Coralline and fleshy algae volume density on epifaunal communities

Samuel J. Field & Christopher D. Gani

Oregon State University - ***Department of Biology***

Abstract

Carbon dioxide emissions greatly affect the carbon chemistry mechanisms within the ocean. Carbon absorbed by the ocean, drops the pH level and creates an environment that is acidic. Acidic conditions prevent calcification mechanisms in coralline algae, and hinder their ability to establish within the intertidal. Coralline algae display structural relevance in the intertidal, and act as foraging and resting areas for smaller epifauna. Structural differences between calcifying algae and fleshy algae are related to thallus density. Corallines are considerably denser with their calcified thallus in comparison to their fleshy counterparts. Worries grow as ocean acidification begins to alter calcifying algae and diluting their roles in the rocky intertidal. A sample of 72 algae specimen were collected from Yachats State Recreation Area from both mid and low elevation zones. Epifaunal densities and volume metrics were measured for each alga to compare each categories relative importance on gastropod and non-gastropod populations. It was found that non-gastropods hold a preference to coralline algae and no preference of algae is held by gastropods.

Introduction

Anthropogenic emission of carbon dioxide is indirectly dropping ocean pH levels by lowering the rate at which carbon can be saturated in water (Ragazzola 2012). Atmospheric concentrations of carbon dioxide are predicted to rise at an increasing rate and could lead to new climate behaviors (Feely 2008). The ocean's ability to absorb carbon from the atmosphere helps reduce the impact of greenhouse gases but increases the rate at which ocean acidification events will occur in the future (Feely 2008). Natural pH conditions are being altered and have an effect on intertidal communities. Ocean acidification is expected to particularly affect upwelling areas, this combination could foreseeably add too much physiological stress for calcifying organisms, such as coralline algae (Shen 2016). When events of upwelling occur, cold, nutrient rich ocean water is brought from the ocean's depths up to the coastal shelf surface. However, this deep ocean water is low in oxygen and high in carbon dioxide due to vertical stratification (Gruber 2011). Ocean acidification and upwelling create conditions that may inhibit calcification practices (Fassbender 2016). Coralline algae hold important ecological roles and are responsible with tasks including photosynthesis, carbon cycling, habitat creation, addition into the food web, and hold the ability to calcify (Kamenos et al. 2016). This environmental pressure could soon affect calcified algae abundances in the intertidal and rearrange abiotic and biotic factors of interaction that cascade below (Kelaher and Castilla 2005).

A loss in coralline species, or any event that threatens algal density is of interest to study because algae are areas of habitat within the intertidal (Hacker and Steneck 1990). Intertidal complexity refers to attributes like texture, shape, composure, and can be a quantitative or qualitative assessment (Hicks 1986). According to a study on grazing patterns observed in tidepools by Segovia-Rivera and Valdivia (2016), intertidal herbivores have shown to have significant effects on the structure of tide pool communities, most influentially by controlling macroalgae abundance through grazing behaviors. An increased complexity of algal physical structure was associated with an increase in invertebrate diversification and species richness (Dean and Connell 1987). Algae structure influences epifaunal communities by decreasing predation mortality and offering protective substrate barriers. Reduction of wave shock and accumulation of individuals passing by wave action are proposed to increase epifaunal abundances as well. (Dean and Connell 1987).

In this study we inspected five different algal species between two categories of either calcifying (*Bossiella plumosa* and *Corallina vancouveriensis*) or fleshy algae (*Neorhodomela larix, Microcladia borealis,* and *Endocladia muricata*). Coralline and fleshy algae responses to ocean acidification are well studied and their roles as ecosystem engineers have been validated (Shen 2016). We were curious to see how gastropod and non-gastropod densities differ between the two algal categories. We hypothesized that a higher species density for both gastropod and non gastropod samples will be found in the coralline than that of the fleshy species as to reflect the findings of Shen (2016), where epifauna were more abundant in coralline algae than in fleshy algae. Which was in part explained by the fact that the thallus density of coralline algae was typically higher than in fleshy (Shen 2016). For the same reason, we hypothesize to see structural differences based on volume density between the coralline and fleshy categories.

Methods

The sampling site was located at The Yachats State Recreation Area, on the Oregon coast. Sampling dates occurred on May 30th and May 31st, and were timed with peak morning low tides. The two categories of algae, “fleshy” or “calcified”, were collected among the low and mid zones of the intertidal. *Bossiella plumosa* and *Corallina vancouveriensis* were used for the calcified category. *Neorhodomela larix, Microcladia borealis,* and *Endocladia muricata* were selected for the fleshy category. Each algae species had 8 specimen collected from the mid and 8 specimen from the low zone. Low zone counts of *Endocladia muricata* were non-existent due to their lack of availability. Before extracting algae form the intertidal, maximum thallus height was measured in centimeters, and a total canopy volume was measured using width and length measurements. The total canopy volume is a measurement of the total cuboidal volume space the algae occupies. Metal scrapers helped remove specimens from the rocky surface, algae were placed in individual ziplock plastic bags with numerical tag indicators.

Once in the lab, algal specimen were individually inspected under a light microscope. During light microscope inspections, gastropod and non gastropod (arthropods and worms) abundances were counted. Algae specimen were properly cleaned of any epifauna and weighed on an analytical balance. A graduated cylinder was filled with water and used to asses volume through the water displacement method. After all measurements specimen were properly disposed. This process was repeated for each individual algae sample, Microsoft Excel was used to record and assort data.

Algae structure is being assessed through volume density, a value comprised of the volume found via water displacement divided by the total canopy volume. A two sample t-test was conducted using Microsoft Excel to assess the structural “likeness” by volume of the two coralline algae species. RStudio was used to run several analysis of variance tests to asses the structural “likeness” by volume for the fleshy algae, also to assess the significant factors on gastropod and non-gastropod abundances. A linear regression was used to assess the relationship between volume density and gastropod density.

Results

The first ANOVA test was used to assess the volume density within the fleshy algae category, Table 1 shows that the p value was 0.17. The p value from the two sample T- test was 0.800, where *Bossiella plumosa* had a mean 0.195 units of volume density, and *Corallina vancouveriensis* had a mean 0.179 units of volume density (Table 2). Figure 1 shows a boxplot of algae species and volume density of organisms, where volume density of organisms is logged to create data of better fit.

Gastropod density was found to be almost significantly different between the two categories of algae, calcified and fleshy, but not significant based on elevation (Table 3). Non-gastropod density was found to be significantly different between algal categories and not significant with elevation (Table 4). The ANOVA that tested the significance of volume density between all species found a p value of 0.745 as seen in Table 5, showing no significant difference between all algal species.

Linear regression analysis reports suggests that volume density among algal species is significantly related to gastropod density. Non-gastropod density was found to be significantly influenced by volume densities of both category of algae ($p = 0.0316$ & $p < 0.0005$ for coralline and fleshy, respectively). Figure 2 and Figure 3 illustrate how an increase in algal density is predicted to increase density counts for both gastropods and non-gastropods.

Discussion

The results suggest that based on volume density, the two calcifying algaes are not significantly different. The results from this statistical assessment allowed us to clump both coralline species together since they were found to not be significantly different in volume density. The fleshy algae used in our sample do not significantly differ in volume density, and can be clumped to represent the fleshy algae category. The coralline samples and the fleshy algae samples did not significantly differ by volume density. With good reason to believe that coralline algae would have more thallus complexity, and be denser than their fleshy counterparts (Shen 2016), it is possible that measuring structure in an alternative way than volume density would give more accurate results to algal structure, and could prove as an interesting path for further research.

While we predicted that both gastropod and non-gastropod samples would show a significant difference in densities between algase categories, this held true for only non-gastropods. Volume densities were not significantly different between algae types, like previously predicted. From our data, we see that non-gastropods are showing a preference on algal type, but it is not being determined by zone elevation or by volume density of algal type. A study conducted by Best et al. (2014) also tested epifaunal algae preferences. Their study showed that epifaunal preference was influenced by size of the animal, rather than algae thallus density. Bigger epifaunal showed to not significantly different between algae categories, while smaller organisms such as copepods and isopods displayed preference. Smaller organisms avoid predation by hiding in spaces provided by algae. Certain algaes provided better space for predation avoidance, while bigger organisms avoid predation through size and do not rely on algae thallus for protection (Best et al. 2014).

Sample size plays as a main hindrance to our statistical findings, if a larger number of samples were used the data could have represented epifaunal populations more accurately. Our results showed that there is a positive relationship between volume density and epifaunal density, which holds consistent with previous studies that assess complexity-species relationships (Kovalenko et al. 2011; Shen 2016). Some studies show negative relationships between coralline density and epifaunal abundances and richness (Kelaher and Castilla 2005), but explain that small bodied organisms were naturally less abundant in study sites. Our data suggests that ocean acidification events would have a smaller effect on gastropods than non gastropods, since gastropods held no preference of algal type and non-gastropods preference coralline algae. Both plant and animal diversity are important for ecosystem health, as well as serve as tools to collect further knowledge about these interactions (Best et al. 2014).

Information collected from this study could be further expanded upon by dividing gastropod and non-gastropod categories further. Assessments of how different types of gastropods and non-gastropods rely on differing algae species could better depict their importance to the intertidal. Volume density worked as a metric to unify a sample measurement between algal species, but our results showed that it was not an accurate measure of thallus structure. Research that can better asses thallus structure and its impacts on epifaunal would help further elaborate on our findings.

Literature Cited

1. Best, R. J., A. L. Chaudoin, M. E. S. Bracken, M. H. Graham, and J. J. Stachowicz. 2014. Plant-animal diversity relationships in a rocky intertidal system depend on invertebrate body size and algal cover. Ecology **95:** 1308–1322.
2. Dean, R. L., and J. H. Connell. 1987. Marine invertebrates in an algal succession. III. Mechanisms linking habitat complexity with diversity. Journal of Experimental Marine Biology and Ecology **109:** 249–273.
3. Fassbender, A. J., C. L. Sabine, and K. M. Feifel. 2016. Consideration of coastal carbonate chemistry in understanding biological calcification. Geophysical Research Letters **43:** 4467-4476.
4. Hacker S.D., and R. S. Steneck. 1990. Habitat architecture and the abundance and body-size-dependent habitat selection of a phytal amphipod. Ecology **6:** 2269-2285
5. Hicks, G. R. F. 1986. Meiofauna associated with rocky shore algae. Pages 36-56 in P. G. Moore and R. Seed, editors. The ecology of rocky coasts: essays presented to J. R. Lewis. Columbia University Press, New York, New York, USA
6. Kamenos, N. A., G. Perna, M. C. Gambi, F. Micheli, and K. J. Kroeker. 2016. Coralline algae in a naturally acidified ecosystem persist by maintaining control of skeletal mineralogy and size. Proceedings of the Royal Society: Biological Sciences **283:** 20161159
7. Kelaher, B. P., J. C. Castilla. 2005 Habitat characteristics influence macrofaunal communities in coralline turf more than mesoscale coastal upwelling on the coast of Northern Chile. Estuarine, Coastal and Shelf Science **63:** 155-165
8. Kovalenko, K. E., S. M. Thomaz, and D. M. Warfe. 2011. Habitat complexity: approaches and future directions. Hydrobiologia **685:** 1–17
9. Ragazzola, F., L. C. Foster, A. Form, P. S. L. Anderson, T. H. Hansteen, and J. Fietzke. 2012. Ocean acidification weakens the structural integrity of coralline algae. Global Change Biology **18:** 2804–2812.
10. Segovia-Rivera, V., N. Valdivia. 2016. Independent effects of grazing and tide pool habitats on early colonisation of an intertidal community on western Antarctic Peninsula. Revista Chileana de Historia Natural **89:** 1-9.
11. Shen, C. 2016. Impacts of Ocean Acidification on Coralline Algae: From Species to Community Consequences. Oregon State University.

Tables

Table 1: ANOVA between fleshy algae and volume density.

	Df	**Sum Sq**	**Mean Sq**	**F value**	**Pr(>F)**
Species	2	0.17	0.085	1.84	0.17
Residuals	37	1.71	0.046		

Table 2: Two sample T-test results from assessing coralline species and volume density.

	Mean	**SD**	**N**	**SE**	**SE/2**
Bossiella plumosa	0.20	0.16	16	0.0392	0.019
Corallina vancouveriensis	0.18	0.20	16	0.05	0.025
T.test		P value	=	0.80	

Table 3: Gastropod density between algal categories

	Df	**Sum Sq**	**Mean Sq**	**F value**	**Pr(>F)**
Category	1	0.56	0.56	3.92	0.051
Elevation	1	0.42	0.42	2.96	0.089
Category:Elevation	1	0.33	0.33	2.32	0.13
Residuals	68	9.77	0.14		

Table 4: Non-gastropod density between algal categories.

	Df	**Sum Sq**	**Mean Sq**	**F value**	**Pr(>F)**
Category	1	38.44	38.43	5.18	0.02
Elevation	1	2.25	2.24	0.30	0.58
Category:Elevation	1	0.67	0.67	0.09	0.76
Residuals	68	503.76	7.40		

Table 5: Density volume between all algae species.

	Df	**Sum Sq**	**Mean Sq**	**F value**	**Pr(>F)**
Category	1	0.00424	30.0042	0.10	0.74
Elevation	3	0.175	0.057	1.44	0.23
Residuals	67	2.686	0.040		

Figures

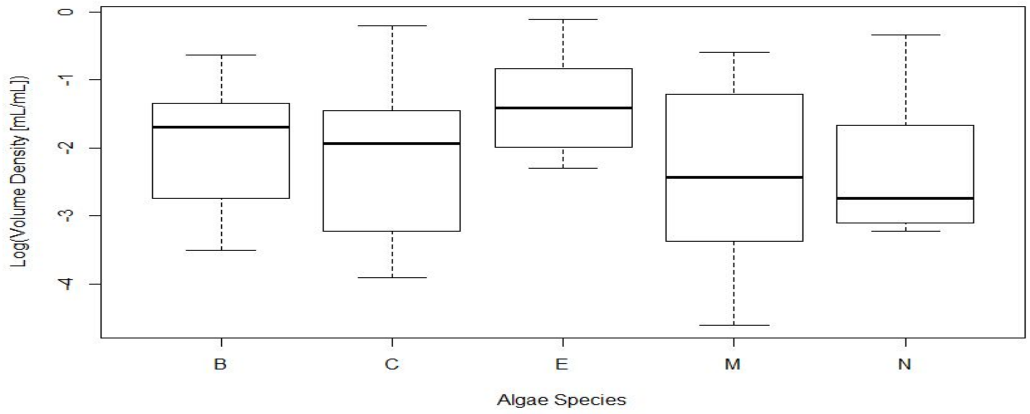

Figure 1: Algae volume density data was log transformed and compared between species (B = *Bossiella plumosa, C = Corallina vancouveriensis, E = Endocladia muricata, M = Microcladia borealis, N = Neorhodomela larix).* The boxplot shows the first 25% of data from lower tail to lower box, first 50% from lower tail to dark line, 75% from lower tail to upper box, and 100% of data from tail to tail.

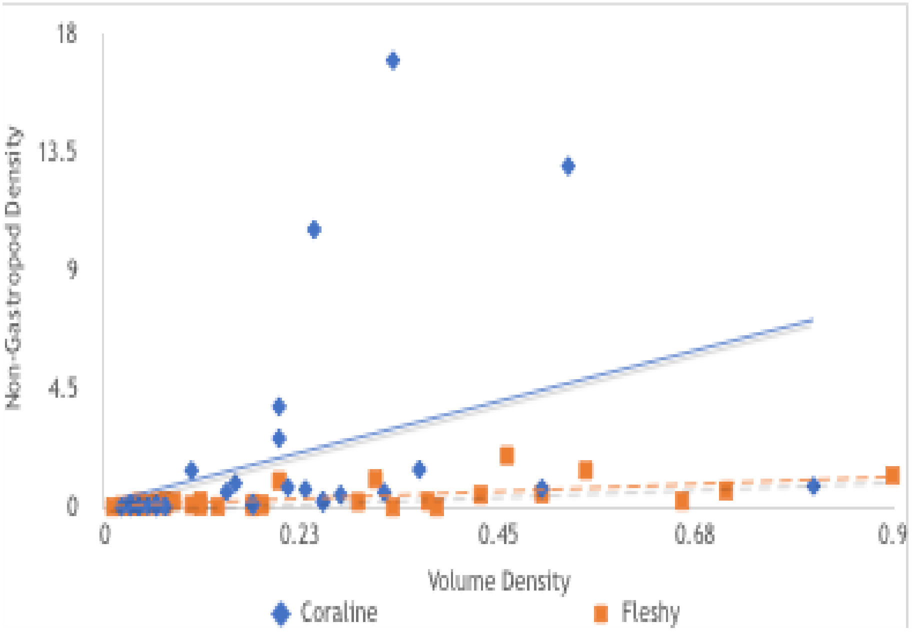

Figure 2: Linear regression between non-gastropod densities and volume densities between algal categories (Coraline: Y = 8.6x+.1433, R^2 = .145, P value = .0316. Fleshy: Y = 1.2358x+.0385, R^2= .3867, P value > .0005).

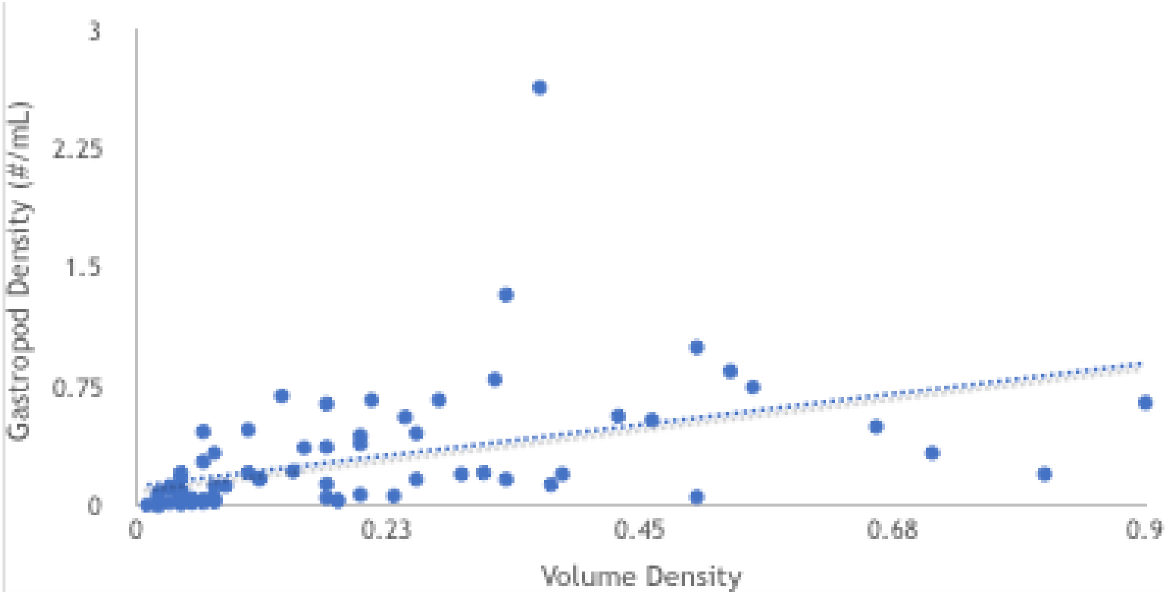

Figure 3: Linear regression between gastropod density and algal volume density (R^2 = 0.1806, p-value= 0.0001174 with 70 DF.