ez = Eo exp^-kz

**Equation 1.2: PAR Irradiance with Depth**

**Figure 1.2:** PAR Irradiance as a Function of Depth

**Question 1C**

Productivty in the ocean drops as a function of depth. Primary autotrophic producers are generally found in the upper depths where light has not been attenuated. Figure 1.3 shows how productivity is at a maximum slightly below the ocean and then begins to fall as you descend downwards out of the euphotic zone.

**Figure 1.3:** Primary Productivity as a Function of Depth

**Question 1D**

We found the daily primary production to be about 560.45 mg\*C/m^2\*d in the mixed layer. The mixed layer depth is an area of the ocean near the surface where many physical parameters of the ocean like temperature and salinity are fairly homogenous. We utilized the Trapezoidal Rule to estimate the area under the curve in 5 meter increments which will give as an estimate of primary productivity per hour in the mixed layer. The Trapezoidal Rule does not give as accurate an estimate as a true integral of a curve but is still close. This data and the calculations are shown in Appendix 1.4 and the outcome for daily and hourly productivity are shown in Table 1.1.

**Table 1.1:** Productivy in the Mixed Layer

|  |  |  |
| --- | --- | --- |
|  | **Amount** | **Units** |
| **Hourly Productivity** | 46.70 | mg\*C/m^2\*h |
| **Daily Productivity** | 560.45 | mg\*C/m^2\*d |

**Question 1E**

Respiration takes place over the course of a 24 hour period but we are calculating our primary production taking place over a 12 hour period. In this case primary productivity refers to the production of organic matter by phytoplankton. These photoautotrophs harvest light and convert inorganic carbon to organic carbon. This carbon is then supplied to heterotrophs which obtain their energy from the respiration of organic matter in this case two of these large groups of heteroautrophs includes microzooplankton and also bacteria. A few key terms important to this problem are discussed below.

* Gross Primary Production (GPP): The total organic carbon production by autotrophs
* Respiration: The process that yields energy and converts organic carbon to carbon dioxide
* Net Primary Production (NPP): Gross Primary Production minus the autotrophs own rate of respiration or the rate at which phytoplankton produce biomass
* Secondary Production (SP): The growth rates of all heterotorphic biomass
* Net Ecosystem Production (NEP): GPP respiration of all other organisms

To find the total respiration we multiply the community respiration rate by 24 hours to get total daily respiration. Since respiration is the area under the curve bounded on the y-axis from meters to 95 meters and on the x-axis by .29 we find the total area of this to get hourly respiration in the mixed layer.

* Hourly Respiration in the mixed layer:
  + (95m)\*(.29 mg C /m^3\*h) = 27.55 mg C /m^2\*h
* Daily Respiration in the mixed layer:
  + (24 hours/1 day)\*( 27.55 mg C /m^2\*h) = 661.2 mg C /m^2\*d

So from this we see that daily production is 560.45 mg C /m^2\*d but daily respiration is 661.2 mg C /m^2\*d. So from this we would expect to see net respiration since a higher level of respiration is occurring in the community. An important point in this is that only photoautotrophs are primary producers but we are looking at community respiration which includes the respiration of these photoautotrophs. So for the community we are actually looking at Net Primary Production minus the respiration of all other heterotrophic organisms. Over time I would expect to see higher levels of primary production to total respiration so there could be an issue with my integration, calculation of respiration or this community could be respiring at a higher rate then total primary production.

**Question 2**

Researchers in this experiment were looking at the effects of microzooplankton’s grazing impact on phytoplankton. They utilized a unique experimental design that allowed them to control the amount of grazers in controlled environments. The environments contained filtered water and unfiltered seawater with three sets of samples containing only seawater. Essentially, this would be like looking at the predation of rabbits by coyotes by controlling for the number of coyotes in five separate enclosures. Rabbits are not primary producers but are in fact heterotrophs so this is not a perfect example but rather an analogy.

**Question 2A**

The realized growth rates for this experiment are shown in Table 2.1. From these equations we can see the effects that grazers have on phytoplankton.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Fraction of Seawater** | **Initial Chl-a** | **Final Chl-a** | **To** Ln(TfChl-a) | **Tf**  Ln(ToChl-a) | **Growth Rate (\*r)** |
| 0.1 | 0.035 | 0.088 | -3.352407217 | -2.430418465 | 92.20% |
| 0.1 | 0.035 | 0.081 | -3.352407217 | -2.513306124 | 83.91% |
| 0.1 | 0.035 | 0.078 | -3.352407217 | -2.551046452 | 80.14% |
| 0.25 | 0.088 | 0.172 | -2.430418465 | -1.760260802 | 67.02% |
| 0.25 | 0.088 | 0.16 | -2.430418465 | -1.832581464 | 59.78% |
| 0.25 | 0.088 | 0.193 | -2.430418465 | -1.64506509 | 78.54% |
| 0.5 | 0.175 | 0.321 | -1.742969305 | -1.136314156 | 60.67% |
| 0.5 | 0.175 | 0.255 | -1.742969305 | -1.366491734 | 37.65% |
| 0.5 | 0.175 | 0.298 | -1.742969305 | -1.210661792 | 53.23% |
| 0.75 | 0.263 | 0.385 | -1.335601247 | -0.954511945 | 38.11% |
| 0.75 | 0.263 | 0.362 | -1.335601247 | -1.016111067 | 31.95% |
| 0.75 | 0.263 | 0.395 | -1.335601247 | -0.928869514 | 40.67% |
| 1 | 0.3 | 0.4 | -1.203972804 | -0.916290732 | 28.77% |
| 1 | 0.3 | 0.43 | -1.203972804 | -0.84397007 | 36.00% |
| 1 | 0.3 | 0.45 | -1.203972804 | -0.798507696 | 40.55% |

**Table 2.1:** Growth rate as a function of microzooplankton grazing

**Question 2B**

By plotting this data an utilizing linear regression we can get the slope and y-intercept from this data. The y-intercept was found to be .85 and represents the maximum growth rate of phytoplankton in the absence of grazing. The slop is -.56 and is the mortality from grazers or the effects that grazing by microzooplankton has on phytoplankton. The reason the slope is negative is that it is showing that in the presence of more predation the growth rate will decline.

**Figure 2.1:** Growth Rate of Phytoplankton as a Function of Seawater Concentration

In normal seawater the average growth rate is around 35% as can be seen in Table 2.2. From this we can estimate that around 60% of the daily phytoplankton growth rate is being consumed by microzooplankton.

|  |  |
| --- | --- |
| **Fraction Seawater** | **Growth Rate** |
| 1 | 28.77% |
| 1 | 36.00% |
| 1 | 40.55% |
| **Average** | **35.10%** |

**Table 2.1:** Average Growth Rate

**Question 2C**

Microzooplankton are capable of feeding on plankton of very large size even in this case micro-pytoplankton. This feeding can be accomplished with peduncles inserted through cell membranes, utilizing a pallium or by stretching around their prey (Lessard, 1991). Considering a filter is removing microzooplankton I think that possibly the phytoplankton would be removed too leaving pico or nano sized phytoplankton. Also, this is taking place in a subtropical gyre which may not be as nutrient dense to support the growth of larger classes of phytoplankton. For these two reasons I would expect nano or possibly pico size phytoplankton to be found in more abundance.

**Question 2D**

The value for primary production at a 10 meter depth was found to be 1.37 mgC/m^3\*h.This would mean that our estimated per day growth rate would be around 37% and our experimental average growth rate was estimated to be about 35%. Both of these experiments took place with the same amount of irradiance and since light is a primary driver of phytoplankton growth so this is not the reason for the difference.

**Question 2E**

The total biomass production by hetertrophic biomass was averaging 70 mg\*C/m^2\*d with an efficiency of .15. From Table 2.2 we can see that around 144% of primary production is being consumed by these two groups which is larger then total carbon being produced by 44%.

|  |  |  |
| --- | --- | --- |
| **Biomass Production of Bacteria** (mg\*C/M^2d)` | **Total Organic Carbon Consumption** (mg\*C/M^2d) | **Total Phytoplankton Production** (mg\*C/M^2d) |
| 70 | 466.67 | 560 |

**Table 2.2:** Production and Consumption of Carbon

From question 1E we had a daily production of 560.45 mg C /m^2\*d and daily respiration of 661.2 mg C /m^2\*d which gives us a value of 117.9%. There is difference between these values.

|  |  |
| --- | --- |
| Percent Used by Bacteria | 83.33% |
| Percent Grazed by Microzooplankton | 60.00% |
| **Total** | 143.33% |

**Table 2.2:** Carbon Utilizaiton

**Question 3**

*Heterotrophic bacteria perform two major functions in the transformation of organic matter: They produce new bacterial biomass (bacterial secondary production [BP]), and they respire organic C to inorganic C (bacterial respiration [BR]). For planktonic bacteria, a great deal has been learned about BP and its regulation during the past several decades but far less has been learned about BR. Our lack of knowledge about BR limits our ability to understand the role of bacteria in the carbon cycle of aquatic ecosystems. Bacterial growth efficiency (BGE) is the amount of new bacterial biomass produced per unit of organic C substrate assimilated and is a way to relate BP and BR: BGE = (BP)/(BP + BR). Estimates of BGE for natural planktonic bacteria range from <0.05 to as high as 0.6, but little is known about what might regulate this enormous range. In this paper we review the physiological and ecological bases of the regulation of BGE. Further, we assemble the literature of the past 30 years for which both BP and BR were measured in natural planktonic ecosystems and explore the relationship between BGE and BP. Although the relationship is variable, BGE varies systematically with BP and the trophic richness of the ecosystem. In the most dilute, oligotrophic systems, BGE is as low as 0.01; in the most eutrophic systems, it plateaus near 0.5. Planktonic bacteria appear to maximize carbon utilization rather than BGE. A consequence of this strategy is that maintenance energy costs (and therefore maintenance respiration) seems to be highest in oligotrophic systems.*

**Question 3A**

**\*help**

We are looking at the change in Heterotrophic Bacteria over the course of six days. This occurs from Day 157 to 163 so over a span of 6 days which we see an increase in roughly 1 million cells due to the enrichment of iron.

**Part 1:** Slope of Line = (2-1.3)/6 =.12 cells / milliter \* day

**Part 2:** (1.25E6Cells/mL)\*(15E-15gC/cell)(1000mL/L)(1E6) = 18.75

**Part 3:** Biomass per Liter 18.75μgC/Liter

This means that because of the bloom there was a total biomass increase in hetertrophic bacteria of 18.75 μgC/Liter.

**Question 3B**

(18.75 μgC/Liter) \* BGE (.25) = 75μgC/Liter

The bacteria utilized 75μgC per Liter during this increase in biomass.

**Question 3C**

The total increase in phytoplankton carbon biomass during the bloom appears to have risen from about 25 μgC/Liter to 125 μgC/Liter for a total rise of about 100 μgC/Liter. The bacterial appeared to have utilized 75 μgC/Liter for their bloom that occurred slightly after the bloom of pythoplankton.

*Dissolved organic carbon (DOC) is defined as the organic matter that is able to pass through a filter (filters generally range in size between 0.7 and 0.22 um). Conversely, particulate organic carbon (POC) is that carbon that is too large and is filtered out of a sample.*

**Question 3D**

Respiration

Grazing

**Question 3E**

Grazing and microbial food procceses

Growth is controlled by

Nutrient supply

Temperature

Light level

pH

**Question 4**

**Question 4A**

Carbon cycling is an integral part of life for both pelagic and terrestrial systems. In this research we are looking at carbon cycyling thorugh the benthic community at a depth of 4,025 meters which means this lies in the Bathypelagic or Abyssopelagic zone of the ocean where no light reaches and primary production by photoautrophs is not occurring. Thus, sinking particulate matter is an important pathway for transporting carbon and other elements to these NE Atlantic Ocean depths.

There are many different physical, chemical and biological processes that result in a sinking flux but without biological processes these would be dominated by physical processes. Generally particles leaving the euphotic zone leave it as large and fairly fast sinking particles and are an important nutrient soure for both benthic and pelagic organisms (Lee, 2004).

**Mechansims for sinking**

The general physical mechanism for this downward sinking flux is related to gravity. However as can be seen from Table 4.2 the ratio of burial into benthic biomass is very small compared to both growth and reminiseralisation. However, from a biological perspective the processes that are being undergone during this sinking flux and the processes that occur before much of this sinking flux reaches the bottom are far more important ecologically as they drive production in the ocean.

**Nature of organic matter**

* **How it was produced**

It seems from the data presented that the primary reason for this doubling of sinking flux is related to a phytoplankton bloom. Most likely this bloom is the result of a seasonal increase in PAR irradiance and also potentially calmer seas with less mixing.

* **Composition**

The composition of this sinking flux could be classified or described by both physical or biological characteristics. From a biological perspective the primary composition in the euphotic zone would be autotrophic phytoplankton produced through increased growth in sunlight. It is also composed of hetertropic organisms including microzooplakton and bacteria. As you get into the mesopelagic zone you begin to see sinking particles and zooplankton migration. In this zone and the deep ocean you will have Particulate Organic Carbon and Dissolved Organic Carbon which can be decomposed or consumed. You also will have bacteria and other deep sea organisms at this level.

* **Why it sunk**

There are a number of regions why this sinking flux began to occur. As mentioned previously the physical process of gravity is important but biological processes effect how this sinking flux happens. Phytoplankton generally will not sink due because they are too small and also have a central water filled vacuole that has electrolytes relative to sea water that allows them to stay buoyant. Sinking usually occurs when they aggregate into larger particles or or packaged into fecal matter by zooplankton. Occasionaly pythoplankton can sink as a result of experiencing nutrient stress (Smetacek, 1985). This bloom is occurring in the North Atlantic and usually will end with large cells sinking to the bottom in days or weeks as a major organic flux (Wheeler, 2012). However, not all of this organic matter will make its way to the benthic zone but you can also have suspended POC.

**Table 4.1:** Sinking Flux

|  |  |  |
| --- | --- | --- |
| **Sinking Flux (mg\*C/M^2d)** | | |
|  | **April** | **August** |
| **Sinking Flux** | 4.42 | 9.32 |
| **Biomass** | 1475 | 2265 |
| **Burial** | 0.02 | 0.18 |
| **Growth** | 0.22 | 1.82 |
| **Remineralisation** | 4.17 | 7.31 |

* **Why Carbon flux is higher in August**

It would seem that the carbon flux is higher due to the phytoplankton bloom. Phytoplankton are a primary producers so as they harvest light energy and convert inorganic carbon to organic carbon they enable the growth of hetertrophic bacteria and zooplankton. This increase is most likely to why we see this flux in August as the bloom occurs in Spring and as nutrient rich waters occur we experience the growth of bacteria and zooplankton that occur after the bloom and also we would expect some time to occur before some phytoplankton begins to sink.

**Question 4B**

Scientists working to quantify the rates of organic matter sinking flux will often utilize sediment net traps at different ocean depths. As this matter sinks its matter often changes from that of an easily identifiable nature through chromatographic techniques to that which is more complex. To estimate remineralisation you would need to sample what is occurring at the benthic region or replicate this in a lab setting if possible. Depending on which elements you were interested in studying you could look at respiration rates for carbon or other sampling techniques for the remineralisation of other trace elements.

**Question 4C**

The carbon cycling and sinking flux discussed above are incredibly important for the benthic community. Without this source of energy organisms at the bottom would have no primary producers since there is no light energy to be utilized for primary production this far down. This sinking matter is thus an important part of the deep sea food web. Growth efficiency was calculated by dividing growth as a function of sinking flux. The outcomes of this are shown in Table 4.2.

* Growth Efficiency April
  + GE = .22 / 4.42 (mg \* C / m^2 \*d)
* Growth Efficiency August
  + GE = .1.82 / 9.32 (mg \* C / m^2 \*d)

It seems that the quality of sinking matter is higher in August then it is in April. Our calculations show what appears to be higher growth rates and higher efficiency utilizing the biomass that occurs in August; this would make sense in that you need less energy to process this higher quality food.

**Table 4.2:** Ratios ofSinking Flux and Growth Effiency

|  |  |  |
| --- | --- | --- |
|  | **April** | **August** |
| Sinking Flux | 4.42 | 9.32 |
| Benthic Biomass | 1475 | 2265 |
| Burial | 0.45% | 18.00% |
| Growth | 4.98% | 19.53% |
| Remineralisation | 94.34% | 78.43% |
| Growth Efficiency | 0.01% | 0.08% |