Epifaunal density differences on coralline algae compared to fleshy algae in the Yachats, Oregon intertidal community

Christopher D. Gani, Samuel J. Field

Oregon State University Department of Biology

Abstract

Ocean acidification has led to many issues regarding the decline of calcifying organisms, such as coralline algae. Acidified sea water inhibits precipitation of $CaCO_3$ that affects the structure and growth of coralline algae. Therefore, non-calcifying algae may outcompete calcifying algae in the intertidal systems with future acidic ocean condition. Variety species of algae possibly have a different habitat architecture that may attract diverse kinds of epifauna. One of the most abundant algal epifauna in Oregon's rocky intertidal system are snails (Gastropoda). They are an important grazer of mussels in rocky intertidal communities. Considering the importance of gastropods in intertidal communities and their relationship with macroalgae, we examined the dependence of gastropods to coralline algae. Algal sampling (n = 72) was done at Yachats State Recreational Park, Oregon. For each sample collected, the number of epifauna and algal density were measured. We found that gastropods did not have preferences to specific type of algae. In contrast, non-gastropods had a preference towards coralline algae in comparison to fleshy algae. However, further studies are needed to elucidate the relationship coralline algae and epifauna community.

Introduction

The California current system is characterized by upwelling that brings nutrients to the surface, thus enhancing productivity (Walsh 1991). However, nutrient rich water from the deep ocean has a higher pCO_2 and lower pH than the surface waters (Feely et al. 2008, Hauri et al. 2013). Thus upwelling regions are highly vulnerable to ocean acidification threats. Ocean acidification has led to the decline of calcifying organism (Orr et al. 2005, Hofmann et al. 2010, Kroeker et al. 2010). Calcifying organisms are unable to produce calcium carbonate because higher CO_2 concentration in sea water leads to lower precipitation of $CaCO_3$ (Kitano and Hood 1962). Like many calcifying organisms, coralline algae have shown to do poorly in a more acidic sea water condition (Anderson et al. 2008). Acidic sea water hugely affect the growth rate and structure of coralline algae which in turn, results in decrease of population of coralline algae. (Ragazzola et al. 2012, Barner 2016, Kamenos et al. 2016). With coralline algae doing worse in acidic ocean condition, non-calcifying algae might out compete calcifying algae in the intertidal systems (Hofmann et al. 2012). Thus, understanding the impact of coralline algae decline to algae epifaunal community in intertidal system might help us to abate the negative effects imposed on the intertidal community.

Algae habitat architecture dictates the type and abundance of epifauna that can live on it (Hacker and Steneck 1990). There are two components of habitat architecture: spatial component, which includes the spaces between algal fronds and structural component, the number of branches and fronds. Variety species of algae possibly have a different habitat architecture that may attract diverse kinds of epifauna. Moreover, size of clumps might also dictate the number of epifauna that can live on the algae (Best et al. 2014).

Some of the most abundant algal epifauna in Oregon's rocky intertidal system are gastropods (Shen 2016). The gastropods in Oregon intertidal system are considered as important grazers of mussels in rocky intertidal community (Phillips and Hutchison 2008) and include the species *Tegula funebralis*, *Nucella ostrina*, *Nucella caniculata*, *Lacuna marmorata*, and *Barleeia haliotiphila*. In the rocky intertidal community, grazers help maintain the abundance of highly competitive species such as mussels. Previous studies showed that without predator control in the community, it is more likely that the intertidal community would be dominated by mussels (Menge et al. 2015). Aside from gastropods, there are other epifauna, such as worms, bivalves, and gammarids, which uses algae as shelters (Hacker and Steneck 1990). For example, they use algal cover as shelter from desiccation and physical disturbances such as waves.

Considering the importance of gastropods on intertidal communities and their relationship with macroalgae, we were keen to observe the dependence of gastropods to coralline algae. We expected that there was a preference towards coralline algae for algal epifauna due to its complex structure (Barner 2016). With the fore mentioned basis, we produced three hypotheses tested in this study. First, we expect there were structural differences between coralline algae and non-coralline (fleshy) algae. Second, we expected that gastropods would be more abundant in coralline algae in comparison to fleshy algae. Finally, we also expected that there would be more non-gastropods present on coralline algae in comparison to fleshy algae.

Methods

The sampling took place at Yachats State Recreational Area, Oregon. Yachats is located on Cape Perpetua and it is a part of the Californian Current System (CCS). Californian Current System spans from Baja California, Mexico, to British Columbia, Canada, and it is known by its upwelling currents (Checkley and Barth 2009). Sample collection was conducted on 30th and 31st May 2017

which were done during low tides. In each zone, eight samples for each species of algae were collected. Species of algae collected were grouped into coralline and fleshy algae. Calcifying algae included *Bossiella plumosa* and *Corallina vancouveriensis*, whereas fleshy algae included *Endocladia muricata*, *Neorhodomela larix*, and *Microcladia borealis*. Low zone *Endocladia* samples were excluded since *Endocladia* were absent in low zone. A total of 72 samples were gathered from the site (2 zones x 5 species x 8 samples). Before collection, we measured the canopy area and the thallus height were measured in cm. We then multiplied area and height to obtain the canopy volume. Canopy volume (CV) is defined as the total cuboid volume that the algae occupy (Hacker and Steneck 1990). After measurement, we transferred the algae to ziploc bags for later processing. We separated different clumps into different ziploc bags.

In the laboratory, we examined collected samples under dissecting microscope to separate epifauna from the algae. Epifauna were identified and sorted out into gastropods and non-gastropods. The total number of gastropod and non-gastropod of each sample were recorded. Separated algae clumps were then measured for thallus volume (TV) by using water displaced from a 100 mL graduated cylinder (Hacker and Steneck 1990). Wet weight of algae clumps were measured using a digital scale (OHAUS). Volume density (VD) of algae was then calculated by dividing thallus volume and canopy volume. To determine if species in each category has similar structure, we tested whether each species in a category had structural differences. In addition, gastropod and non-gastropod abundance was standardized by dividing the total abundance with canopy volume of the clump. Standardized values for epifauna abundance are referred as gastropod and non-gastropod density.

We tested the relationship of gastropod and non-gastropod density with elevation and algae category using analysis of variance (ANOVA). Epifauna density was regarded as the response variable while elevation and algae category were regarded as explanatory variables. Influence of VD of algae to the density of epifauna was tested with linear regressions. In addition, we tested if species differ in VD for each category. Differences in VD within coralline species were tested with t-test while differences in fleshy species were tested with ANOVA. All ANOVAs and linear regressions were calculated with R (R project 2017). The t-test was calculated in Microsoft Excel (Microsoft 2017).

Results

Algae Volume Density Across Categories and Species

We found that there were no significant differences between algae VD for each species within coralline category (mean ± SE: *B. plumosa* 0.19 ± 0.039, *C. vancouveriensis* 0.179 ± 0.050; two-sample *t* test; n=16; p-value=0.8003). Similarly, there are no significant differences of VD between fleshy algae species (ANOVA, Table 1 & Figure 1). Tests for the influence of algae category or species to algae VD showed that there were no significant effects of species or category to VD (ANOVA, Table 2).Therefore, We were able to group algae species to categories because our data supports the assumption that there were no significant structural differences between each species within a category.

Effect of Category, Elevation, and Volume Density on Epifauna Density.

In general, we found that there was variability among the gastropod and non-gastropod densities in different algae category and elevation (Figure 2). Gastropod density was found to be not affected by elevation (p = 0.089) but there was slight influence of algae category (p = 0.051) (ANOVA, Table 3). There was a linear correlation between VD of algae and gastropod density indicating a strong positive relationship (Figure 3). Gastropod density was predicted to increase by 0.8636 units for one unit increase in algae VD. Furthermore, we found that non-gastropod density was significantly influenced by algae category but not the elevation gradient (ANOVA, Table 4). We observed that there were more non-gastropods in coralline in comparison to fleshy algae. Most of the non-gastropods in the coralline consisted of isopods. Since there was an influence of algae category on non-gastropod density, we used separate linear regressions for the two algae categories to test the relationship between non-gastropod density to algae VD. We found that a strong (strong nya dari mana?) relationship between VD to non-gastropod density in both algae categories (Figure 4). Moreover, non-gastropod density in the coralline algae has steeper slope than in the fleshy algae, implying that non-gastropod density in coralline will increase more than in fleshy algae for a unit increase in algae VD.

Discussion

There were no structural differences between algae categories based on VD. Thus, our first hypothesis was not supported although previous study suggest that coralline algae would have more thallus complexity, thus denser structure in comparison to fleshy algae (Shen 2016). However, this similarity in algae density was due to using VD to determine the structure of algae. Other methods such as using algae surface area to volume (SAV) could be used to quantify the structure of algae in future studies (Harrod and Hall 1962, Barner 2016). Ultimately, the results do not support the proposed hypothesis that differences in non-gastropod density for algal category were due to different structures since both categories had similar structure.

Our second hypothesis was also not supported since gastropods did not have any preferences for algae category. However, our observations and the nearly significant p-value suggest an effect of algae category on gastropod preferences may be detectable with a larger sample size. However, it is also possible that epifauna do not have algal species or category habitat preferences. Previous studies have shown that some epifauna select their habitat based on the size of the algae clump without any species preferences and epifauna prefer larger clumps of algae rather than smaller clumps (Dean and Connell 1987).

The results supported our third hypothesis finding that non-gastropods were more abundant in coralline species rather in fleshy species. This finding was consistent with the epifaunal survey by Shen (2016). However, this was not consistent with another previous study suggesting that epifauna that were larger relative to the algae thallus or have high mobility relative to algae area (bivalves and gammarids) were less likely to respond to algal species identity (Best et al. 2014). Classifying non-gastropods into more specific groups, we may have found similar results to Best et al. 2014.

Volume density to epifaunal density linear regressions indicated a close relationship between epifauna density and algae VD. This was consistent with prior studies that found more epifauna in denser algae clumps (Best et al. 2014, Shen 2016). One of the factors that leads to denser clumps were structure complexity of the algae (Hacker and Steneck 1990). Previous studies suggest that in addition to larger clumps, algal structure complexity might also affect epifaunal abundance on the algae (Dean and Connell 1987).

Since our result found no gastropod preferences to either category of algae, future coralline algae loss due to ocean acidification might not strongly impact gastropod community in the rocky intertidal system. However, coralline loss might have an impact on non-gastropod species such as worms and arthropods. To understand the strength of interaction between these communities with coralline algae, further study is needed. Future studies can include larger sample size and different sites along the CCS for each species of algae. Observation can also be done in different seasons since other studies have found temporal variability on the community structure in the CCS intertidal systems (Huyer 1983, Menge and Menge 2013).

References

Anderson, A. J., F. T. Mackenzie, and N. R. Bates. 2008. Life on the margin implication of ocean acidification on Mg-calcite, high latitude and cold water marine calcifiers. Marine Ecology Progress Series **373**:265–273.

Barner, A. K. 2016. Predictability and Constraints on the Structure of Ecological Communities in the Context of Climate Change. Oregon State University.

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.

Checkley, D. M., and J. A. Barth. 2009. Patterns and processes in the California Current System. Progress in Oceanography **83**:49–64.

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.

Feely, R. A., C. L. Sabine, J. M. Hernandez-Ayon, D. Ianson, and B. Hales. 2008. Evidence for Upwelling of Corrosive "Acidified" Water onto the Continental Shelf. Science **320**:1490–1492.

Hacker, S. D., and R. S. Steneck. 1990. Habitat architecture and the abundance and body-size-dependent habitat selection of a phytal amphipod. Ecology **71**:2269–2285.

Harrod, J., and R. E. Hall. 1962. A Method for Determining the Surface Areas of Various Aquatic Plants. Hydrobiologia **20**:173–178.

Hauri, C., N. Gruber, M. Vogt, S. C. Doney, R. A. Feely, Z. Lachkar, A. Leinweber, A. M. P. McDonnell, and M. Munnich. 2013. Spatiotemporal variability and long-term trends of ocean acidification in the California Current System. Biogeosciences **10**:193–216.

Hofmann, G. E., J. P. Barry, P. J. Edmunds, R. D. Gates, D. A. Hutchins, T. Klinger, and M. A. Sewell. 2010. The Effect of Ocean Acidification on Calcifying Organisms in Marine Ecosystems: An Organism-to-Ecosystem Perspective. Annual Review of Ecology, Evolution, and Systematics **41**:127–147.

Hofmann, L. C., S. Straub, and K. Bischof. 2012. Competition between calcifying and noncalcifying temperate marine macroalgae under elevated CO2 levels. Marine Ecology Progress Series **464**:89–105.

Huyer, A. 1983. Coastal upwelling in the California Current System. Progress In Oceanography **12**:259–284.

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 B: Biological Sciences **283**:20161159.

Kitano, Y., and D. W. Hood. 1962. Calcium Carbonate Crystal Forms Formed from Sea Water by Inorganic Processes. The Journal of the Oceanographical Society of Japan **18**:35–39.

Kroeker, K. J., R. L. Kordas, R. N. Crim, and G. G. Singh. 2010. Meta-analysis reveals negative yet variable effects of ocean acidification on marine organisms. Ecology Letters **13**:1419–1434.

Menge, B. A., E. L. Berlow, C. A. Blanchette, S. A. Navarrete, and B. Sylvia. 2015. The Keystone Species Concept : Variation in Interaction Strength in a Rocky Intertidal Habitat. Ecological **64**:249–286.

Menge, B., and D. Menge. 2013. Dyanmics of coastal meta-ecosystems: the intermitten upwelling hypothesis and a test in rocky intertidal regions. Ecology **83**:283–310.

Orr, J. C., V. J. Fabry, O. Aumont, L. Bopp, S. C. Doney, R. A. Feely, A. Gnanadesikan, N. Gruber, A. Ishida, F. Joos, R. M. Key, K. Lindsay, E. Maier-Reimer, R. Matear, P. Monfray, A. Mouchet, R. G. Najjar, G.-K. Plattner, K. B. Rodgers, C. L. Sabine, J. L. Sarmiento, R. Schlitzer, R. D. Slater, I. J. Totterdell, M.-F. Weirig, Y. Yamanaka, and A. Yool. 2005. Anthropogenic ocean acidification over the twenty-first century and its impact on calcifying organisms. Nature **437**:681–686.

Phillips, N. E., and E. Hutchison. 2008. Grazer effects on algal assemblages and mussel recruitment in two different mid-intertidal communities in the Cook Strait, New Zealand. New Zealand Journal of Marine and Freshwater Research **42**:297–306.

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.

Shen, C. 2016. Impacts of Ocean Acidification on Coralline Algae: From Species to Community Consequences. Oregon State University.

Walsh, J. J. 1991. Importance of continental margins in the marine biogeochemical cycling of carbon and nitrogen. Nature **350**:53–55.

Tables

Table 1. Result of ANOVAs testing the influence of species within fleshy algae to the VD of algae.

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Species	2	0.17098	0.085492	1.8491	0.1716
Residuals	37	1.71066	0.046234		

Table 2. Result of ANOVAs testing the influence of category and species to the VD of algae.

	DF	Sum Sq	Mean Sq	F value	Pr(>F)
Category	1	0.00427	0.004271	0.1067	0.745
Species	3	0.1731	0.057699	1.4412	0.2386
Residuals	67	2.68234	0.040035		

Table 3. Result of ANOVAs testing the influence of category, elevation, and category:elevation to gastropod density.

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Category	1	0.5636	0.5636	3.921	0.05173
Elevation	1	0.4267	0.42666	2.9683	0.08946
Category:Elevation	1	0.3338	0.33377	2.3221	0.13219
Residuals	68	9.7742	0.14374		

Table 4. Result of ANOVAs testing the influence of category, elevation, and category:elevation to non-gastropod density. Significant P-values are shown with asterisk.

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Category	1	38.44	38.439	5.1886	0.02588*
Elevation	1	2.25	2.247	0.3033	0.58361
Category:Elevation	1	0.67	0.675	0.0911	0.76374
Residuals	68	503.76	7.408		

Figure Captions

Figure 1. Boxplot of VD for each species of algae. Volume density was log transformed. Box indicates 25-75% with median; whiskers span 10-90%. Species name are abbreviated as follow: B = *Bossiella plumosa*, C = *Corallina vancouveriensis*, E = *Endocladia muricata*, M = *Microcladia borealis*, N = *Neorhodomela larix*

Figure 2. Mean Epifauna density differences between elevation gradient and algae category. X axis label shows elevation zone followed by algae category. Error bars indicate standard error. Blue represent gastropod density, orange represent non-gastropod density. Epifauna density (gastropod and non-gastropod) is defined as number of Epifauna divided by canopy volume.

Figure 3. Linear relationship between gastropod density to algae VD. Includes both coralline and fleshy algae categories.

Figure 4. Linear relationship between non-gastropod density to algae VD between coralline and fleshy algae.
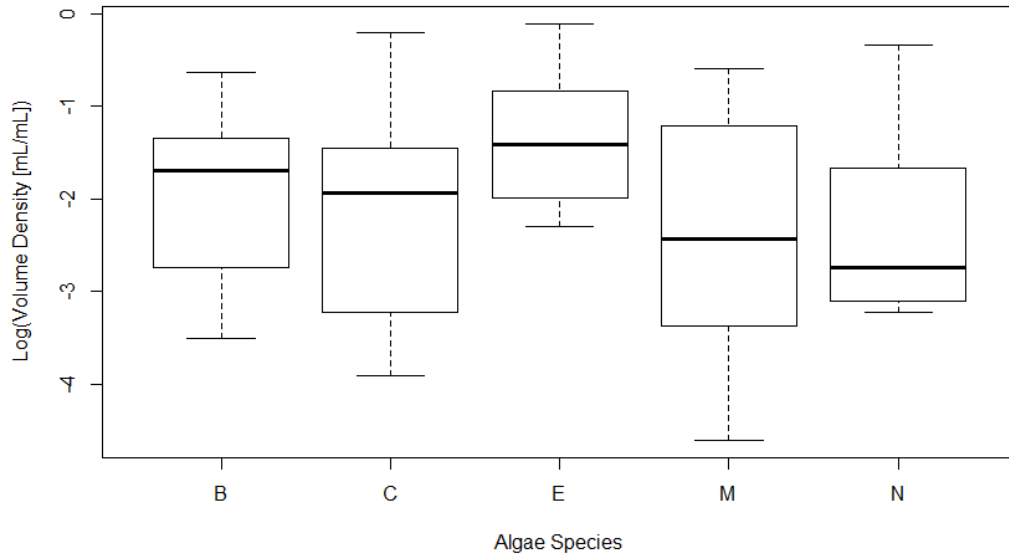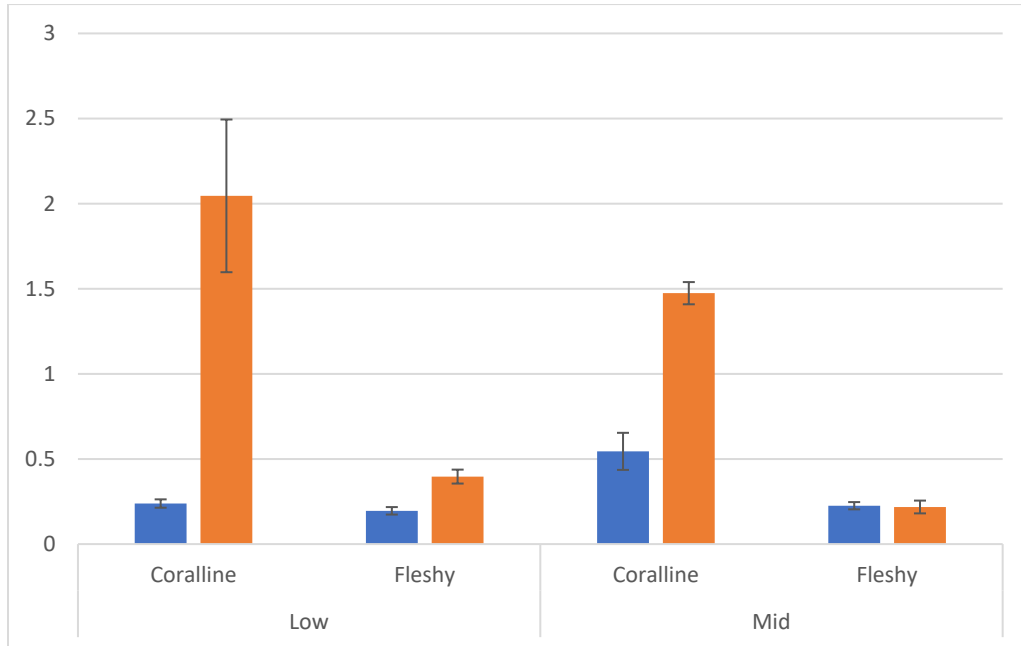
Figures
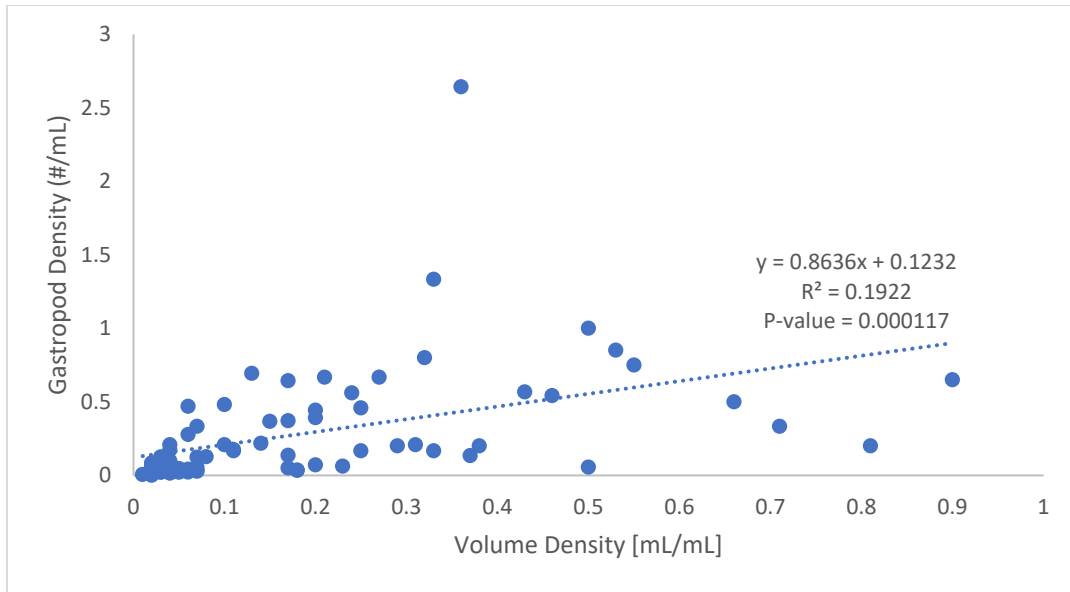
Figure 1

Figure 2

Figure 3

Figure 4