Quantifying biologically-driven coral reef carbonate production via high-resolution stereophotogrammetry

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Abstract

Coral reefs provide important habitats for many fish species, as well as coastal protection and socio-economic services to many developing countries. The production of calcium carbonate ($CaCO_3$) by corals and calcareous encrusters (specifically calcareous coralline algae) represent the primary constructive process on many reefs. Bio-erosional factors such as endolythic cyanobacteria and, fungi and boring sponges represent important loss. A reef which produces more $CaCO_3$ than it loses grows, continuing to provide a complex and healthy habitat.

One method of quantifying net $CaCO_3$ accumulation rates is by an *in-situ* census based approach, termed ReefBudget. This methodology relies on high-intensity investigation of multiple transects per study site to give estimates of carbonate production and framework erosion. These census-based assessments, carried out by divers using slates and tape measures, are time-intensive and thus limited in both spatial coverage (10s m^2) and depth range (<20m).

Stereophotogrammetry, the production of digital, measurable, 3-dimensional models from a series of overlapping images, has the potential to increase the productivity of diving-based research markedly. An area of hundreds of square metres can be mapped on a single dive, whilst smaller areas can be profiled in detail to mm-scale resolution.

In this present study, we compared widely-used *in-situ* census based assessments with stereophotogrammetric methods. The surveys that used stereophotogrammetry were up to three times faster than *in-situ* assessments and additionally gave two orders of magnitude greater coverage. However, because stereophotogrammetry relies on photographic data for construction of the models, some benthic taxa were obscured by overgrowth and missed from the digital analyses. The photogrammetric method introduced some scale errors but these were corrected for by using physical calibration points within the measurement areas.

Overall, the stereophotogrammetric method supported the rapid, accurate quantification of structurally-complex, biologically-driven coral reef carbonate production. The resultant models that were generated are a permanent, holistic record of whole reefs or sections of reef. As such, they provide baseline assessments of reef status than can used for accurate quantification of the impacts of environmental change. The enhanced productivity of using this technique would also come from the models supporting research from other science disciplines without the need for further diving

Acclimation responses to phosphorous availability in *Phaeodactylum tricornutum*

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Phytoplankton play a key role in ecosystem functioning and global biogeochemical cycles, being responsible for approximately half of global primary production (Falkowski et al. 2004). Theoretical models aimed at understanding and predicting phytoplankton diversity and dynamics use functional traits such as the maximum growth rate, minimum cell quota, and maximum nutrient uptake rate (e.g. Droop 1973). These traits might change plastically when cells acclimate to specific environmental conditions (Bonachela et al. 2011; Lomas et al. 2014); however, such responses have rarely been quantified for all these traits. In the present study, we acclimated the model microalgal species *Phaeodactylum tricornutum* (Baccilariophyceae) to different phosphate limiting conditions. Subsequently, we measured its phosphorous minimum quota (Q^P_{min}) and maximum uptake rate (V^P_{max}) by adapting the protocol employed by Lomas et al. (2014). Our objectives were a) to determine the occurrence and type of acclimation responses, reflected by changes in the V^P_{max} b) use the measured functional traits to parameterize and develop a more realistic phytoplankton growth model. Here, we present our protocols for carrying out analysis of uptake rates and quotas for this species, and the findings related to the observed acclimation responses. Moreover, by including the acclimation responses into the phytoplankton growth model, we show some preliminary estimates of the impact of those acclimation responses on phosphorous uptake rate and growth of phytoplankton.

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Contemporary and historic carbon burial by coralline algal beds

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Abstract: Carbon sequestration by natural systems plays a key role in removing anthropogenically-derived carbon from the atmosphere. In the oceans, such sequestration of carbon into marine sediments by marine ecosystems for long-term storage is termed 'blue carbon'. The coastal benthic environment plays a large role in carbon storage via seagrass meadows, salt marshes, and coralline algal beds, together with the sediments they bind. While organic carbon production in seagrass meadows, salt marshes and mangroves has been well quantified, few estimates of carbon production and burial are available for other benthic marine carbon repositories. Meta-analysis reveals that coralline algal beds are a potentially large carbon store due to their global ubiquity and high carbon content, however, those estimates likely underestimate total organic sequestration as they do not consider the high biodiversity of species associated with coralline algal beds. We quantified organic and inorganic carbon content in coralline algal beds showing significant changes in carbon burial over the last 1000y; significantly, coralline algal deposits bury similar quantities of carbon as seagrass beds. That buried carbon is derived both from the marine and terrestrial environment. As coralline algal deposits have a global distribution, their ability to store large quantities of organic carbon suggests they may play a key role in the coastal environment storing both organic and inorganic carbon globally.

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Analysis of the potential impact of ocean acidification on the pelagic gastropod community in the North East of Scotland

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The potential impact of ocean acidification (OA) on plankton calcifiers is a focus of interest for the marine science community. Most planktonic studies have focused on coccolithophores with mixed results, while other calcareous groups of great ecological significance have received less attention.

This study will present the first investigation of the impacts of OA on pelagic gastropods at the Marine Scotland Science (MSS) monitoring site at Stonehaven (56º 57.8´ N, 02 º 06.2´ W). Temperature, salinity, nutrients, phytoplankton and zooplankton have been monitored at the site weekly since 1997. Carbonate chemistry parameters; total alkalinity (TA) and dissolved inorganic carbon (DIC) were measured between 2009 to 2015. During this study the dissolution and elemental composition of archived pelagic gastropods shells from 2011-2013 were examined using Scanning Electron Microscopy (SEM) and X-ray microanalysis.

TA and DIC showed a seasonal pattern with considerable interannual variability. The seasonality of calculated pH values was influenced by the phytoplankton biomass in the water. Evidence of shell dissolution in pelagic gastropods was observed and the relationship with OA and environmental parameters examined. SEM images and molecular analysis reveal a diverse pelagic gastropod community at the Stonehaven monitoring site and provides the first record of the polar pteropod *Limacina helicina* in Scottish waters.

Assessing the Resilience of a Blue Carbon Store: Characterizing the Lateral Flux of DIC from an East Coast U.S. Saltmarsh using Δ14C and δ13C

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Intertidal saltmarshes are highly productive coastal habitats and important blue carbon stores. They commonly exhibit high salinity, low oxygen environmental regimes which lend themselves towards reduced rates of microbial respiration, and the assimilation of atmospheric CO_2 into plant biomass tends to outpace the rate at which that biomass is broken down. As a result, a relatively high proportion of CO_2 entering the system can be expected to become incorporated into marsh sediment before it can be metabolised, potentially entering storage for thousands of years and providing a sizeable natural carbon sink. However, the rate at which these habitats are now being degraded is substantial and growing: the combined impacts of stressors such as increasing temperature and sea level rise are predicted to reduce global saltmarsh coverage by 30-40% by the end of the century, and many saltmarsh carbon stores can be expected to shift from net sinks to sources within the same time frame.

Based on high resolution measurements and modelling in a north-eastern U.S. saltmarsh, a recent study reported a marsh DIC export of 414g C m_2 yr^{-1}. This is more than twice that put forward in previous estimates, and is larger than the total measured uptake by plant biomass, translating into one of the largest carbon fluxes to the coastal ocean found along the U.S. East Coast. Additionally appears that the marsh carbon budget is not in balance, with export exceeding carbon fixation rates. Here we characterise this carbon flux using $\Delta^{14}C$ and $\delta^{13}C$ data to age and source the exported dissolved carbon pools. Carbon isotope mixing models between surface (modern) and pore water (old) carbon sources are constrained by creek samples and pore waters from multiple depths and locations within the marsh. We determine the age of exported carbon and investigate whether carbon stored over the lifetime of the marsh (c. 2000 years) continues to be respired, thereby evaluating the long term resilience of the carbon sink.

Scavenging Processes at Jelly-Falls

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The fall of large jellyfish blooms to the benthic seafloor has increased in frequency in many areas around the world. Recent baited camera studies in coastal Norwegian fjords have been the first to demonstrate that jelly-fall material can be rapidly consumed by deep-sea benthic scavengers (Sweetman et al., 2011; Sweetman et al., 2014) and thus distributing carbon back into the bentho-pelagic food web (Sweetman et al., 2015). The factors governing scavenging on jelly-falls are unknown with background food availability being potentially significant. This study has set out to test the hypothesis that scavengers feed on jelly-falls more frequently in environments characterized by limited food availability, thus increasing their role in the cycling of carbon in the benthic environment. Results will be presented from baited camera deployments across a bathymetric gradient in a deep Norwegian fjord to address changes in scavenger diversity, abundance and carbon consumption/ scavenging rates as a function of depth and by inference, food availability. This work makes significant advances in the mechanistic understand of the factors impacting scavenger consumption of jelly-falls and the role of this process in fjord benthic biogeochemical cycling.

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