"Locational and Temporal Abundance of Various Net Zooplankton in Bermuda"

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Author Commentary and Excerpt

Over the summer I spent a month in Bermuda studying Marine Biology (EEB 312) with James Gould (Princeton) and Samantha de Putron (BIOS). As part of the course, we collected data in the field, analyzed it in the lab, and wrote about it. The two latter stages of this process—reporting and analyzing data in the results and discussion sections—are arguably the critical sections of the report. The results are your evidence, and the discussion is where you use this evidence to investigate your motive and answer your research question.

This particular study was investigating the composition of zooplankton at different times (night and day) and different locations (inshore and offshore). Zooplankton are small, nonphotosynthetic organisms that cannot swim against the ocean's current. They do, however, have the ability to maintain and control their depth in the water. Typically, zooplankton will vertically migrate throughout the day, coming the surface of the ocean at night and sinking into the depths during daylight hours. While scientists have theories as to why this pattern occurs, no one reason or combination of reasons exists to explain this phenomenon. The goal of our research was to shed light on this area—to observe the abundance of zooplankton on the surface of the water at three different points: inshore daytime, offshore daytime, and offshore nighttime.

The first piece of evidence I examined was the number of plankton per liter at these three points (Figure 1). The data showed that during the daytime, there were more zooplankton inshore than offshore. However, for collections offshore, there were more zooplankton at night than during the day.

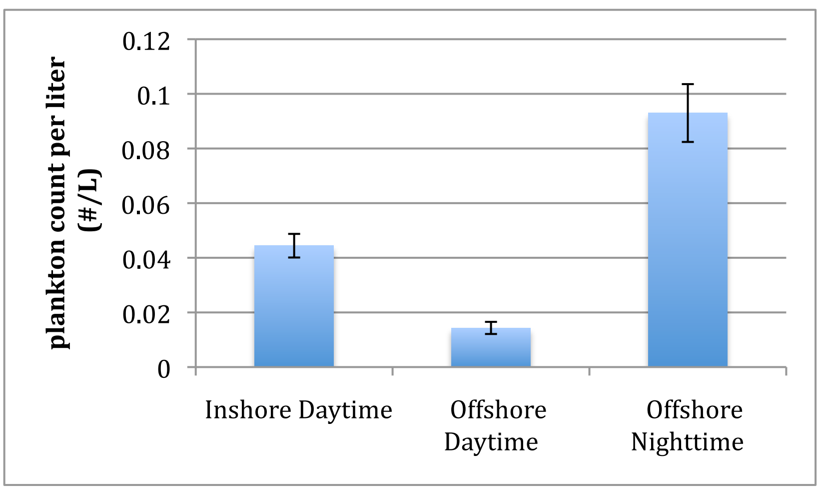

Fig. 1. Zooplankton densities in the inshore daytime tow were significantly greater than those in the offshore daytime tow ($p < 0.001$). Plankton densities in the offshore daytime tow were significantly lower than those in the offshore nighttime tow ($p < 0.001$). Inshore daytime/offshore daytime and offshore daytime/offshore nighttime were compared via a two-tailed t-test. The sample sizes for inshore daytime, offshore daytime, and offshore nighttime were 15, 8, and 7 respectively.

The first thing I wanted to focus on given these initial results was the difference between offshore daytime and offshore nighttime. The general pattern corroborated the standard dogma of zooplankton migration and suggest that Bermudian zooplankton fall within the typically observed model. While this seems like a straightforward claim (it is what you would expect), making this connection allows for in-depth investigation to follow.

> "The increase of zooplankton density that we saw from the offshore daytime tow to the offshore nighttime tow is consistent with vertical migration. As detailed in the introduction, scientists have observed that many zooplankton undergo dial vertical migration—sinking to deeper in the water column as the sun rises and ascending to surface waters as the sun sets. In accordance with this phenomenon, we found higher zooplankton concentrations at night—perhaps because many zooplankton were feeding on phytoplankton at the surface. During the day we found lower zooplankton densities at the surface—perhaps because many zooplankton had sunk deep into the water column to evade UV rays or visual predators, to ride deeper-water currents, to slow their metabolisms, or to gain some other unexplored advantage linked with vertical migration. Our offshore daytime vs. offshore nighttime data suggests that net zooplankton in this offshore region of Bermuda undergo significant vertical migration."

The next thing I wanted to investigate was species-specific patterns. Yes, zooplankton tend to be on the surface more during the night, but is this true of all zooplankton we observed? To examine this, I analyzed the density of each species we observed at the three points (Figure 3).

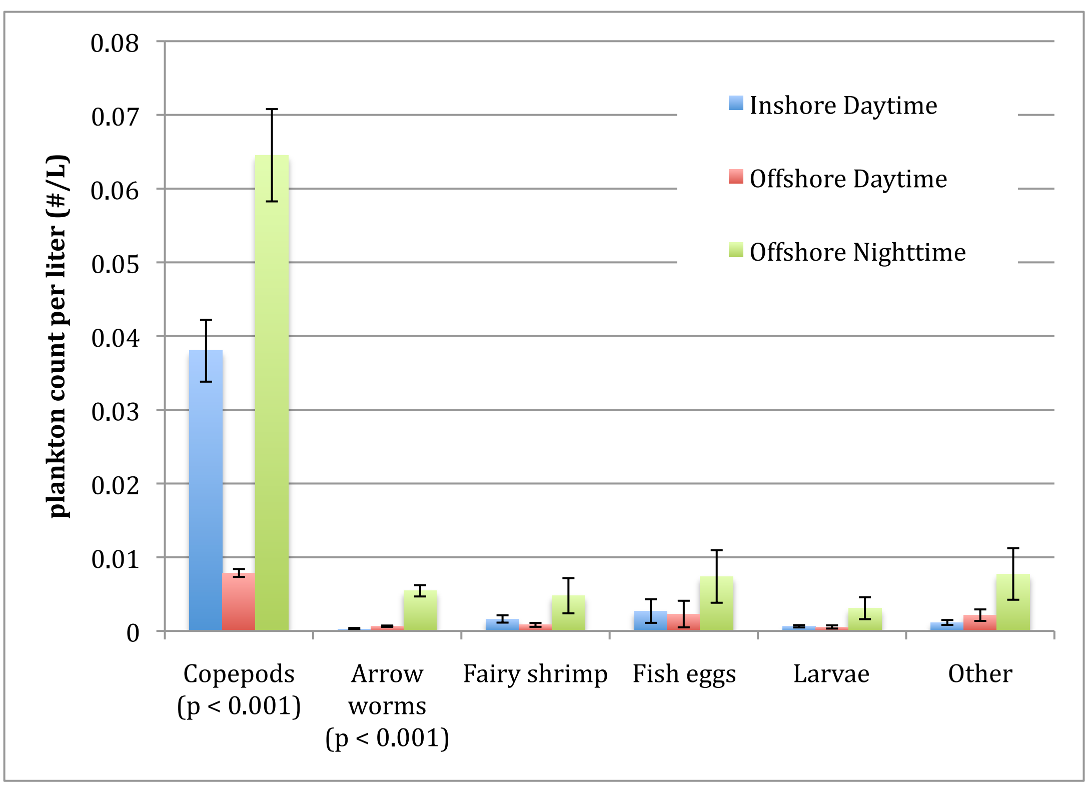

Fig. 3. Copepod, arrow worms, fairy shrimp, fish eggs, larvae, and "other" zooplankton densities were compared from inshore/offshore data and from offshore daytime/nighttime data. Copepod density significantly decreases from inshore daytime to offshore daytime (blue vs. red columns, $p < 0.001$ [t-test]) and significantly increases from offshore daytime to offshore nighttime (red vs. green columns, $p < 0.001$ [t-test]). Arrow worm density significantly increases from inshore daytime to offshore daytime (blue vs. red columns, $p < 0.001$ [t-test]) and significantly increases from offshore daytime to offshore nighttime (red vs. green columns, $p < 0.001$ [t-test]). All of the other zooplankton species density variations were insignificant. All t-tests were run with two tails. The sample sizes for inshore daytime, offshore daytime, and offshore nighttime were 15, 8, and 7 respectively.

This graph reveals that copepods and arrow worms appeared in statistically significant densities offshore daytime vs. nighttime while fairy shrimp, fish eggs, and larvae did not. Thus, discussion of this graph surrounded the question: why do some types of zooplankton vertically migrate more than others?

> "Perhaps more interesting than this general trend is the observation that the composition of zooplankton changed between the offshore daytime and offshore nighttime tows. A more detailed investigation of species' densities revealed that greater copepod and arrow worm densities are the main cause of the overall plankton increase at night. These data might imply that copepods and arrow worms are the main participants in vertical migration while fairy shrimp, fish eggs, and larvae make up a smaller, less significant portion. While it is impossible to determine why we saw this pattern, it stands to reason that fairy shrimp, fish eggs, and larvae would undergo less vertical migration if they lack the ability to control their depth in the water column or if they did not experience the same benefits that copepods and arrow worms experience in deeper water. Fish eggs have only an oil-filled bubble promoting buoyancy and may lack the mechanism to control their density in the water. On the other hand, fairy shrimp and larvae—both slower moving than copepods and arrow worms—might be less adept at avoiding underwater predators and therefore remain on the surface. These reasons are, of course, speculation. More data are needed to corroborate this trend and further experiments are needed to explain it."

At this point, I felt I had presented the data and exhausted discussion about offshore daytime/nighttime zooplankton densities. As I suggested, more evidence is needed to come to a true discovery; however, the presence of vertical migration offshore enhanced my discussion of the next comparison, daytime inshore vs. offshore. As seen in Figure 1, there are more zooplankton inshore than offshore during the daytime. My first goal was to extrapolate on the data we had and argue that there is less vertical migration inshore vs. offshore. (At this point I should mention it would have been immensely helpful to have inshore nighttime data. Because we did not have any, discussion was greatly constrained by lack of evidence.)

> "The decrease in zooplankton density we observed from the daytime inshore to the daytime offshore tows suggests that the inshore zooplankton underwent less vertical migration than offshore zooplankton. Assuming that the low zooplankton density offshore is caused by vertical migration, it is reasonable to conclude that higher zooplankton densities inshore at the same time of day are due to less vertical migration. (If fewer zooplankton sink in the water column,

> there will inevitably be more zooplankton at the surface.) This interpretation is further supported by changes in species composition and densities from inshore to offshore tows. Copepods in particular experienced a dramatic change in percent composition from nearly 85% inshore to around 60% offshore. As noted earlier, our offshore daytime/offshore nighttime data suggest that copepods comprise a large portion of vertical migrators. Offshore, where they evidently undergo vertical migration, the percent composition of copepods remains relatively low during the day; however, inshore, unable to vertically migrate, the percent composition of copepods greatly increases."

Having concluded that inshore zooplankton undergo less vertical migration, the next question is: why? What could explain this trend?

> "The presence of upwellings or deep penetration of light might explain this phenomenon. Because inshore waters are shallower than offshore waters, they experience different currents and temperature gradients. A costal front or upwelling in the inshore waters of Saint George's Harbor (the location where we collected the inshore sample) would produce a strong upwards current. While zooplankton can often control their position in the water column, such a current would make maintaining a deep position nearly impossible, thus minimizing vertical migration. Additionally, if light penetrated all depths of the inshore tow area, it is possible that zooplankton would not gain much protection from harmful UV rays; this lack of protection might discourage the energy costly vertical migration process. While one (or both) of these hypotheses might explain the inshore/offshore variation in zooplankton, further experimentation is needed to draw a concrete conclusion."

A main motivating question in EEB and this lab is the distribution of energy. Where are the primary producers (photosynthetic plankton)? Where are the primary consumers (zooplankton)? Where are the secondary consumers (also zooplankton)? Overall our data illuminated much about the trophic pyramid in our three test points (Figure 4) and my final point of analysis was bringing our findings into this larger picture.

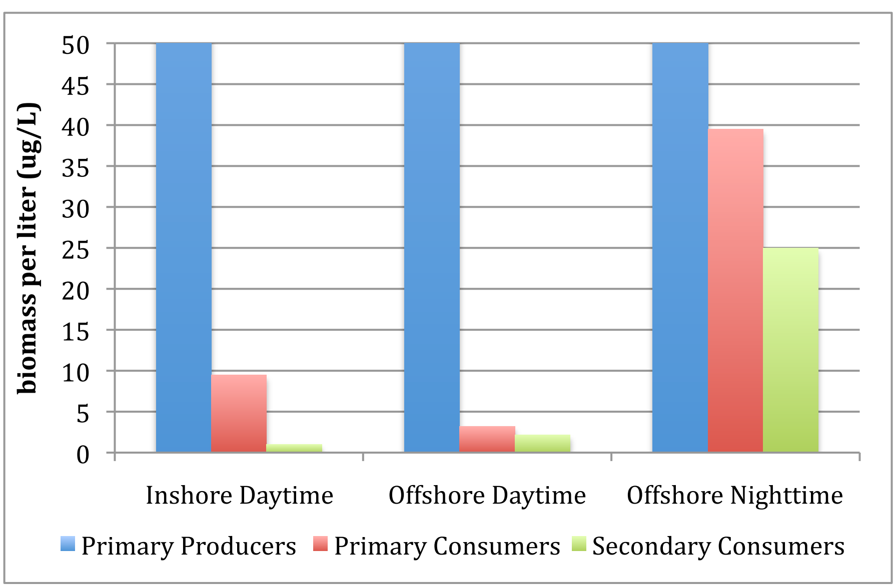

Fig. 4. Biomasses per liter of three trophic levels were examined qualitatively. The inshore daytime and offshore nighttime tows appear to have a typical distribution of biomasses. The biomasses of primary and secondary consumers in the offshore daytime tow appear to be fairly close and therefore do not display a typical trophic pyramid. No statistical analysis was run due to the large approximations used to obtain biomass values. The sample sizes for inshore daytime, offshore daytime, and offshore nighttime were 15, 8, and 7 respectively.

> "As mentioned in the introduction, phytoplankton and zooplankton provide an incredibly important link between solar energy and the biomass that larger aquatic organisms can eat. While the distribution of zooplankton through the ocean is incredibly important to ocean ecosystems, so too is the biomass of these plankton patches. In the offshore nighttime tow and inshore daytime tow, where fewer zooplankton have sunk to deeper water, zooplankton trophic structure reflected a typical trophic pyramid. However, in the offshore daytime tow, when a great portion of biomass had traveled to deeper waters, no such pyramid was observed. Beyond static biomass values, we might also obtain estimates of productivity through further experimentation. Isolating phytoplankton, herbivorous zooplankton and carnivorous zooplankton in the ocean via containers or in the lab and observing their populations over time would give us good estimates of their productivity.
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> This lab raises more questions about the distribution of zooplankton in Bermuda—which organisms vertically migrate? which factors effect vertical migration inshore? how productive is each trophic level? These tiny plankton are of great importance in the food web and more experiments are necessary to further understand their migration patterns and densities in Bermuda over different time points and locations."

In practice, results and discussion are two separate sections, but they are fundamentally rooted together. Results, graphs, and statistics are the evidence you have to work with. The discussion is where you explain what the results indicate and delve into possible explanations. A result is there are more zooplankton offshore during the night than during the day. This result indicates that vertical migration is occurring. Vertical migration might occur for x, y, and z. In the end, the discussion is limited, structured, and dictated by the results. Understanding how the sections are different yet very much interdependent is crucial in lab report success.