Understanding the response of tropical corals to heavy metal pollution in a changing climate (Ref IAP2-18-79)

University of St Andrews, Earth and Environmental Sciences

In partnership with Heriot-Watt University, The Lyell Centre, School of Energy, Geoscience, Infrastructure and Society.

Supervisory Team

- Dr Nicola Allison, University of St. Andrews
- Dr Alex Poulton, Heriot-Watt University
- Prof Adrian Finch, University of St. Andrews

Key Words
Coral, biomineralisation, metal, ocean acidification, photochemistry

Overview

Coral reefs are important marine habitats and are at risk from both climate change (ocean acidification and increasing seawater temperatures) and heavy metal (e.g. copper, nickel, zinc) contamination. Metal pollution in coastal waters can be caused by leaching of metal-based anti-fouling paints in ports and marinas and by runoff from local landfill and mining wastes. Rising atmospheric CO_2 has fundamentally affected seawater carbonate chemistry, lowering seawater pH. This pH change alters metal speciation and by 2100 the proportions of some dissolved free metal ion species e.g. Cu^{2+} and Pb^{2+}, will approximately double compared to the present day (Millero et al., 2009). These free metal ions are probably the most bioavailable metal forms and the speciation changes will likely increase the toxicity of metals in polluted waters.

Metal toxicity mechanism in corals are not well understood. For example, Cu increases some anti-oxidant enzyme activities (Bielmyer et al., 2018) but may inhibit enzymes implicated in calcification (Fernandes de Barros Marangoni et al. 2017). Increasing seawater pCO_2 and temperatures may either exacerbate or reduce the toxicity of metals. For example, Cu may inhibit electron transport in photosystem II (Samson et al, 1988) but the inhibitory effects of Cu on photosynthesis in a green alga is reduced by modest increases in seawater pCO_2 (Gao et al., 2017). Nickel and seawater warming have a greater inhibitory effect on coral calcification than nickel alone (Biscere et al., 2017).

Corals are small invertebrate organisms composed of the coral animal, its algal symbionts and associated bacteria. The algal symbiosis is crucial to the success of the coral and a positive correlation is observed between net coral photosynthesis and calcification in most corals (Gattuso et al., 1999). Our preliminary work indicates that ocean acidification and Cu in combination reduce coral calcification rate but do not

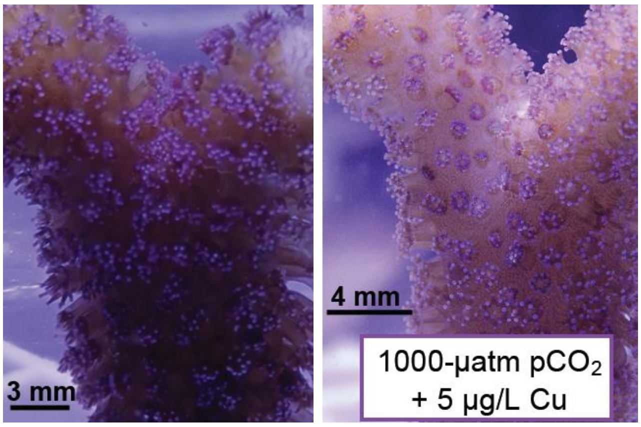

Figure 1. Stylophora spp. coral cultured under OA and Cu after 7 days (left) and 14 days (right). Cryer and Allison (unpublished data).

affect photosynthesis, although corals became paler over the course of the study (Figure 1).

The aims of this project are to resolve how heavy metals and ocean acidification/rising seawater temperatures interact to affect tropical corals and to identify the predominant toxicity mechanisms. The student will determine how metals and climate change affect photosynthesis, calcification and respiration, and will identify how these stressors affect key enzyme activities, photochemistry and algal function. Ultimately the student will resolve if metals and ocean acidification/ rising seawater temperatures act synergistically or antagonistically.

Methodology

The student will work in the coral culture laboratory at St. Andrews (Figure 2) to identify how metals and ocean acidification/temperature, separately and in combination, affect coral calcification, photosynthesis and respiration (Cole et al., 2018). The student will study 2 coral species: the massive coral *Porites lobata* and the branching coral *Pocillopora damicornis*. Both are important reef building species but they exhibit different sensitivities to increasing seawater pCO_2 and metals.

The student will identify potential toxicity mechanisms by determining the impacts of the stressors on key processes within the calcification and photosynthetic pathways, e.g. the activities of Ca-ATPase (responsible for increasing the pH at the coral calcification site), carbonic anhydrase (which facilitates the conversion of CO_2 and HCO_3^-), chlorophyll synthesis (facilities light capture) and the quantum yield of photosynthesis (the conversion of light energy to carbon fixation). The student will identify if metals and ocean acidification/temperature affect the same or different biochemical processes and will produce a metabolic model to explain how these stressors interact to behave either synergistically or antagonistically.

The student will test this model in the field, at the Phuket Marine Biological Centre in Thailand, by sampling corals along a metal pollution gradient and from reefs which exhibit a range of seawater pCO_2 and local temperature. They will compare the physiological processes (calcification, photosynthesis etc.) and enzyme activities to confirm if coral performance in the field can be predicted from the metabolic model.

Figure 2. Heads of massive Porites lutea corals in the controlled CO_2 culture system at St. Andrews

Timeline

<u>Year 1:</u> Literature survey, method development (enzyme assays, coral physiological measurements), start of coral culturing work, national conference.
<u>Year 2:</u> Coral culturing work, identification of stressor effects and toxicity mechanisms, preparation of first manuscript, national conference.
<u>Year 3/3.5:</u> Fieldwork experiment, preparation of other manuscripts, international conference, submit thesis.

	Year 1	*Year 2*	*Year 3/3.5*
Method development			
Coral culturing			
Development of metabolic model			
Field testing			
Manuscripts			
Conferences			

Training & Skills

The student will develop skills in coral metabolism, coral photochemistry, aquarium husbandry, trace element speciation and in understanding and manipulating the seawater carbonate system. The student will receive full training in all required techniques. We will consider applicants from a range of environmental, marine and biological backgrounds.

The student will present results at national & international workshops and conferences and will be assisted in preparing scientific manuscripts to be published in international peer-reviewed journals. The student will join a NERC-funded team studying coral biology and biomineralisation in the School of Earth and Environmental Sciences at the University of St Andrews and will be a member of the Marine Alliance for Science and Technology for Scotland (www.masts.ac.uk) with access to wider training and networking opportunities. All project supervisors are highly research-active and the student has opportunities to learn other techniques and research areas which may be applicable to their interests.

References & Further Reading

Bielmyer-Frasera GK et al. (2018) Physiological responses of corals to ocean acidification and copper exposure, Mar. Pollut. Bull., 133, 781-790.

Biscere T. et al. (2017) Nickel and ocean warming affect scleractinian coral growth, Mar. Pollut. Bull., 120, 250-258.

Cole C et al. (2018) Effects of seawater pCO2 and temperature on calcification and productivity in the coral genus Porites spp.: an exploration of potential interaction mechanisms, Coral Reefs, https://doi.org/10.1007/s00338-018-1672-3.

Fernandes de Barros Marangoni et al. (2017) Copper effects on biomarkers associated with photosynthesis, oxidative status and calcification in the Brazilian coral Mussismilia harttii (Scleractinia, Mussidae), 130, 248-257.

Gao G et al. (2017) Expected CO_2induced ocean acidification modulates copper toxicity in the green tide alga Ulva prolifera, Env. Exp. Botany, 135, 63-72.

Gattuso JP et al. (1999) Photosynthesis and calcification at cellular, organismal and community levels in coral reefs: a review on interactions and control by carbonate chemistry, Integrative Comp. Biol, 39, 160-183.

Millero FJ et al. (2009) Effect of ocean acidification on the speciation of metals in seawater, Oceanography 22, 72–85.

Samson G et al. (1988) Copper quenching of the variable fluorescence in *Dunaliella tertiolecta*. New evidence for a copper inhibition effect on PSII photochemistry. Photochem. Photobiol. 48, 329–332.

Further Information

Dr Nicola Allison
School of Earth and Environmental Sciences,
Irvine Building, North Street,
University of St. Andrews,
St. Andrews, Fife KY16 9AL
Email: na9@st-andrews.ac.uk
Phone: +44 (0)1334 463952

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