Coral Reef Conservation and the Role of Blue Carbon

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The oceans are the greatest carbon sink on Earth (Sabine et al., 2004). Around half of all atmospheric CO_2 emissions since the industrial revolution have been absorbed by the ocean (Nellemann et al., 2009). The term **blue carbon** refers to the carbon sequestered in coastal ecosystems and stored in their sediments over geological timescales (Howard et al., 2014). Quantification of carbon storage by mangroves, seagrasses and saltmarshes is well established and these systems are increasingly included in conservation efforts to protect them as a strategy for mitigation against high CO_2 emissions (Howard et al., 2017).

Coral reefs are not currently included in blue carbon budgets due to their carbon-releasing process of calcification by Scleractinian corals, however, there is debate surrounding their properties as a carbon source/sink (Suzuki & Kawahata, 2003). Reviews of previous studies into the carbon budgets and community metabolism of coral reefs have highlighted the need for further investigation, clarification and a consensus on the carbon status of coral reefs (Cyronak et al., 2018).

The sink/source debate

Coral reefs cover 5-15% of shallow oceans within 0– 30m depth (Jackson et al., 2014) and contribute to the ocean carbon cycle through photosynthesis, respiration, calcification and dissolution . They recycle their nutrients efficiently, so that carbon sequestered into the coral reef should, in theory, stay within in the reef system (Froelich, 1983). Reefs are built by Scleractinian corals, ecosystem engineers, which secrete a calcium carbonate skeleton to form the solid foundation of the reef matrix. This process of calcification both captures (at geological time scales) and releases (at annual time scales) CO_2 at a rate of 0.6 moles for each mole of $CaCO_3$ deposited:

$$Ca^{2+} + 2HCO_3^- \leftrightarrow CaCO_3 + H_2O + CO_2$$ (Ware et al., 1992)

This has led to the assumption that coral reefs are not carbon sinks, but in fact are sources of atmospheric CO_2.

However, it is likely that the carbon released by calcification is consumed in other biological processes on the reef, such as photosynthesis by associated macrophytes and kept within the system (Courtney et al., 2017; de Goeij et al., 2013). The cycling of carbon on coral reefs is thus more complex than that of other shallow coastal ecosystems and their actual role as blue carbon repositories has not been clarified.

Several processes suggest that coral reefs lock down significant organic carbon, such as:

1. The cryptic structure of reefs maximises the habitat they provide, and crevices and cavities which make up to a third of the reef are significant stores of organic carbon (de Goeij & van Duyl, 2007).
2. The high biodiversity of coral reefs means they provide habitat for many organisms which are important in the marine carbon cycle; fleshy macro-algae, coralline algae, and sponges. For example, crustose coralline algae (CCA) covers up to 60% of some reef areas and is estimated to have a significant capacity to sequester carbon (Van Der Heijden & Kamenos, 2015). It can survive

naturally acidified seawater conditions (Kamenos et al., 2016) where it seems that over time it can adapt to low pH environment.

3. Recent changes to coral reef dynamics impact the way that carbon is cycled within coral reefs. Whilst live coral cover is decreasing rapidly across the Caribbean (Gardner et al., 2003), some reef organisms; such as algae and cyanobacteria show resilience to the changing environment and appear to be thriving in some of the worlds' most degraded reefs (Jackson et al., 2014). Each has different interactions with the marine carbon cycle and could potentially sequester more carbon than todays´ coral-dominated systems. Due to their resilience, and the loss of corals, phase-shifts to reefs dominated by organisms other than coral are expected (Hughes et al. 2007; Norström et al. 2009), which will affect the carbon storage potential of this ecosystem.

One predicted scenario is a sponge-dominated phase-shift (Bell et al. 2013). Sponges process high rates of dead organic matter and there is evidence to show that they are integral in the nutrient cycling within coral reefs (de Goeij et al. 2013). Alternatively, a shift to macroalgal-dominated reefs would result in higher rates of primary production, but over shorter timescales than calcifying organisms and the release of carbon currently stored in long-term ocean sediments (Price et al. 2012). At present, the balance between organic carbon release and storage on modern coral reefs has not been assessed.

Contemporary coral reefs

The increasing threat to coral reefs and predictions suggesting that corals may become extinct within this century (Carpenter et al. 2008) urges further research to understand the intricate dynamics of coral reef ecology and carbon cycling before it is too late.

Changes in marine conditions caused by global climate change have fundamentally changed the key processes on coral reefs, the species composition, and the way that carbon interacts with this ecosystem. No-where is this more apparent than in the Caribbean, where catastrophic degradation and phase-shifts have been observed since the 1970s (Hughes, 1994). Loss of Scleractinian coral cover (Gardner, 2003), subsequent reduction in structural complexity (Alvarez-Filip et al., 2009) and macroalgal-dominated phase shifts (Hughes et al., 2007) all indicate that the Caribbean reef carbon repository is substantially altered. This study will provide a modern day coral reef budget, measured on a Caribbean reef ecosystem undergoing drastic change.

Methods

At our research site in Akumal, we are collecting data at dive and snorkel sites to monitor change in benthic cover, as well as conducting in-situ incubations of key functional groups to work out their rates of photosynthesis, respiration and calcification. Students will be trained to identify Scleractinian coral species, key fish species and invertebrates and transect surveys may then be used to map the coral population of Akumal, including the size and health of colonies to identify hotspots for reproduction, measure changes to benthic composition, and help with our long-term data collection on the fragments in the coral nurseries and transplants on the reef. We will use underwater videography and photography, as well as traditional scientific diving methods to collect extensive data on the coral reef sites. Key species selected for their abundance from each functional group will be isolated in aquaria tanks where rates of photosynthesis and respiration will be measured. Using reef survey data and rates of respiration/ photosynthesis, species will be selected for their importance to the reef carbon budget to be included in the following steps.

For reef carbon projects, in-situ measurements of physiological processes of key reef species are taken on the reef, using the adapted FlexiChamber (Camp et al., 2015). These units are deployed at each research site to measure physiological processes of individuals from each functional group. Samples will be analysed for respiration, photosynthesis and growth, using measurements of O2 saturation, pH and the Total Alkalinity (TA) anomaly calculation. Sampling will be repeated over a 24-hour period during each of the warmest and coolest weeks of the year to provide upper and lower range estimates for respiration, photosynthesis and calcification.

Suggested Reading

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