Influence of Overlying Sediment on The Dissolution of Coral Carbonate Skeletons

Sia S.Y.¹ and Chou L.M.²

Department of Biological Science, National University of Singapore
14 Science Drive 4, Blk S1, #02-05, Singapore 117540

ABSTRACT

Overlying sediment plays an important role in dissolution of coral carbonate skeletons. One of the high sediment affected sheltered reefs at Pulau Semakau registered a sedimentation rate of 13.29 mg cm⁻² day⁻¹. Seawater pH was significantly different from the fluid within the skeletal structure of two coral species, *Platygyra pini* and *Merulina ampliata*, although no significant difference was found between both. Significant reduction in absolute dry weight was obtained for the skeletons of both coral growth forms in the field and change in structural integrity was observed. Aquaria experiment with four sediment-load treatment groups (0 mg cm⁻² day⁻¹, 5 mg cm⁻² day⁻¹, 10 mg cm⁻² day⁻¹ and 15 mg cm⁻² day⁻¹) for each skeletal growth form in filtered seawater showed that the pH of fluid within the dead coral skeleton structure did not decrease with increasing level of overlying sediments. Moreover, results did not convincingly show that increased levels of overlying sediment increases dissolution rate of dead coral skeletons. However, the total weight loss of coral skeletons increased with increasing level of overlying sediment. The results indicate that overlying sediment induced dissolution and changes in structural integrity of coral carbonate skeletons.

INTRODUCTION

Sediments are believed to be the main player on the decalcification of dead carbonate skeletons in a heavily sedimented environment; however, there are no known published studies that describe or quantify this effect. In this study, skeletons of the scleractinians, *Platygyra pini* (massive growth form) and *Merulina ampliata* (foliose growth form) were used to investigate and quantify the influence of varying levels of overlying sediments on the dissolution rate and structural integrity of carbonate skeletons. Accumulated sediments are suggested to not only enhance dissolution but also prevent the settlement of coral larvae. This study aims to test out the following hypotheses: Increased levels of overlying sediments increases the dissolution of dead coral skeletons, the pH of fluid within the dead coral skeleton structure decreases with increasing levels of overlying sediments and the total weight loss of coral skeletons increases with increasing level of overlying sediment. This study is believed to be the first reported *in situ* investigation of the influence of different levels of overlying sediments on the dissolution of dead coral skeleton and their structural integrity.

¹ Student
² Supervisor
MATERIALS AND METHODS

The sheltered southwestern reef of Pulau Semakau was chosen as the field experimental site while the aquaria experiments, which required controlled conditions, were conducted at the Tropical Marine Science Institute aquarium facility on St John’s Island. Massive and foliose growthforms were selected for the experiments as they represent the dominant growthforms on Singapore coral reefs. *Platygyra pini* was used as a model for the massive growthform and *Merulina ampliata*, the foliose growthform. For field experiment, seven dead coral skeleton fragments of each growthform were secured onto a plastic mesh using stainless steel wire and secured to floating underwater platforms at the Pulau Semakau field site. These fragments were left out in the field for the entire duration of the experiment for four months. Fluids within the skeleton structures were extracted fortnightly using 1-cc/ml Terumo syringes with fine needles. Three fluid samples were collected from three random points of each skeleton fragment, stored in appendorf tubes during transport back to the laboratory before their pH were measured using a micro pH meter. For aquaria experiment, four treatments of 6 replicate *Merulina ampliata* and *Platygyra pini* skeleton fragments were placed in a tank with flow-through filtered seawater in Aquaria B on St John Island. Four sediment treatments - 0, 5, 10 and 15 mg cm⁻² - were applied onto the surface of the fragments. Fluids were collected and processed as similar methods to field experiment.

RESULTS

For field experiment, average ambient sedimentation rate at the experimental site, measured with sediment traps, was 13.29 mg cm⁻² day⁻¹ for the duration of the field experiment, while, the ambient sedimentation rates measured from sediment covering the skeletons’ surfaces of *Merulina ampliata* and *Platygyra pini* were 1.56 and 1.70 mg cm⁻² day⁻¹ respectively. The average ambient seawater pH was measured at 8.22, while the mean pH of the fluids extracted from within the skeletal structures of *Merulina ampliata* and *Platygyra pini* was 7.96. The pH of seawater was always higher than the pH of the fluid extracted from both *Merulina ampliata* and *Platygyra pini*, except at week eight. One way ANOVA showed that the pH of seawater was significantly different from the pH of the fluids extracted from *Merulina ampliata* and *Platygyra pini* (p=0.016). Pairwise comparison further showed that the pH of seawater was significantly different from the pH of fluid extracted from coral structures whereas there was no significant difference in mean pH between fluid in *Merulina ampliata* and *Platygyra pini* structure. There were significant differences in mean dry weights measured before and after the experiment for both coral growthforms (p<0.05). A mean reduction of 0.26g was recorded in the weight of *Merulina ampliata* coral skeletons and 4.43g for *Platygyra pini* coral skeletons. In addition, mean weight differences per unit area of exposed skeleton were measured at 0.87 mg cm⁻² and 14.34 mg cm⁻² for *Merulina ampliata* and *Platygyra pini* respectively. Structural morphology of each coral skeleton for the field study was observed and compared before and after the experiment. One sample t-test showed significant differences in septa length and wall thickness for both growthforms.

For aquaria experiment, one-way ANOVA showed significant differences between the mean pH among the different treatment groups for *Merulina ampliata* (p-value=0.029). Tukeys simultaneous
tests further indicated that the mean pH levels for seawater and skeletal fluid with a sedimentation rate treatment of 0 mg cm$^{-2}$ day$^{-1}$ were significantly higher than those of the other sedimentation rate treatment groups. However, mean pH levels of skeletal fluids for sedimentation rate treatments of 5, 10 and 15 mg cm$^{-2}$ day$^{-1}$ were not significantly different from each other. For the treatment groups of Platygyra pini, one way ANOVA showed significant difference in pH value of skeletal fluids (p-value = 0.03). Subsequent Tukeys simultaneous tests indicated that the mean pH levels for seawater and sedimentation rate treatment of 0 mg cm$^{-2}$ day$^{-1}$ were significantly higher than that of the other sedimentation rate treatment groups. However, mean pH levels of sedimentation rate 5, 10 and 15 mg cm$^{-2}$ day$^{-1}$ were not significantly different from each other. There was a reduction in the mean weight of coral skeleton for all treatment groups of both species after the 20 weeks of aquaria experiment. For absolute weight reduction, there was a general increase from 0 mg cm$^{-2}$ day$^{-1}$ treatment group to 15 mg cm$^{-2}$ day$^{-1}$ treatment group for both species. The exception was the 0 mg cm$^{-2}$ day$^{-1}$ treatment group for Merulina ampliata, which was higher than that of 5 mg cm$^{-2}$ day$^{-1}$ and 10 mg cm$^{-2}$ day$^{-1}$ treatment groups but lower than the 20 mg cm$^{-2}$ day$^{-1}$. Paired t-tests of all sediment treatment groups for both species showed significant differences in absolute dry weight before and after experiments. The exception was the 15 mg cm$^{-2}$ day$^{-1}$ sediment treatment group for Merulina ampliata, which showed no significant difference in absolute dry weight (p-value = 0.067). However, one-way ANOVA showed no significant differences between the treatment groups for both species.

**DISCUSSION**

The field results showed that the pH of seawater was significantly different from the pH of the fluids extracted from within Merulina ampliata and Platygyra pini skeleton structures, the means of which were both lower than the ambient seawater pH. This indicates that the overlying sediment caused a reduction in the pH within the underlying skeleton structure, thus creating a more acidic condition. The presence of overlying sediments alters the physical, chemical and biological conditions within the coral skeleton. The lower pH value may be explained by the respiration of microorganisms that produces acidic compounds or chemicals. Moreover, the decay of dead microorganisms requires oxygen and also produces acid and carbon dioxide gas that contributes to the acidity of fluid within the coral skeletons. Accumulation of acid can directly react with carbonate skeletons.

Increased amount of localised carbon dioxide gas lowers the pH and reduces the availability of CO$_3^{2-}$ within the localised area. This decreases the CaCO$_3$ and aragonite saturation state ($\Omega$-arag). The carbonate dissolution rate is inversely proportional to CaCO$_3$ saturation state (Fine and Tchernov, 2007; Kleypas et al., 2006). In addition, the presence of burrowing microorganism can cause bioerosion of coral skeleton which could not be observed by the naked eye for both field and aquaria experiments. The average ambient sedimentation rate in the sheltered reef environment was 13.29 mg cm$^{-2}$ day$^{-1}$. This rate was estimated from sediment traps, and was higher in value compared to the sedimentation rates measured from the surfaces of the coral skeletons. The lower values obtained from the coral surfaces reflects the hydrology of the area, which is influenced by water movement and movement of aquatic organisms like fish which can sweep sediment away.
from skeleton surfaces. However, the average sedimentation rate estimated using *Platgyra pini* skeletons was higher compared to that of *Merulina ampliata*. This is likely due to the structural morphology of *Platgyra pini*, which is characterized by larger and deeper cavities with larger surface areas, thus allowing greater amounts of sediment to be trapped.

The mean pH of filtered seawater in aquarium tank was around 8.1 which was slightly lower than the mean pH of seawater of 8.22 in the field. The lower pH value may be due to the closed environment of the seawater storage tanks and the limited water flow. Respiration and decay of microorganisms present within the water storage tanks can decrease the pH of seawater inside the tank and thus indirectly affecting the pH of fluids extracted from within coral skeleton structures. The aquaria results showed no clear patterns, with the pH fluctuating throughout the 20-week experiment. One-way ANOVA revealed that at least one mean pH for one treatment group was significantly different from the others for both growthforms in the aquaria experiment. Subsequent Tukey’s post-hoc pairwise comparison tests showed that the pH from seawater and treatment group one (0 mg cm\(^{-2}\) day\(^{-1}\)) were significant different from treatment group two, three and four (5, 10 and 15 mg cm\(^{-2}\) day\(^{-1}\)). However, there was no significant difference for seawater and treatment group one, and between the remaining three groups. The pH of treatment group one was expected to be the similar to the seawater pH but contrary to expectations, there was no significant difference among the remaining three groups and this may due to the short experimental duration. It is also possible that the range of sediment treatments used for the experiments were not wide enough to show significant changes within the duration of the experiment.

Dissolution of coral skeletons for both growthforms was recorded even for the treatment without any overlying sediments. This may be due to the lower pH of filtered seawater and biological growth on the surface of the coral skeletons which effectively reduced the pH of fluid within coral skeletons. Similar to the field results, *Platgyra pini* carbonate skeletons recorded higher dissolution than *Merulina ampliata* skeleton, which is likely due to its more complex structural morphology with greater surface area. Nevertheless, all treatment groups showed significant differences in dry weight before and after experiment except for treatment group four for *Merulina ampliata*. However, there was no significant difference among treatment groups for both growthforms.

In conclusion, significant differences in the dry weight before and after experiment for all treatment groups of coral skeletons were recorded. The results of this study indicated that overlying sediments can increase the dissolution of carbonate skeletons. However, the results were not conclusive in showing that increased levels of overlying sediment can increase the dissolution of dead coral skeletons. In addition, the pH of fluid within the dead coral skeleton structure did not decrease with increasing level of overlying sediments. Nevertheless, the total weight loss of coral skeletons increases with increasing level of overlying sediment.

**REFERENCES**
