Deep-sea Epibenthic Echinoid *Echinocrepis rostrata*: Indicator of change on the deep-seafloor

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Abstract

Bioturbation rates can be monitored as potential indicators for climate regulated impacts in the deep sea. One species of sea urchin, *Echinocrepis rostrata*, is a good proxy to use due to contributing a high rate of bioturbation on the abyssal plain, as well as having a body shape and bioturbation trail that can be easily monitored. This study sought to 1.) determine whether or not *E. rostrata* species population size frequency changes with time, by conducting a population cohort follow through study; and 2.) contribute to a bigger continuing 27-year time series study that looked into the relationship between total megafauna density and POC flux, by adding our focal species' size frequency distributions to the time-series study. We obtained three video transect surveys previously collected by MBARI in 2014-2015 and conducted data analysis on our focal species using VARS software to determine size frequency distributions by survey. Our findings indicate there is possibly a slight change in *E. rostrata* population size frequency over time, indicating a potential recruitment event. However, it is too soon to tell, and we need more data due to their being a lot of biological variability. Future studies will extend the time series study; adding population size frequency distributions to the existing density data and comparing these with POC flux, SCOC flux, and climate indices to determine any relationships between the variables and to gain a better understanding of how climate change is potentially impacting deep-sea ecosystems.

Introduction

Since the mid-1800s, there has been a tremendous increase in carbon dioxide (CO_2) due to the combustion of fossil fuels on a global scale. This rise in CO_2 is cause for concern because it has the potential to aggravate the greenhouse effect, an event that consists of CO_2 and other gases trapping solar heat within our atmosphere, making the planet warmer than it otherwise would be (Recent Global Warming 2002). Atmospheric CO_2 content is naturally regulated by the world's oceans, which have been referred to as carbon sinks (Shah 2002). The world's oceans are considered major carbon controls due to a biologically mediated cycling process known as the "biological pump". This process involves the incorporation of atmospheric CO_2 by planktonic organisms, which in turn exports particulate organic carbon (POC) into the deep sea or abyssal plain that is then ingested by benthic organisms in the form of phytodetritus and recycled back into the water column in the form of dissolved CO_2. (Sarmiento and Siegenthaler 1992; Bopp et al. 2005; Marinov et al. 2006; Vardaro 2008).

The POC that reaches the sea floor is taken up and repackaged by benthic organisms. This process is referred to as carbon sequestration, and leads to the repackaged carbon getting buried within the deep sea sediment; where it is remineralized (Thunell et al. 1994; Thunell et al. 2000; Vardaro 2008), and exported back into the water column over hundreds to thousands of years (Bauer et al. 1992; Reimers et al. 1992; Smallwood et al. 1999; Miller et al. 2000; Vardaro 2008). Benthic megafauna bury or feed on the organic carbon phytodetritus; therefore, such organisms heavily influence the fate of the POC that reaches the sea floor (Aller 1982; Smallwood et al. 1999; Kuhnz et al. 2014). Bioturbation, or the biological mixing of sediment, by benthic organisms, is an important process in carbon sequestration because it contributes to changing geochemical gradients, microfaunal and bacterial community restructuring, and the redistribution of nutrients on the sea floor (Meysman et al. 2006). In his dissertation, Vadaro states that "If bioturbation levels also fluctuate with climate, the amount of carbon that is sequestered in the sediments could be affected by changes in surface conditions as well." (Vardaro 2008). Bioturbation rates can be monitored as potential indicators for climate regulated impacts in the deep sea. One species of sea urchin, Echinocrepis rostrata, is a good proxy to use due to contributing a high rate of bioturbation on the abyssal plain, as well as having a body shape and bioturbation trail that can be easily monitored with the tools that are currently available for monitoring deep sea ecosystems.

We sought to determine whether or not *Echinocrepis rostrata* species population size frequency changes with time, by conducting a population cohort follow through study. We also sought to add on to a bigger continuing 27-year time series study conducted independently by the Smith lab at MBARI, that looked into the total megafauna densities and how they relate to POC flux, by adding our focal species' size frequency distributions to the time-series study; so as to contribute to the continuing time-series study and to gain a better understanding of how climate change is potentially impacting deep sea ecosystems.

Methods

We obtained three separate video transect surveys of the sea floor taken in October 2014, June 2015, and November 2015 previously collected independently by the Smith lab at MBARI using with the Dock Rickets ROV. We obtained POC flux data relating to the three video transect surveys previously collected from the Smith lab using sediment traps 100 m and 50 m above the bottom of the seafloor. The traps collected the particulate that fell through the water column and determined the quantity of POC in the sediment samples every ten days. We also obtained transect area data previously calculated by the Smith Lab to use in our data analysis. The study site for which the surveys were taken by the Smith lab occurred within Station M, an area located within the Eastern Pacific abyssal plain that is approximately 200 km off Point Conception and 4000 m deep.

We used the previously obtained data to conduct a population cohort follow through study in order to determine whether or not *Echinocrepis rostrata* species population size frequency changes with time. In order to determine the size frequency and density of our focal species, we used MBARI's in-house software called VARS, which stands for Video Annotation and Reference System. VARS allows for annotation at any level of detail, including making comments on aspects such as behavior and color, and can be used to make measurements on individual organisms. The VARS software stores all of the data and annotations within the system. (Linda Kuhnz, pers. comm.)

In order to determine the density of *Echinocrepis rostrata*, we determined their abundance for each survey and then divided the species abundance by its respective total transect area (m^2), to calculate the number of individuals present per square meter. To collect abundance data, we visually observed each of the three video transect surveys using the VARS software, and counted the number of the *Echinocrepis rostrata* individuals that were present in the video, as well as documented the time code affiliated with each individual for each survey. In order to determine size frequency, we used the VARS software to measure the size (cm^2) of each of the counted individuals. To do this, we first lined up each individual to the two lasers pointers located at the center of the 1 m wide screen in a manner suited for the Canadian grid used for the VARS software (see Kuhnz et al. 2014 for more details). Individuals that were difficult to identify or that appeared only partially on the screen were excluded from the dataset. Once the individuals were lined up with the laser pointers, we took frame grabs of the screen and used them to make size measurements. Using the line measurement tool in VARS, we first measured the distance between the left and right laser pointers, which is approximately 29 cm. To calculate the size of each individual, we first measured the anterior width and overall length of each urchin, using the same line measurement tool mentioned above. The anterior width was determined by measuring from end to end across the front "lobes" of the test, near the oral opening. The overall length was determined by measuring from oral opening to anal opening at the rear of the test (Michael Vardaro, pers. comm.).

A script was then used to convert all measurements from pixels to centimeters (Linda Kuhnz, pers. comm.), using the following formula:

Distance (cm) = (pixel distance*29)/laser distance

Once the measurements were converted to centimeters, we took the individual length and width measurements (distances) and multiplied them to calculate the size (cm^2), or area, of each urchin. Individuals were then categorized into eleven size classes for data analysis.

Results

We plotted a histogram representing the density (ind./m^2) corresponding to each of the three transect surveys in order to determine whether *E. rostrata* species density is changing over time (see figure 1). A slight decrease in density was observed in the June 2015 survey when compared to the survey taken in October 2014; however, there was a population increase by a small percent observed overall. For more information refer to Table 1 in the Appendix and the end of this paper.

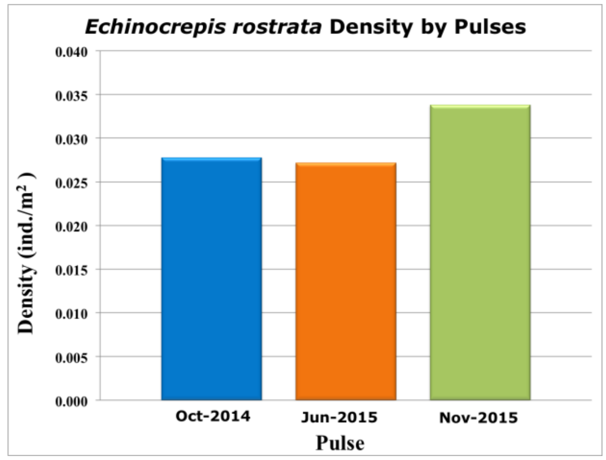

Figure 1.) Histogram representing *E. rostrata* sample population density (ind./m^2) by survey, indicating a slight population increase from October 2014 - November 2015.

To assess size frequency distributions among our focal species, we calculated size class percentages and plotted the size class percentages by survey (see figure 2). We observed a larger quantity of smaller sized individuals for each of the three surveys, as opposed to medium sized and large sized individuals. Over time there tends to be an increase in the quantity of larger individuals. In the June 2015 survey, there were more medium sized individuals than was observed in the October 2014 survey, but there appeared to be no increase in the quantity of large sized individuals. In the November 2015 survey, there was a higher quantity of large sized individuals than was observed in the two earlier surveys, however, there was appeared to be a decrease in the quantity of medium sized individuals compared to the June 2015 survey. For more information, see Table 2 in the Appendix.

To gain a better understanding of *E. rostrata* size frequency distributions, we plotted cumulative sizing curves by survey (see figure 3). This was done by plotting size classes against the percentage frequency of the size class plus the sum of the percentages in preceding size classes. We observed a similar trend for all three surveys, in that most of the sample population tends to fall within less than the 20 cm^2 range for each survey, indicating the sample populations are mostly made up of small sized individuals as opposed to medium sized or large size individuals. The cumulative sizing curves for all three surveys also indicate that there were more medium sized individuals than there were large individuals.

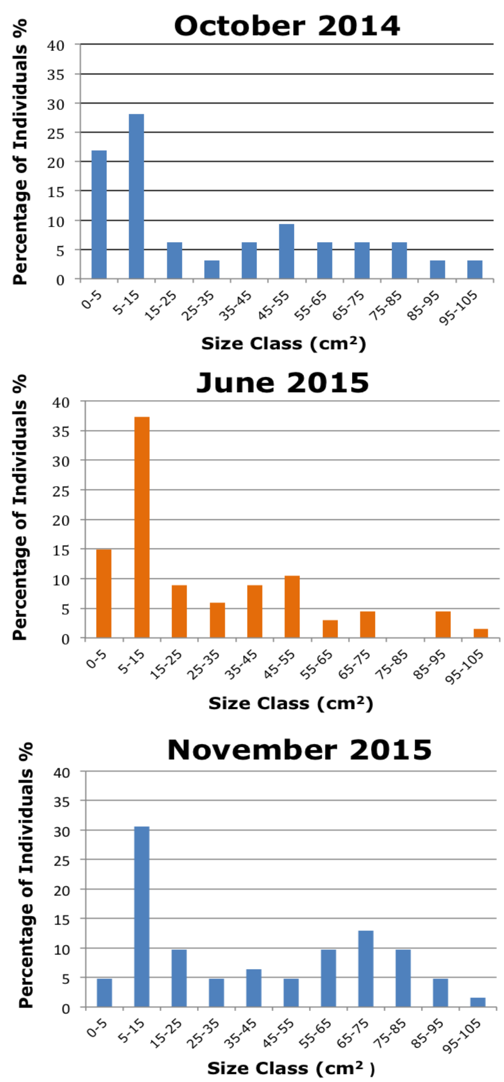

Figure 2.) *E. rostrata* sample population size class

percentages (%) plotted by survey. Results for all three surveys indicate a larger quantity of smaller sized individuals for all three surveys. Over time there tends to be an increase in the quantity of larger sized individuals, indicating a potential recruitment event.

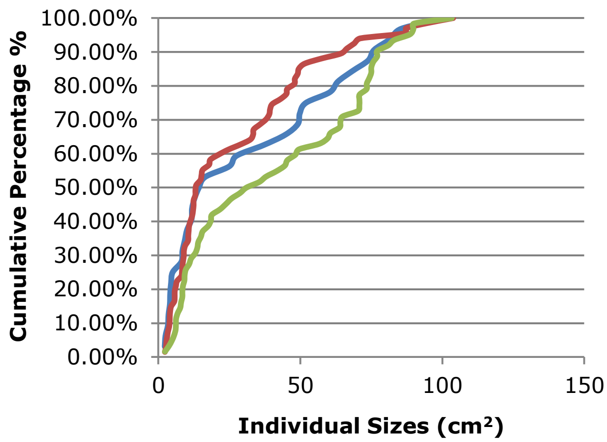

Figure 3.) Cumulative sizing curves (%) plotted by survey. The blue line represents the October 2014 survey. The red line represents the June 2015 survey. The green line represents the November 2015 survey. Our findings show that most of the *E. rostrata* sample population tends to fall within less than the 20 cm^2 size range for each survey.

As previously stated, we sought to add on to a bigger continuing 27-year time series study that compared total megafauna densities and how they relate to POC flux over time. The time span for the study was 1989-2015. We combined the findings from the original time-series study with the density results for our focal species in order to observe similarities among the *E. rostrata* sample population and total megafauna sample population densities in relation to POC flux over time (see figure 4). For more details on the original 27-year time series study, see Kuhnz et al. 2014).

For the years 2014-2015, there appears to be an increase in the *E. rostrata* sample population density similar to the increase observed for the total megafauna sample population densities; however, there is no indication that there is necessarily a pattern or relationship between *E. rostrata* sample population density and POC flux over time. More information is necessary for determining if there is a relationship occurring between the two variables.

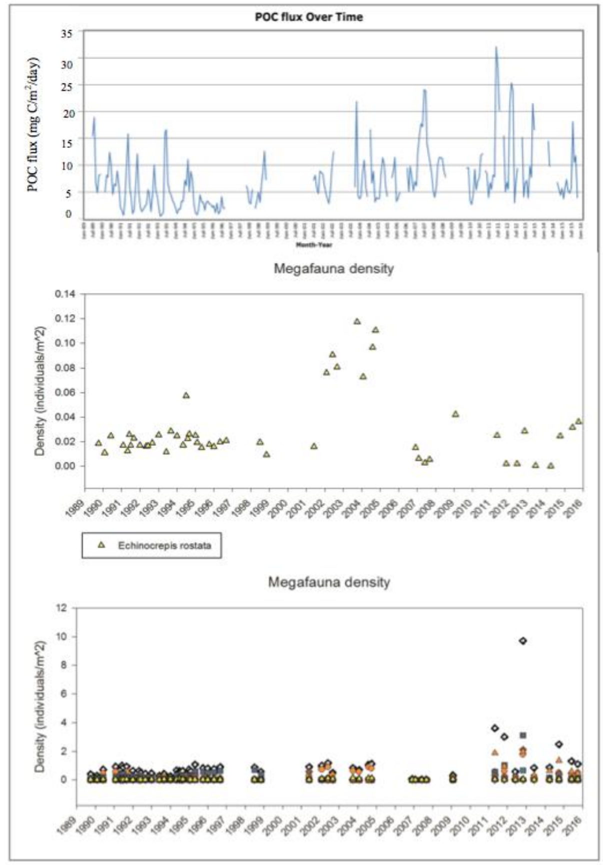

Figure 4.) Relationship between POC flux (mg C/m^2/day)(top graph), *E. rostrata* sample population density (ind./m^2)(middle graph), and total megafauna density (ind./m^2)(bottom graph). Time (years) is plotted on the x-axis, ranging from 1989-2015. There is no indication of a pattern or relationship between *E. rostrata* sample population density and POC flux over time.

Discussion

Our findings provide evidence to support that *E. rostrata* species population size frequency may be changing with time to a small degree; however. further research that includes more population samples over time is necessary to determine this for certain. Our results also indicate a potential recruitment event, specifically referring to the histogram of population densities by survey (figure 1) and size class percentages plotted by survey (figure 2). The densities histogram shows a population increase by a small percent over time, providing evidence for a potential recruitment event. Concerning figure 2, we observed a pattern for each of the three surveys, in that there is a relatively larger quantity of small sized individuals (>20cm^2) compared to medium sized and large sized individuals; while over time there tends to be larger and larger individuals, providing further evidence for a recruitment event. The large quantity, or bulge, of small individuals that outnumbers the medium sized and large sized individuals that persists through each of the three surveys is interesting because it could mean that there is a high juvenile mortality rate, in that a lot of juveniles were born at a certain time but may tend to die off quickly afterwards. If we were to observe the bulge starting to move over time towards the large size classes, we could then assume that something is throwing off their equilibrium. In the future, we intend to plot more size class percentages by survey when we extend the time series survey in order to see whether the bulges are moving towards larger size classes or if they remain constant at the smaller size class range, implying that they keep dying off after a certain point.

Potential limitations of the work include: insufficient data and replication, human error, and a lack of statistical analysis. For future studies, I would like to go back and determine *E. rostrata* population size frequency distributions for all of the surveys included in the continuous 27-year time series study that occurred before 2014, as well as for future surveys that will take place after 2015. Doing this will allow us to observe any patterns occurring among the population cohort sooner than would be possible if we only focused on what will be occurring in future surveys. I would like to then plot the *E. rostrata* population size frequency distributions for 1989-2015 and compare them to the results in Figure 3 in addition to SCOC flux, so as to determine if there is a relationship occurring among *E. rostrata* population density, *E. rostrata* population size frequency, total megafauna density, and POC flux, and SCOC flux.

For future work, I would also like to determine if growth changes are impacted by climate. Expanding this population size frequency study through the 27+ time series and comparing the changes with climate indices will allow us to determine a potential relationship between climate and *E. rostrata* population growth changes, and will help us to gain a better understanding of how climate change is potentially impacting deep sea ecosystems.

Conclusion

In conclusion, there is possibly a slight change in *E. rostrata* population size frequency over time, indicating a potential recruitment event. However, it is still too soon to tell, and we need more data due to their being a lot of biological variability. Future studies will extend the time series study, adding population size frequency distributions to the existing density data and comparing these with POC flux, SCOC flux, and climate indices; so as to determine any relationships between the variables, as well as to gain a better understanding of how climate change is potentially impacting deep sea ecosystems.

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Appendix: Tables

Month-Year	Sample Size (n)	Area (m^2)	Density (ind./m^2)
14-Oct	34	1219	0.028
15-Jun	77	2830	0.027
15-Nov	62	1837	0.034

Table 1. (Linked to Figure 1)
Data table used as basis for data analysis and to plot *E. rostrata* sample population density (ind./m^2) by survey. Column 1 represents the three surveys by month and year. Column 2 represents the number of *E. rostrata* individuals (n) counted by survey. Column 3 represents the total area (m^2) of each transect survey. Column 4 represents *E. rostrata* sample population density (ind./m^2) by survey.

Month-Year	Sample Size (n)	Max Area (cm^2)	Min Area (cm^2)	Average (cm^2)
Oct-14	32	101.53	2.23	32.12
Jun-15	67	103.83	2.29	26.81
Nov-15	62	103.36	2.30	40.04

Table 5. (Linked to Figure 2)
Data Table used to plot *E. rostrata* sample population size class percentages (%) by survey. Column 1 represents the three surveys by month and year. Column 2 represents the *E. rostrata* sample size (n) by survey after omitting the individuals that could not be counted from the raw data. Columns 3 and 4 represent the maximum area (cm^2) and minimum area (cm^2), or size, measured for an individual in the sample population. Column 5 represents the average area (cm^2), or size, measured for an individual in the sample population.