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REVIEWS

Opinion

Global Carbon Cycling on a Heterogeneous Seafloor

Paul V.R. Snelgrove,[1,*] Karline Soetaert,[2] Martin Solan,[3] Simon Thrush,[4] Chih-Lin Wei,[5] Roberto Danovaro,[6,7] Robinson W. Fulweiler,[8] Hiroshi Kitazato,[9] Baban Ingole,[10] Alf Norkko,[11,12] R. John Parkes,[13] and Nils Volkenborn[14]

Diverse biological communities mediate the transformation, transport, and storage of elements fundamental to life on Earth, including carbon, nitrogen, and oxygen. However, global biogeochemical model outcomes can vary by orders of magnitude, compromising capacity to project realistic ecosystem responses to planetary changes, including ocean productivity and climate. Here, we compare global carbon turnover rates estimated using models grounded in biological versus geochemical theory and argue that the turnover estimates based on each perspective yield divergent outcomes. Importantly, empirical studies that include sedimentary biological activity vary less than those that ignore it. Improving the relevance of model projections and reducing uncertainty associated with the anticipated consequences of global change requires reconciliation of these perspectives, enabling better societal decisions on mitigation and adaptation.

Trends

Climate-change models hinge upon understanding how living ecosystems influence carbon cycling, but global models of oceanic systems produce carbon turnover estimates with a high degree of uncertainty.

Environmental conditions, and temperature in particular, strongly influence rates of carbon and nutrient cycling in the global ocean

Recent studies demonstrate a link between seafloor biodiversity and organic matter processing and nutrient efflux, suggesting that the functional group composition of biota is the most critical aspect of biodiversity for ecosystem functioning in the context of global biogeochemical cycles.

Strong spatial variability in carbon burial and recycling rates of organic material may relate to recognized variation in seafloor functional group composition.

Where Has All the Carbon Gone?

Rapid and well-documented environmental change over the past century has accelerated interest in quantifying the critical role of the ocean in global carbon and nutrient cycling [1]. As human pressures [e.g., climate change and **biodiversity** (see Glossary) loss] alter physical and biological processes, we must improve our capacity to predict the consequences of these alterations and their links to global cycles [2]. Divergent thinking in evaluating global cycles [3,4] and the role of biodiversity [5] has led most marine studies to compartmentalize biogeochemical versus biological approaches, with little effort to integrate alternative perspectives [6]. The functioning of most of the global seafloor depends largely upon the addition of oxygen and organic matter to the sediment–water interface [7] (Figure 1). Biogeochemical and ecological approaches both have value in assessing these processes, but remain poorly reconciled [8], an issue also noted in geological [9] and paleobiological [10] studies. Previous authors have highlighted the need for all types of model to improve how they represent sedimentary processes [8,11,12]. Here, we illustrate how different biases and/or perspectives associated with different world views (Figure 1) can lead to both different model projections and differential abilities to interrogate model outcomes to understand better the cumulative effects of drivers of change. The nature of the questions a model is expected to inform should influence the complexity of the model. However, the application of models to broad-global scale projections often requires simplification and averaging [13], which can lose key complexity or heterogeneity [14] essential in detecting all but the coarsest change. Biogeochemical modelers focus on the physical and chemical processes [15] that affect microbial activity in a way highly suited to developing global models [16], whereas ecologists focus on developing overarching themes governing ecosystems by studying different groups of organisms and how their activities

[1]Department of Ocean Sciences and Biology Department, Memorial University of Newfoundland, St John's NL A1C 5S7, Canada
[2]Estuarine and Delta Systems, Netherlands Institute of Sea Research and Utrecht University, Yerseke, The Netherlands
[3]Ocean and Earth Science, National Oceanography Centre Southampton, University of Southampton, Waterfront Campus, European Way, Southampton, SO14 3ZH, UK
[4]Institute of Marine Science, The University of Auckland, Auckland, 1142, New Zealand
[5]Institute of Oceanography, National Taiwan University, Taipei 106, Taiwan