Comparison of Diet of *Chlamys hastata* and *Chlamys rubida* from Shallow and Deep Waters off the San Juan Islands

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Marine Zoology/Botany 2011 at Friday Harbor Laboratories

Spring 2011

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Key Words: filter-feed, sediment, benthic, detritus, ingestion, selection

Abstract

Gut contents of two species of sea scallops, *Chlamys rubida* and *C. hastata*, were compared for individuals from the San Juan Channel collected in shallow (20m) and deep (~80m) habitats. Gut contents were preserved in paraformaldehyde and an Olympus microscope with 10x and 20x lenses was used to view phytoplankton. Food constituents of different categories were counted using an ocular micrometer transect. No noticeable trends regarding dietary constituents were seen across species or habitat which supports our null hypothesis. A count of identifiable diatoms showed that Thalassiosira and CF Melosira were the most abundant diatoms. In addition, CF Melosira was more abundant (~2x greater) in shallow animals from both species relative to deep animals. The results imply that both species of scallops are consuming similar organic and inorganic matter at different depths.

Introduction

Molluscs are an important phylum ecologically, commercially and as bioindicators (Rittschof & McClellan-Green, 2005). They have demonstrated their ability to improve water quality in Chesapeake Bay when filter feeding in large numbers (Gottlieb and Schweighofer 1996). Oysters from Chesapeake Bay and Willapa Bay and sea scallops in the Northeast Atlantic have been harvested by commercial fisheries. Many filter feeding molluscs are also considered good bio indicators because they feed on what is in the water column and are therefore sensitive to anthropogenic inputs (Rittschof & McClellan-Green, 2005).

Since scallops are semi-mobile filter feeding molluscs dependent on suspended organic matter for food (Shumway 1987), they bio concentrate pathogens and other harmful organic matter. As opportunistic filter feeders, scallops can take advantage of a variety of food sources including phytoplankton, diatoms and other particulate organic matter (Shumway 1987). Scallops have the ability to swim through the water column by opening and closing the valves of their shells, whereas most bivalves are cemented to a substrate via byssal threads or a foot and are limited to local food sources (Brand 2006). The swimming movement of scallops also allows them to stir up benthic sediment. As a result they can access suspended materials in the near-bottom water and newly deposited materials (Shumway et al. 1987).

It has been assumed that a filter feeder's diet is restricted to material that passes their gills, but they might selectively feed. At least some scallops have the ability to select food after it is ingested. Sea scallops collected from Deer Island, Canada, can sort organic from inorganic particles before and after ingestion (Brillant and MacDonald 2002). Scallops also can retain protein-coated micro beads longer than uncoated ones by postingestive selection based on chemical properties (Brillant and MacDonald 2002). In addition, suspension feeding bivalves have the ability to select particles by size (Riisgård 1988), and perhaps by chemical/nutritional properties (Ward et al. 1998). However, less is known about whether scallops have the ability to select among organic particles.

Since scallops are important commercially as food products and biologically for their position in the food web, it can be beneficial to analyze the gut contents at near shore locations and deeper depths. In 2002, Lehane and Davenport compared the gut contents of scallops taken directly from their natural benthic habitat with scallops that were suspended in cages in the water column. They found that benthic scallops consumed many zooplankton species and that the suspended scallops consumed prey of longer length. In another study, gut contents preserved in formaldehyde were analyzed, and benthic detritus was found to be the main food item, with large quantities of planktonic algae and diatoms as well (Mikulich 1981). When distinguishing between diets of scallops at two different depths, one might expect the scallops from shallower waters to consume more zooplankton, which tend to concentrate near the surface in order to take advantage of photosynthetic processes. Scallops in deeper water might rely more on detritus. In some areas, low oxygen concentration of near-bottom water and high resuspension of inorganic particles enriched with inedible dead organic matter are responsible for reduced scallop sizes (Silina and Zhukova 2007). This could also result in reduced gonad weight for deep water scallops and therefore less offspring. Such information would prove useful regarding the commercial use of scallops.

Different species of scallops at different depths may encounter differences in food quality and quantity. Cranford (1995) fed varying concentrations of organic and inorganic matter to scallops to look for relationships between food quality, quantity, and efficiency/absorption rates of dietary constituents. The absorption efficiencies of particulate organic matter decreased as dietary inorganic content increased (Cranford 1995). When poor quality inorganic material is present, the scallops will consume less organic matter. By comparing the gut contents of different species of scallops at different depths, we also might notice trends in terms of proportion and quality of organisms ingested.

In this study we asked whether individuals across depths and species had different gut contents. Our null hypothesis is that there will be no difference between the gut contents of individuals across species or depth.

Methods

Supervisor: Aaron Galloway

On 4/22/11, deep water scallops *Chlamys rubida* and *Chlamys hastata* were collected on the Centennial via trawls with the first from about ~60m and the second from ~90m in the San

Juan Channel west of Point Caution in the San Juan Islands. Within 2 hours of collecting, the dorsal valve was removed and the stomach/digestive glands were removed using scalpels and forceps. Stomachs were placed in glass vials with 1ml 1.6% concentration of paraformaldehyde solution to preserve the gut contents until analysis could take place. The shell length, sponge cover, and sex of each individual were recorded.

Near shore scallops of *C. rubida and C. hastata* were collected via SCUBA in ~20m at Point Caution on 4/26/11. The same dissection methods used on the deep water scallops were used on the shallow water scallops.

Gut contents of each individual were analyzed within 2 weeks after collection. A scalpel was inserted into the glass vials and the stomach was cut and the vial shaken to preserve equally distributed gut contents. One drop of the gut contents mixed with the 1.6% paraformaldehyde was pipetted onto a slide and looked at under a compound microscope. Each stomach was sampled with 3 slides, each slide had 5 areas of analysis (4 corners and middle) and each area had 5 data points to identify adding to a total of 75 counts per stomach. The 5 data points were the 0, 20, 40, 60, and 80 marks on the ocular micrometer. We spun the ocular micrometer to ensure that the transect placement was unbiased. Any material directly under the tick mark was recorded. The contents were identified to the best of our abilities with unidentifiable contents regarded as particulate organic matter. For each stomach we compiled two data sets: 1) percent cover of slide broken into each of the food categories and 2) we further identified the number of individual phytoplankton within each stomach to compare phytoplankton composition. The sixteen diet categories were divided as the following: dinoflagellates, ovate diatoms, empty spots, unidentifiable particles, inorganic detritus, stomach cells, macroalgae, microalgae, biogenic inorganic material, miscellaneous diatoms, chain diatoms, CF Melosira, Chaetoceros, pennate diatoms, centric diatoms, and Thalassiosira.

For each of the 5 areas per slide, the first two identifiable diatoms were recorded. This led to a total of 10 diatoms per slide and 30 diatoms per stomach.

Discussion

Although the data exhibit no obvious trends in gut content between species or habitat, the fact that the diets of different species at different depths appear similar is significant in itself. Most likely, both scallop species at both depths are selecting the same particles for consumption. One could also argue that the scallops are not selecting certain particles at all, and that the food available to them is merely the same in both habitats. Figure 5 demonstrates that there were some outlier groups. The deep *rubida* take up their own individual space on the graph, mainly in the bottom areas, which implies that they differ from the other groups in terms of diet composition. Figures 4 and 5 support this. Similarly, the *hastata* occupy solely the upper margins of the plot, with some overlap of species and depths in the middle.

Some general trends were observed when completing the transect analysis part of the experiment. For instance, in shallow species, CF Melosira was much more abundant compared to deeper species. This might be due to the fact that individuals from shallow depths have more access to CF Melosira. Further studies of CF Melosira in deep and shallow water might prove that the diatom is more abundant in shallow water. In *C. hastata* shallow individuals specifically, micro and macro algae existed in pellet form and comprised the majority of data points on the transect. For the *C. rubida*, the Thalassiosira were obviously the most abundant diatom. However, diatoms in general appeared rare in the transect studies even though they were abundant in the samples. To provide further insight regarding the diversity of diatoms, 30 diatoms were identified per stomach sample. The most common were Thalassiosira, CF Melosira, and Stephanopyxis respectively. This diatom count was potentially biased since our eyes were likely drawn to the largest, most familiar diatoms. To account for this in a future study, it would be ideal to identify all individual diatoms in a given area of the slide in the microscope view. Since lipid drops were present across all samples in large quantities, they were ignored in the transects.

The data points that we considered "microalgae" consisted of brownish/green clumps with some digested diatoms mixed in. It is possible that this microalgae was actually detritus from kelp. As kelp decays, it is exported from shallow waters either on the beach or to deeper waters (Duggins 1997). Much of the kelp degrades into dissolved particles that are available to offshore pelagic and benthic organisms. For simplicity, inorganic detritus, microalgae and macroalgae can be thought of as a combined group of unknown, non-phytoplankton derived detritus (see Figure 4).

One alteration that would make for more reliable depictions of stomach contents would be to dissect and identify the stomach contents immediately instead of preserving them in paraformaldehyde. Since the gut contents were preserved for an extended time, this is likely to have contributed to the large amounts of microalgae/detritus gunk. At the same time, the longer that the dissections and analysis take, the more time the scallops have to digest their food. Ideally, the dissections would not have been completed on live specimens. If there is a way to use a chemical to anesthetize all the scallops collected at once, the dissection process would have been easier and more humane. Additionally, samples from the water column would have been collected at the time and place where the scallops were taken to correlate the phytoplankton in the water column with the diatoms in the guts. Similarly, samples could have been collected for the detritus "scum" of the benthic sediment surface where the shallow scallops were taken.

One problem that we encountered was the presence of stomach tissue cells in the stomach samples. It was difficult to get a clean dissection of the stomach inserted and retrieved from the glass jars. If a needle could have been inserted directly into the stomach to retrieve gut contents, then perhaps less stomach tissues would have been present.

Conclusion

At length, our experiment did not exhibit any differences in diet among the four treatments except for the greater abundance of CF Melosira in shallow waters based on the diatom count. The fact that *Chlamys rubida* and *C. hastata* eat the same food at two different depths is an enlightening result that I did not expect. Whether the scallop species both select to eat the same diet or simply eat the same particles because they are available at both locations is unknown. Either way, both species are coexisting in shallow and deep waters while consuming similar diets that seem to sustain both species.

Acknowledgements

I'd like to thank Aaron Galloway for guiding us throughout our entire project, scuba diving for us to collect scallops, and being a helpful supervisor. I also acknowledge Meghan Rock for offering guidance regarding microscope identification procedures and general experienced tips regarding her past research with chiton gut contents. I'm very grateful to Megan Dethier for helping with our statistical analysis. Hilary Hayford and Mike Nishizaki were always available to offer beneficial advice throughout the program. I also acknowledge Adam Summers for his mentorship throughout the research apprentice process. Finally, I acknowledge the Mary Gates Endowment for providing funding for the research experiment.

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Results

The experiment consisted of 2 variables: species and habitat. The 4 treatments were *Chlamys hastata* deep, *C. hastata* shallow, *C. rubida deep*, and *C. rubida* shallow. The data do not imply any noticeable differences in diet composition between either species or depth. Additionally, the statistics tests did not support the presence of significant results since all P values were greater than the ideal .05. This is supported by the ANOSIM pairwise tests depicted in Table 1.

Group Comparisons	**P Value**
rubida deep v. hastata deep	0.67
rubida deep v. rubida shallow	0.43
rubida deep v. hastata shallow	0.14
hastata deep v. rubida shallow	0.3
hastata deep v. hastata shallow	0.24
rubida shallow v. hastata shallow	0.52

Table 1: Comparison of Significance Values of Relative Total Diet Between Groups using ANOSIM

Figure 1 displays the average diet composition for all stomachs, divided into the four treatments. The counts for all sixteen food categories were averaged using the 75 tallies per stomach. The majority of transects points were empty or microalgae.

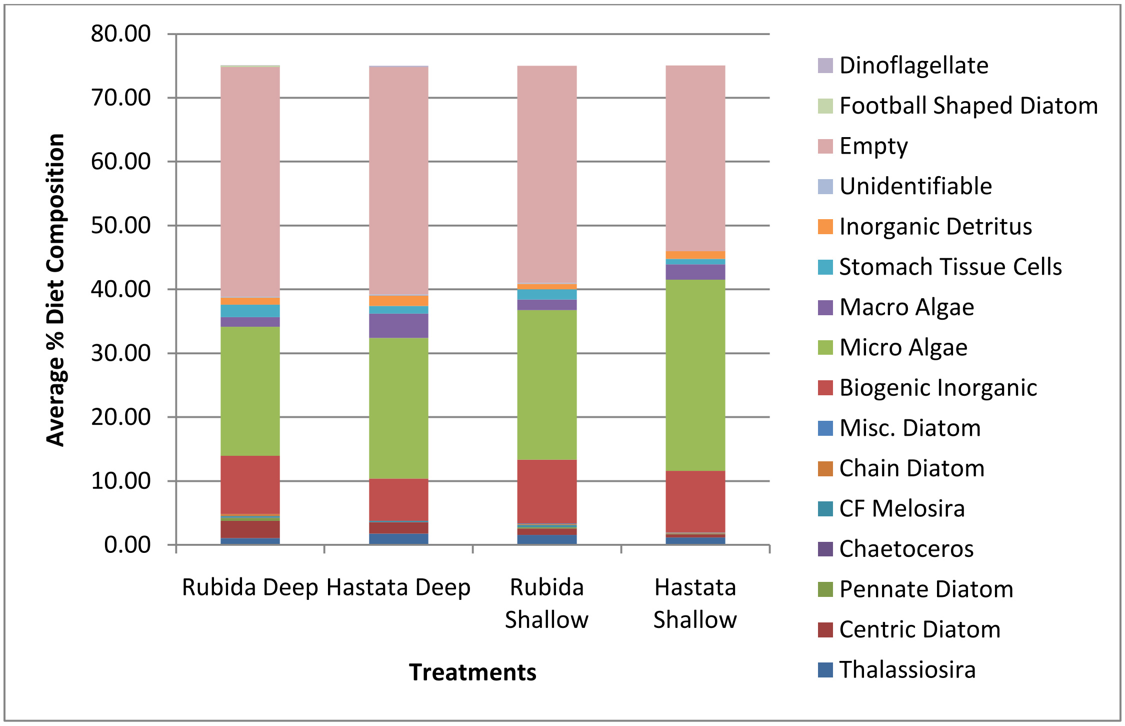

Figure 1: Average Composition of Diet as a Function of Species and Depth

Since many of the transect points were empty, it was desirable to illustrate the same concept as Figure 1, but with the empty points removed. Figure 2 allows us to see what the compositions would be of actual material that was present in the stomachs. Besides microalgae, biogenic inorganic material which consisted of digested diatom fragments was abundant.

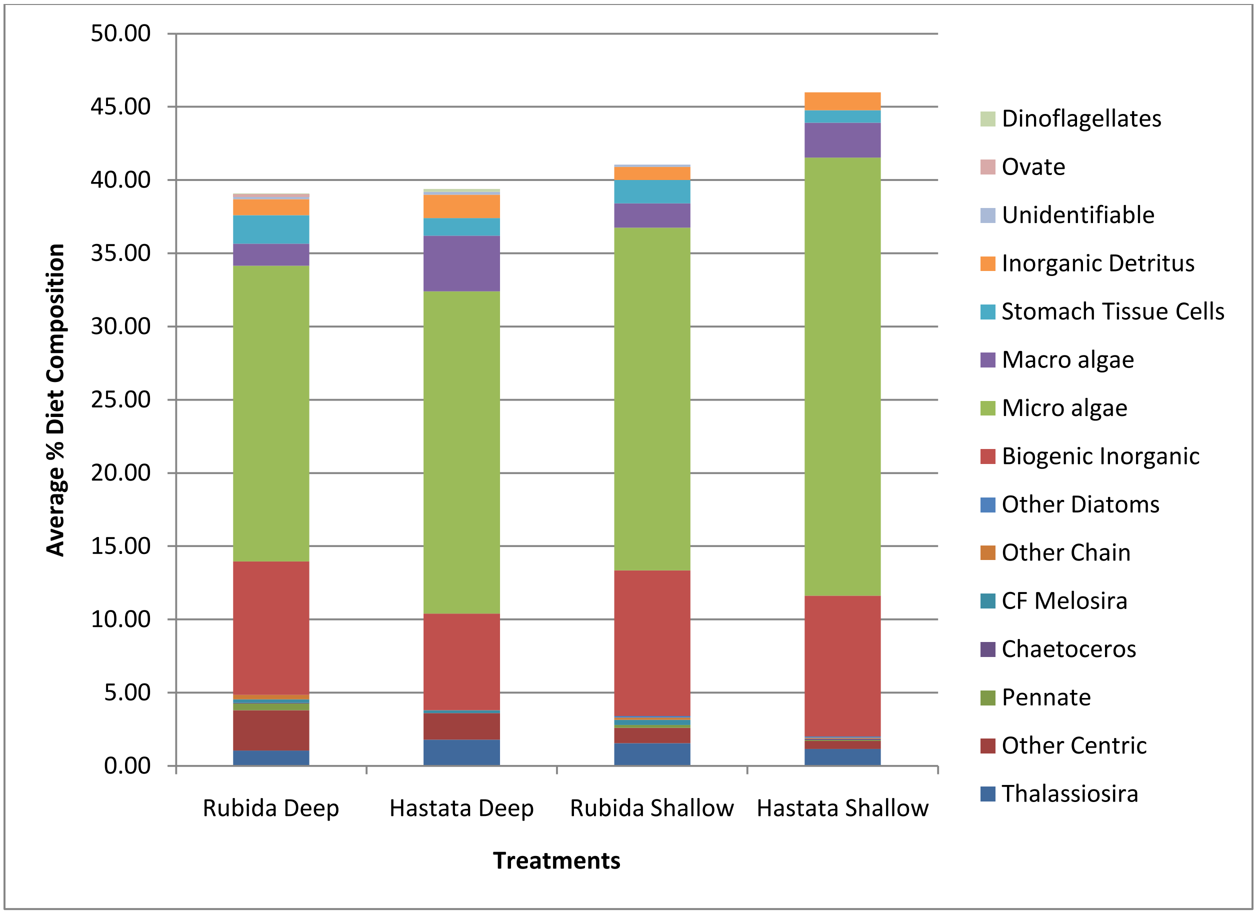

Figure 2: Average Composition of Diet as a Function of Species and Depth with the Empty Data Removed

Figure 3 illustrates the relative amounts of diatoms among treatments. Although diatoms were abundant and seemingly diverse when viewed on the microscope slides, the diatoms appeared rare since they did not often appear on the transect points. To counteract this, 30 diatoms were identified for each stomach in order to give an idea of which diatoms the scallops were consuming as well as their abundances.

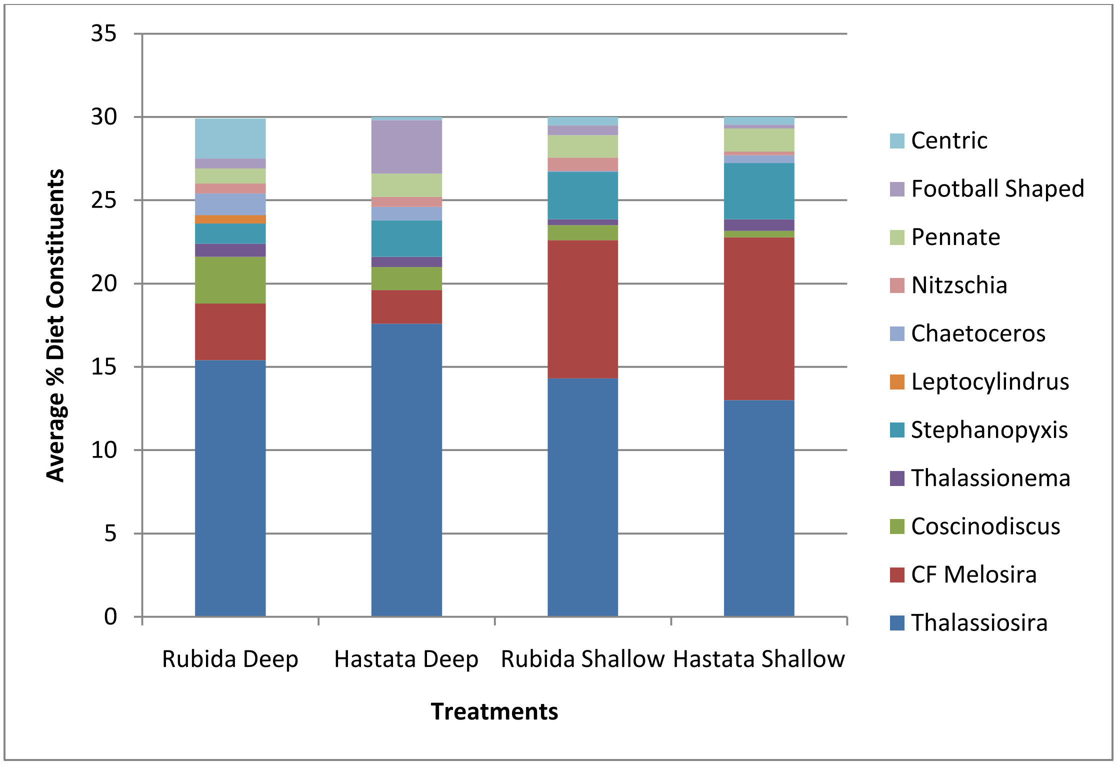

Figure 3: Average Composition of Diatoms in Diet as a Function of Species and Depth

Figure 4 exhibits the same data as Figure 3, but with the detritus and algae categories combined. Since we were unsure of the content of the algae categories and they were presumably made of detrital material, it is useful to see how much total detritus makes up the scallops' diets.

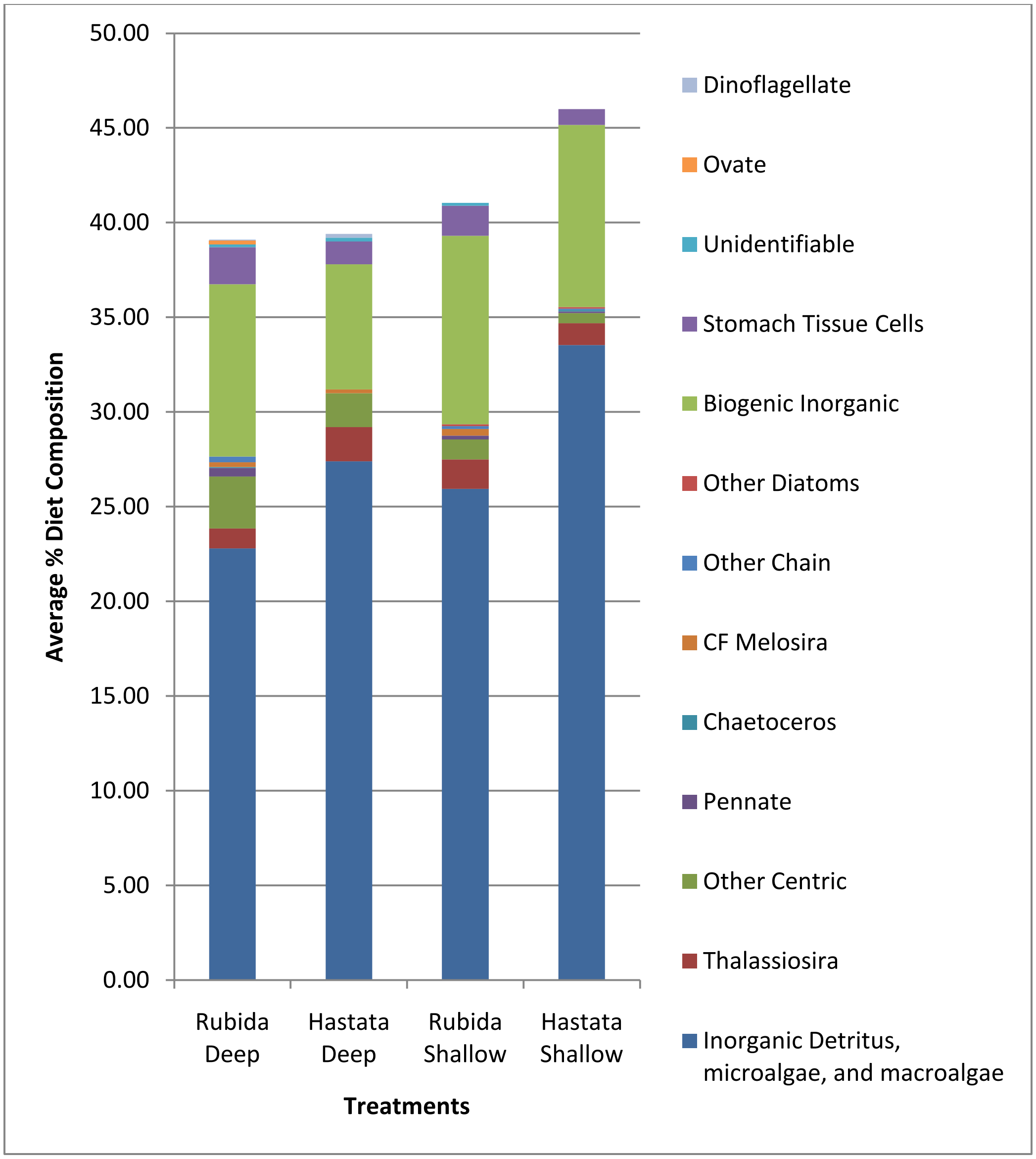

Figure 4: Average Composition of Diet as a Function of Species and Depth with the Empty Data Removed and the Inorganic Detritus/Microalgae/Macroalgae Combined

Figure 5 shows how the stomach contents for each individual scallop relate to each other. The closer the triangles are to each other, the more similar the gut contents are. Ideally, the plot would exist in sixteen dimensions for the 16 food categories. Most of the treatments overlap, but the deep *rubida* individuals seem to be the most dissimilar from the rest.

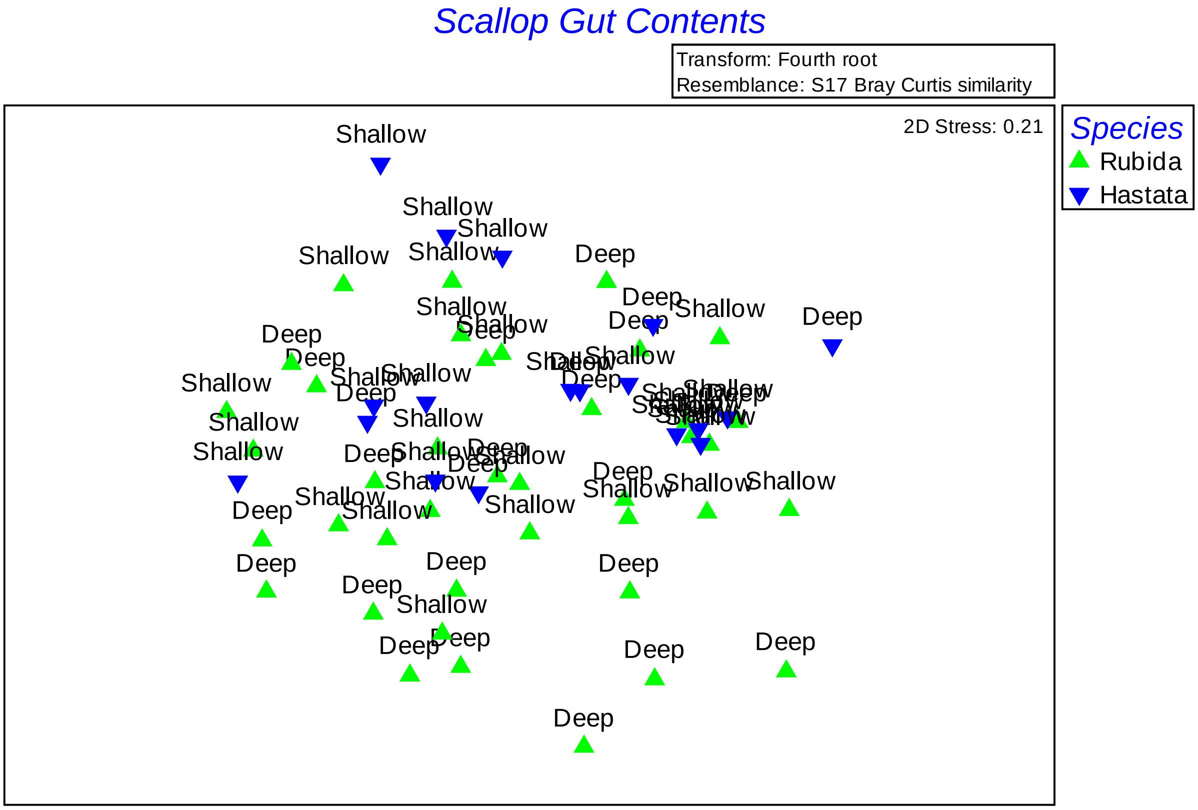

Figure 5: Multidimensional Plot Depicting Average Relations of Gut Contents

Figure 6 shows the average similarity of individual guts within each treatment. Similar to Figure 5, the deep rubida individuals are the least similar to each other, with the lowest similarity of 69% which is why they stand apart from the rest. Overall the similarities are very high, which is why there is so much overlap in Figure 5 as well.

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SIMPER(similarity percentage) analysis:
Group RubidaDeep
Average similarity: 69.15

Species               Av.Abund  Av.Sim  Sim/SD  Contrib%  Cum.%
Micro algae              4.46    30.92    7.25     44.72   44.72
Biogenic Inorganic       2.92    18.41    3.93     26.63   71.34
Other Centric            1.31     5.00    0.91      7.24   78.58
Macro algae              1.00     4.57    1.03      6.61   85.19
Stomach Tissue           1.08     4.45    0.90      6.44   91.63

Group HastataDeep
Average similarity: 70.42

Species               Av.Abund  Av.Sim  Sim/SD  Contrib%  Cum.%
Micro algae              4.66    32.30    6.29     45.86   45.86
Biogenic Inorganic       2.45    14.14    3.50     20.08   65.95
Macro algae              1.83    10.20    3.72     14.48   80.43
Inorganic Detritus       1.11     5.34    1.09      7.59   88.02
Thalassiosira            1.15     4.74    1.10      6.72   94.74

Group RubidaShallow
Average similarity: 73.29

Species               Av.Abund  Av.Sim  Sim/SD  Contrib%  Cum.%
Micro algae              4.80    34.03    6.42     46.44   46.44
Biogenic Inorganic       3.09    20.49    5.82     27.96   74.40
Stomach Tissue           1.11     5.91    1.48      8.07   82.47
Macro algae              1.09     5.59    1.25      7.62   90.09

Group HastataShallow
Average similarity: 74.30

Species               Av.Abund  Av.Sim  Sim/SD  Contrib%  Cum.%
Micro algae              5.41    39.30    8.84     52.89   52.89
Biogenic Inorganic       3.02    20.43    4.76     27.50   80.39
Macro algae              1.27     5.73    1.06      7.71   88.10
Thalassiosira            0.83     3.45    0.72      4.64   92.74
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Figure 6: SIMPER Analysis Data Showing Average Similarity Within Treatments