Coral metabolism: from the micro to the macro-scale.

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Introduction:

I started my research on corals during my PhD. The first goal was to show the relation between coral associated bacteria and corals. For this I used vitamin B$_{12}$ as a tool (Agostini et al. 2008). Vitamin B$_{12}$ is known to be only produced by prokaryotes and to be required by all animals. The idea came from the comparison of corals with cows. It may seems far fetched but cows and others ruminants acquire vitamin B$_{12}$ for the internal production by symbiotic bacteria in their stomach. Therefore I designed a method to sample the gut content of corals' polyps and a method to measure vitamin B$_{12}$ in the low volume available. From this point, I started to explore micro environments within corals and to link them with macro scale phenomenon such as the maintenance of coral health and metabolic rates.

This year, 2013, our paper entitled "Biological and chemical characteristics of the coral gastric cavity" published in Coral Reefs, the journal published by the International Society for Reef Studies was voted the Best Paper of the year 2012. It is a great honor and I hope that this paper and our research will inspire more research on micro scale processes within marine organisms.

My research interests are presented below. The different topics are the research on the gastric cavity and new research topics such as: micro scale environments and the mechanism of calcification, and temperate corals.

The study of the gastric cavity of corals.

All corals have a common structure: two tissue layers enclose a lumen, which forms the gastric cavity. Few studies have described the processes occurring inside the gastric cavity and its chemical and biological characteristics. Using micro manipulation techniques and micro sensors, we could show that the coral gastric cavity has distinct chemical characteristics with respect to dissolved oxygen, pH, alkalinity and nutrients (vitamin B$_{12}$, nitrates, nitrites, ammonium, and phosphates) and also has a distinct bacterial community. From these results, the gastric cavity can be described as a semi-closed sub-environment within the coral. Dissolved oxygen shows very low constant levels in the deepest parts of the cavity, creating a compartmentalized, anoxic environment. The pH is lower in the cavity than in the surrounding water and, like alkalinity, shows day/night variations different from that of the surrounding water. Nutrient concentrations found in the cavity are greater than the concentrations found in reef waters, especially those for phosphate and vitamin B$_{12}$. The source of these nutrients may be an internal production by symbiotic bacteria and/or the remineralization of organic matter ingested or produced by the corals. The importance of the bacteria inhabiting the gastric cavity is supported by the finding of a high bacterial abundance and a specific bacterial community with affiliation to bacteria found in other corals and in the guts of other organisms. The findings presented here open a new area of research that may help us to understand the processes that maintain coral health. It also shows that like other animals, corals are likely reliant on their gut microflora for the maintenance of their health and growth (Agostini et al., 2012).

This research is still ongoing. Recent work using next generation sequencing and metagenomics techniques, done in collaboration with Dr David Bourne of the Australian Institute of Marine Science, will give more details on the species diversity and the functional diversity of the gut microflora. Moreover the gut microflora of colonies of *G. fascicularis* sampled in Okinawa, Japan and Heron Island, Australia are compared.
Micro scale environments and the mechanism of calcification

Although the calcification mechanisms in corals have been widely documented, many questions remain on the exact physiological mechanisms and the linkage between environmental changes and the coral calcification response to these. In corals, calcification occurs under a tissue layer named calicoblast. The chemical conditions of the calcifying fluid in the subcalicoblastic space are thought to enable the precipitation of CaCO3 by increasing the aragonite saturation state through the maintenance of a high pH and high carbonate concentration (Allemand et al., 2004). Our recent research showed the relation between respiration rates, which is the production of energy, and calcification (S Agostini, et al., 2013). This results support the hypothesis that energy is required for the maintenance of favorable conditions in the micro environment at the calcification site.

Different stresses strongly affect the calcification processes of corals and other calcifying organisms. High temperature stress has been shown to cause damages to coral mitochondria (Dunn, et al., 2012; Agostini et al. In prep.). The decrease in respiration rates could therefore lead to a lack of energy for the maintenance of favorable chemistry for calcification and explain the reduced calcification rates of corals observed. Moreover due to the increase of atmospheric CO₂, the pH of seawater which has been stable for thousands of years at an average value of 8.2, is predicted to decrease to 7.8 by the end of the century. However we showed that due to the influence of coral metabolism, the chemistry in the micro environment surrounding corals do not always reflect changes in the surrounding water chemistry. For example, during daytime the pH in the diffusive boundary layer do not differ between corals incubated at normal pCO₂ and corals incubated under increased pCO₂ (Agostini et al. 2013). This results highlight the need to study the chemistry of micro-environments within corals to allow better predictions of the effects of climate change on corals. Using micro sensors techniques and a novel technique for the sampling of calcifying fluid, we are studying the becoming of the subcalicoblastic microenvironment and its linkage with metabolic processes under different conditions.
Temperate corals community and poleward migration.

Since I started to work for the University of Tsukuba at the Shimoda Marine Research Center, I started to study and monitor the local coral community. Shimoda is located on the tip of the Izu peninsula, Shizuoka, Japan. Corals can be easily observed near the center. There the coral of the species *Porites heronensis* and *Alveopora japonica* are abundant. Other species are also found including temperate only species and tropical species. Rising temperature has resulted in a poleward shift/expansion of Earth fauna and flora (Parmesan and Yohe, 2003) including corals in Japan (Yamano et al., 2011). However corals at high latitude are confronted to environmental conditions that differ from tropical conditions with lower temperature in winter, lower light levels, higher nutrients concentrations, etc. Moreover due to the increase in CO$_2$, aragonite saturation state of the ocean is decreasing (Kleypas, 1999) and this trend may counter the expansion of corals.

Different approaches are taken to study the local coral community in Izu and the possibility of a poleward expansion of corals. A coral community dominated by *P. heronensis* is being monitored every monthly. Corals coverage and percentage of bleached corals are surveyed. Preliminary results shows a high incidence of bleaching during winter. This bleaching could be due to the low temperature experienced during this season. For more detail analysis, colonies of *P. heronensis* and *A. japonica* were transplanted in the field. Every two months, three colonies of each species are sacrificed: their metabolism is first measured *in situ* and then different physiological parameters are measured. Through this experiment we aim to understand how seasonal variations influence the physiology of corals in temperate zone. Finally cold stress experiment in controlled environment are being done to study the mechanism of bleaching under cold temperature.

References:

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