Within ARMS' Reach: An Assessment of Diversity, Abundance, and Size Effects of CO_2 Venting and Associated pH Change on Coral Reef-Dwelling Invertebrate Communities

Brianna Weir[1,2] and Laetitia Plaisance[2]

[1]Department of Biological Sciences, Mount Holyoke College, South Hadley, MA

[2]Department of invertebrate Zoology, National Museum of Natural History, Smithsonian Institution, Washington, DC

Context

Ocean Acidification: As the concentration of carbon dioxide (CO_2) increases in the atmosphere, CO_2 levels also increase in the ocean thus changing the water chemistry, a phenomenon known as Ocean Acidification (OA).

Impacts on Coral Reefs: OA has been shown to negatively impact calcifying organisms such as corals and many invertebrate species (Kroeker et al 2013) but studies evaluating the impacts of OA on the invertebrate communities associated with coral reefs are scarce (Fabricius et al. 2014).

Invertebrate community patterns on Acidified Reefs: We investigated the effects of low pH on the invertebrate communities associated with naturally acidified coral reefs near Normanby Island, Papua New Guinea. There, portions of the reef featuring CO_2 seeps (Figure 1) exhibit a pH gradient that is comparable to projected pH conditions over the next century and coral communities have adapted to these environmental conditions (Fabricius et al. 2011).

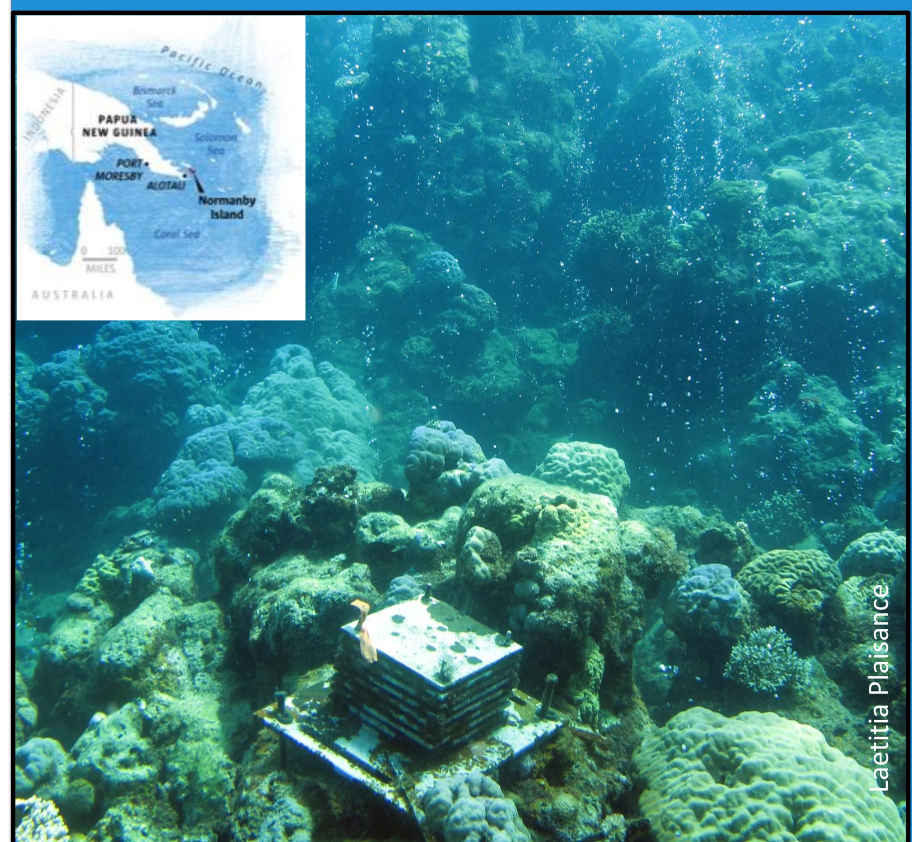

Figure 1. An ARMS unit deployed on a reef with a volcanic CO_2 seep.

We hypothesize that invertebrate diversity and abundance will show an overall decrease with decreasing pH and that the size of organisms will exhibit mixed responses depending on their biological characteristics.

Methods

Invertebrates were collected from 18 Autonomous Reef Monitoring Structures (ARMS) deployed for two years at two locations (Illi and Dobu) and three pH sites (control: pH 8.2; medium: pH 7.9; and low: pH 7.7).

The organisms (>2mm in size) were all sampled, counted and the cytochrome oxidase subunit I (barcoding gene) was sequenced in order to discriminate species at a 95% threshold and investigate their diversity.

All the specimens with a shell or an exoskeleton were photographed for measurements of their bodies (Figure 2).

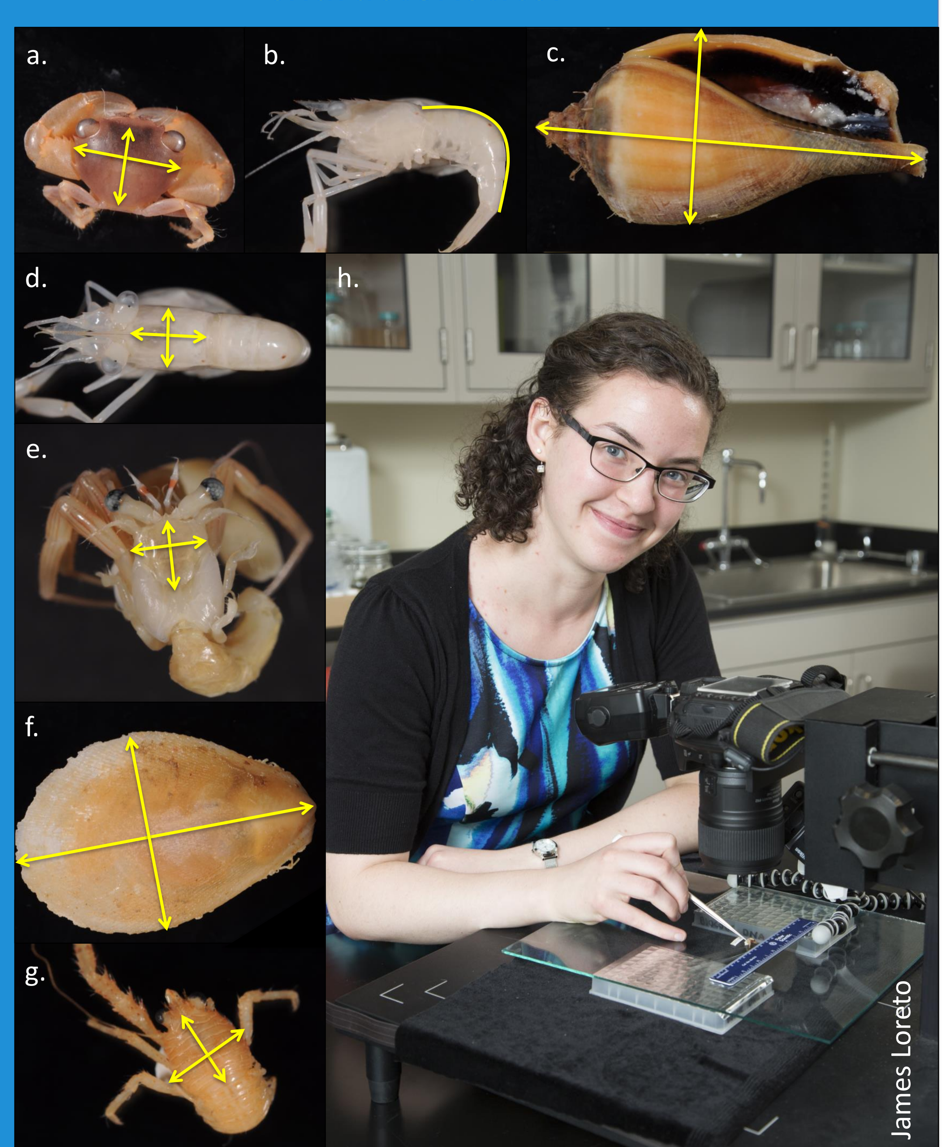

Figure 2. Measurements taken of crabs (a), shrimp (b, d), gastropods (c), hermit crabs (e), bivalves (f), and squat lobsters (g). Photos taken by myself. Also shown is the photo setup (h).

Diversity

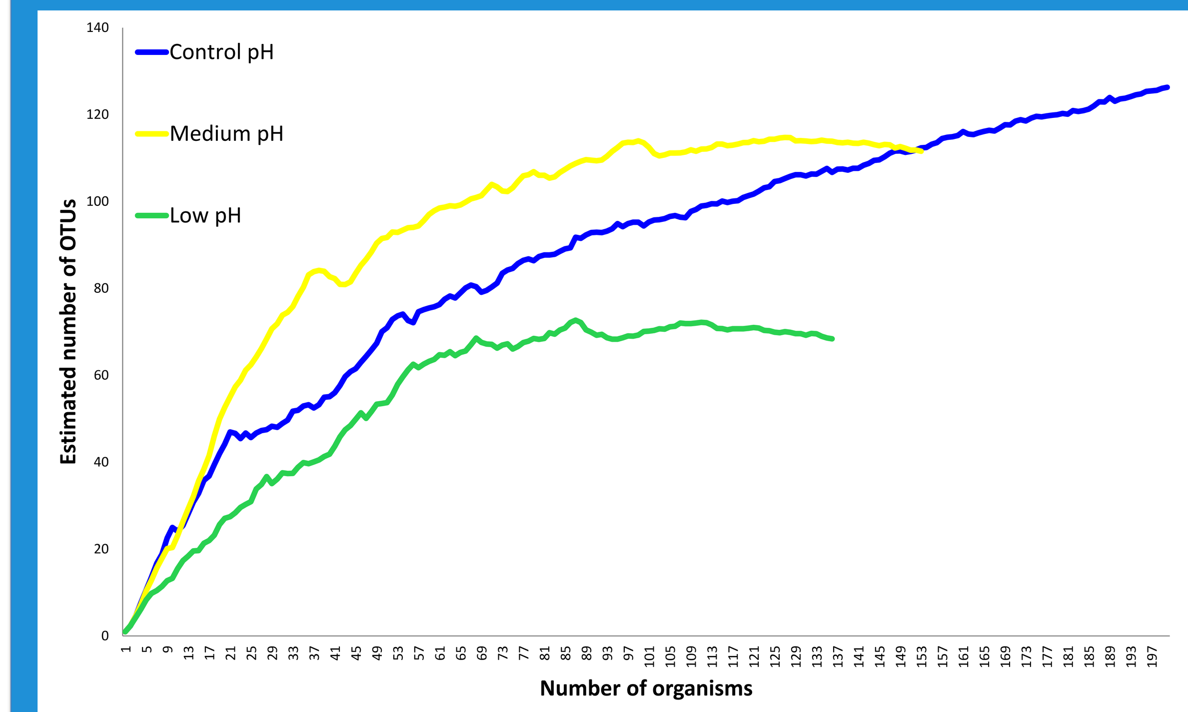

Figure 3. Rarefaction curve of species diversity in Illi generated using the biodiversity estimator Chao1. Similar trends are found in Dobu.

- Relative to the control pH, low pH communities have 45.8% fewer species in Illi and 59.7% fewer species in Dobu.
- The diversity of the medium pH is in the same range as that of the control pH in both locations.
- The rarefaction curves for low and medium pH reach a plateau, so our sampling is representative of the true diversity.
- The curve for control pH is still growing, indicating that we are yet to encompass the higher diversity that is present.

Abundance

- In Illi, the abundance was highest at control pH (n=200), followed by medium pH (n=185) and low pH (n=136).
- This trend is seen in all taxa except for the gastropods (Figure 4).
- In Dobu, trends are different. The medium pH exhibits the highest abundance.

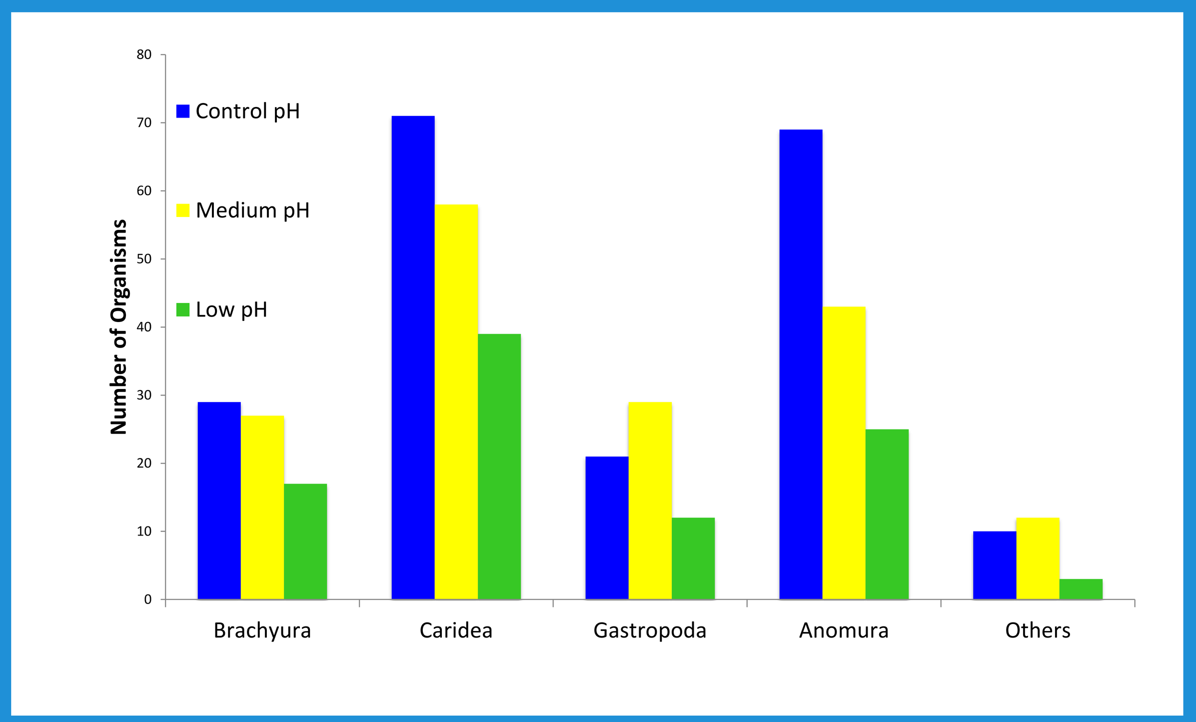

Figure 4. Abundance of 2mm invertebrates in each of three pH levels at Illi, separated by taxon.

Size

- Size results were log corrected to account for skew, and length and width measures were combined to address shell size more accurately.
- All statistics were done in R (R Core Team 2016).

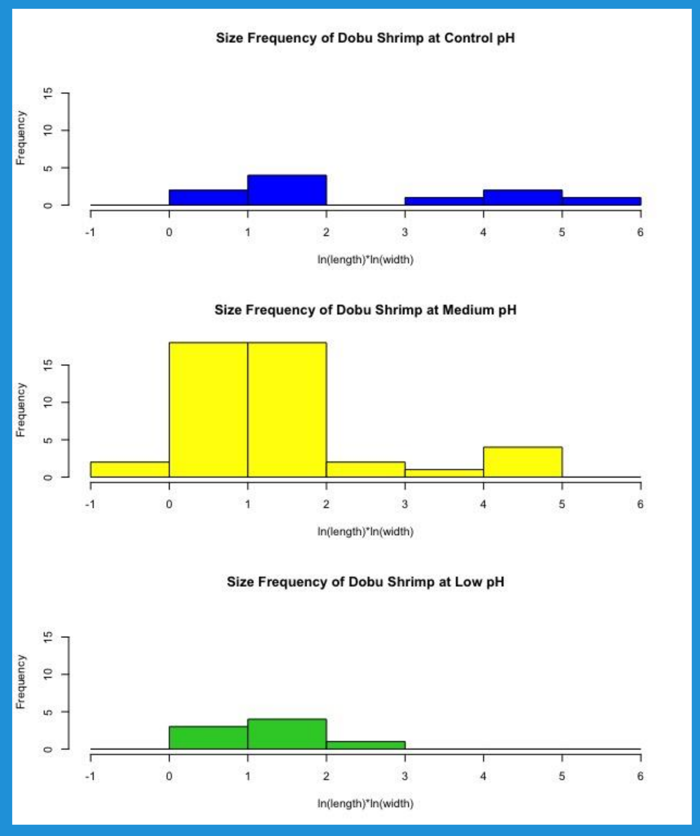

Figure 5. Size distribution of shrimp in Dobu by pH (p=0.029). Average length was 13.6 mm at control pH, 9.0 mm at medium, and 8.0 mm at low.

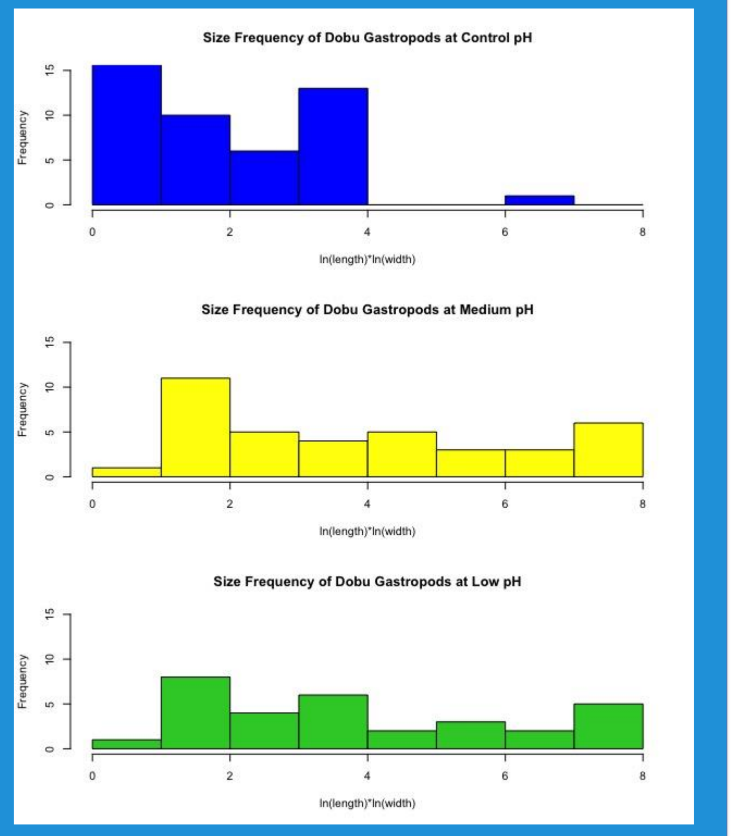

Figure 6. Size distribution of gastropods in Dobu by pH (p=2.26e-06). Average length was 6.8 mm at control pH, 11.7 mm at medium, and 10.8 mm at low.

- Shrimp size in Dobu significantly decreased in lower pH (Figure 5). This trend was not found in Illi.
- Gastropod size in both locations showed the opposite trend. Larger individuals were found at low pH (Figure 6).
- All other taxa produced mixed results

Implications

Stronger effects of global ocean acidification?

These reefs represent communities that are adapted to their respective pH conditions but with a replenishing effect from drifting of invertebrate larvae from nearby healthy reef communities. Global ocean acidification could potentially induce more drastic diversity reductions due to the scarceness of unaffected "refuge" habitats.

Some organisms may benefit from ocean acidification…

Seagrasses and macro-algae have been shown to exhibit a higher growth rate when exposed to higher CO_2 concentrations (Koch et al. 2013). Therefore, grazers could potentially benefit from the increased food supply, as seen in the sea urchins at the seep sites (Uthicke et al. 2016). The size trend observed in this study for the gastropods could result from a similar dynamic.

Whole communities' responses to ocean acidification

This study focuses on community-level trends and confirms the findings of species-specific studies. Studying whole communities in their natural habitats enables us to broaden our understanding of the potential consequences of ocean acidification from direct impacts (physiological) and indirect impacts (loss of reef structure, changes in the food chain, and more), thus allowing a clearer picture of coral reef responses in the face of ocean acidification.

Acknowledgments and References

I'd like to thank Sarah Leinbach and Max Morgan for their help in the lab; Bastian Bentlage for his help with data structuring; Gene Hunt for his help with statistics; Chris Meyer and Lee Weigt for the use of photo equipment and lab space; Virginia Powers, Gene Hunt, and Elizabeth Cottrell for their stewardship of the NHRE program; and the Sant Chair for Marine Science, the Scholarly Studies for Science Award, the Great Barrier Reef Foundation and NSF grants OCE-1558868 and EAR-1560088 for funding. All work was done in the L.A.B. facilities at the Smithsonian Museum of Natural History.

Fabricius KE et al. (2011) Losers and winners in coral reefs acclimatized to elevated carbon dioxide concentrations. Nat. Clim. Change 1:165–169

Fabricius KE et al. (2014) Ecological effects of ocean acidification and habitat complexity on reef-associated macroinvertebrate communities. Proc. R. Soc. Biol. Sci. 281:20132479

Koch M et al. (2013) Climate change and ocean acidification effects on seagrasses and marine macroalgae. Glob. Change Biol. 19:103–132

Kroeker KJ et al. (2013) Impacts of ocean acidification on marine organisms: quantifying sensitivities and interaction with warming. Glob. Change Biol. 19:1884–1896

Uthicke et al. (2016) Echinometra sea urchins acclimatised to elevated pCO2 at volcanic vents outperform those under present-day pCO2 conditions. Glob. Change Ecol. 22:2451-61

R Core Team (2016). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.