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Too hot to handle? An urgent need to understand climate change impacts on the biogeochemistry of tropical coastal waters

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Abstract

Tropical regions contain ecologically and socio-economically important habitats, and are home to about 3.8 billion people, many of which directly depend on tropical coastal waters for their well-being. At the basis of these ecosystems are biogeochemical processes. Climate change is expected to have a greater impact in the tropics compared to temperate regions because of the relatively stable environmental conditions found there. However, it was surprising to find only 660 research articles published focusing on the impact of climate change on the biogeochemistry of coastal tropical waters compared to 4823 for temperate waters. In this perspective, we highlight important topics in need of further research. Specifically, we suggest that in tropical regions compared to temperate counterparts climate change stressors will be experienced differently, that organisms have a lower acclimation capacity, and that long-term baseline biogeochemical datasets useful for quantifying future changes are lacking. The low number of research papers on the impacts of climate change in coastal tropical regions is likely due to a mix of reasons including limited resources for research and limited number of long time series in many developing tropical countries. Finally, we propose some action points that we hope will stimulate more studies in tropical coastal waters.

Keywords: tropic, biogeochemistry, coastal waters, climate change, impact, knowledge gap, stressors, acclimation, datasets

Introduction

The region between the tropics of Cancer and Capricorn is home to an estimated 3.8 billion people, with about 500 million people directly dependent on tropical coastal waters and ecosystems for their livelihoods and well-being (Tropics, 2020). As such, tropical coastal regions harbour a range of ecologically and socio-economically important habitats. While coral reefs are perhaps the most recognisable, others include mangroves, seagrasses, and non-vegetated soft sediment. The functioning of all these habitats relies upon an array of biogeochemical processes, which transfer energy and nutrients across trophic levels, thereby sustaining the respective ecosystems.

The regulation of biogeochemical processes is influenced by biological (e.g. microbial degradation) and environmental conditions (e.g. temperature), thus climate change may induce major impacts on the processes themselves and on their associated organisms. Climate change is expected to have greater impacts in the tropics due to the relatively stable environmental conditions compared to temperate regions (Newbold et al., 2020). For example, temperate bivalve species were found to have greater lethal thermal windows than those of a tropical area, which appeared to reflect the greater temperature variation measured in temperate sediments, supporting the climate variability hypothesis (Compton et al., 2007).

While effects of climate change on biogeochemical processes have been extensively documented (Hutchins & Capone, 2022), how much do we actually know about these processes in tropical coastal waters? We suggest that our understanding of the effects of climate change on biogeochemical processes in tropical regions is scarce, thus hindering our ability to predict impacts on ecosystems and sustain these important hotspots of biodiversity and productivity. Therefore, in this perspective article we: 1) highlight some knowledge gaps of how climate change impacts the biogeochemistry in tropical coastal waters, 2) discuss why these gaps persist, and 3) suggest some action points which we anticipate will inspire further studies on the biogeochemistry in tropical coastal waters and the response to climate change.

Climate change in tropical coastal waters: What do we know?

A Web of Science search to determine the number of studies addressing the impacts of climate changes on the biogeochemistry of coastal tropical waters (string: ALL = (("climate change" or "global change") and coast* and (respiration or product* or biogeochem*) not land not soil not crop AND tropic* not (polar* or ice or glac* or Arctic or Antarctic)) returned only 660 research articles (as of July 2023; Fig. 1). In comparison, the same string excluding 'tropic*' (i.e., NOT tropic*) returned 4823 research articles, indicating greater study efforts in temperate regions (Fig. 1). In fact, there are more than double the number of studies on the impacts of climate change on biogeochemistry conducted in remote polar regions (string excluding 'tropic*' but including 'and (polar* or ice or glac* or Arctic or Antarctic)'; 1385 research articles; Fig. 1) than in the tropics, where half of the world's population live. It should be noted that Web of Science mainly searches articles written in English, which is a more prominent language (Bitetti & Ferreras, 2016), thus we are likely missing publications in other languages found in tropical areas. Our aim here, however, is to highlight that the impact of climate change on the biogeochemistry of tropical coastal waters is not being sufficiently considered by the world's scientific community, despite their importance. Therefore, we advocate for an increased effort to study biogeochemical processes in tropical coastal waters.

Climate change stressors will be experienced differently in tropical coastal regions

Stressors commonly associated with climate change such as warming, acidification, marine heatwaves, sea level rise and increased magnitude of extreme weather events (i.e. cyclones), will have large impacts in tropical coastal regions compared to other regions (Cooley et al., 2022). For example, peak increases in marine heatwaves in tropical waters are suggested to have decreased phytoplankton blooms with implications for biogeochemical cycling and ecosystem dynamics (Hayashida et al., 2020). Furthermore, it is predicted that more extreme cyclones will impact tropical regions, possibly resulting in increased precipitation and material flushing from land to coastal waters (Knutson et al., 2010), which will change the cycling of matter of these systems (McCabe et al., 2021). Nonetheless, impacts on tropical coastal waters still need to be further investigated.

Tropical organisms have a lower acclimation capacity

Tropical regions have relatively stable environmental conditions (e.g., temperature, air humidity) compared to other regions. These conditions have been suggested to limit tropical species' tolerance to environmental changes, and hence it is particularly important when considering climate driven changes in tropical regions. Studies have demonstrated that warming tolerance and acclimation ability of tropical species (including fish and crustaceans) is lower than for closely related temperate species (Vinagre et al., 2016). Further, warming oceans have a lower oxygen supply that will likely increase the vulnerability of marine organisms to reduced oxygen concentrations (Vaquer-Sunyer & Duarte, 2010). With tropical ecosystems already suffering from anoxic events (Altieri et al., 2017), further reductions in oxygen availability in these regions will possibly make organisms more susceptible to hypoxia than in temperate systems.

Limited long-term biogeochemical datasets available in tropical waters

To detect biogeochemical and ecological changes in response to long-term climate change in aquatic ecosystems, and distinguish these from natural variability, at least decadal observation periods are necessary. Long-term time-series stations are therefore valuable tools to obtain a baseline from which to determine future climate change impacts. The Joint Global Ocean Flux study established several open ocean time series stations focused on biogeochemical processes across the globe in the late 1980's, a few of which are still active (e.g. Bermuda Atlantic Time-series Study (BATS)) and have provided essential information on the impact of climate change (Ducklow et al., 2009). However, these time series are focused on open oceans. Furthermore, there are many biogeochemical time series in temperate coastal waters (e.g. Sylt Roads Marine Observatory, Western Channel Observatory, Santa Barbara Coastal Long Term Ecological Research). To the knowledge of the authors, there is only one coastal tropical time series, the Cairns Time Series (CaTS; Lønborg et al., 2016), focused on biogeochemistry, which has been running since 1989 in the Great Barrier Reef (Australia). Other than that, such long-term monitoring series are non-existent in tropical coastal areas, hampering our ability to anticipate and assess future changes.

Why the gap?

Whether it is the number of publications or sampling bias, there appears to be an underrepresentation of tropical studies (Stroud & Feeley, 2017), particularly regarding the impacts of climate change on the biogeochemistry of tropical coastal waters. While there are a myriad of reasons for such skewed research results, we highlight a few key points that play a major role in this pattern. Many developing countries are found within tropical regions and these countries often lack funds, human resources, and facilities for conducting research and publishing. Anglo-Saxon and European countries have a much higher publication rate compared to the rest of the world as these countries are regarded as producing ‘better quality research’, and so have a better chance of publishing (Skopec et al., 2020). Further, researchers in developing countries can find several barriers at the manuscript preparation and submission level due to lack of fluency in the English language, use of analytical tools, or experience with editorial processes (Freeman & Robbins, 2006). Consequently, there is a risk that research conducted in tropical coastal waters is not reaching the global research community.

What about the future?

Although there is currently a lack of information about the impacts of climate change on biogeochemical processes in tropical coastal waters, we suggest a few action points. Establishing collaborations between countries with more resources and those without should be promoted to increase research capacity in tropical regions, taking care to avoid ‘parachute science’ (Genda et al., 2022). While this would require changes in funding schemes and political efforts, such collaborations would foster increased research outputs by supporting not only sampling and laboratory work, but also analytical tools and editorial support for producing publications. ‘AuthorAid’ is a free global network of researchers offering ‘support, mentoring and training for researchers in low- and middle-income countries’ (Freeman & Robbins, 2006), already facilitating some of this work. Another important activity is to improve our knowledge by establishing more long-term biogeochemical time-series stations in tropical coastal waters. Such efforts could be coordinated through the International Ocean Carbon Coordination (IOCCP) project and/or the Integrated Marine Biosphere Research (IMBeR) project, with the latter already funding a study group on the Northwest Pacific and Indo-Pacific regional seas, which includes many tropical nations. A good starting point to many of these action points would be the creation of a working group through funding from for example the Scientific Committee on Oceanic Research (SCOR) that could help initiate and coordinate efforts.

Overall, there is a clear need to increase our knowledge of how climate change will affect the biogeochemistry in tropical coastal waters. Collectively such knowledge will be essential for our capacity to understand and predict ecosystem impacts at local, regional, and global scales.

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Figures

Figure 1. Number of research articles published over time focused on the biogeochemistry of polar, temperate, and tropical regions. As of July 2023, tropical regions have 660 publications, polar 1385, and temperate 4823. Data extracted from Web of Science.

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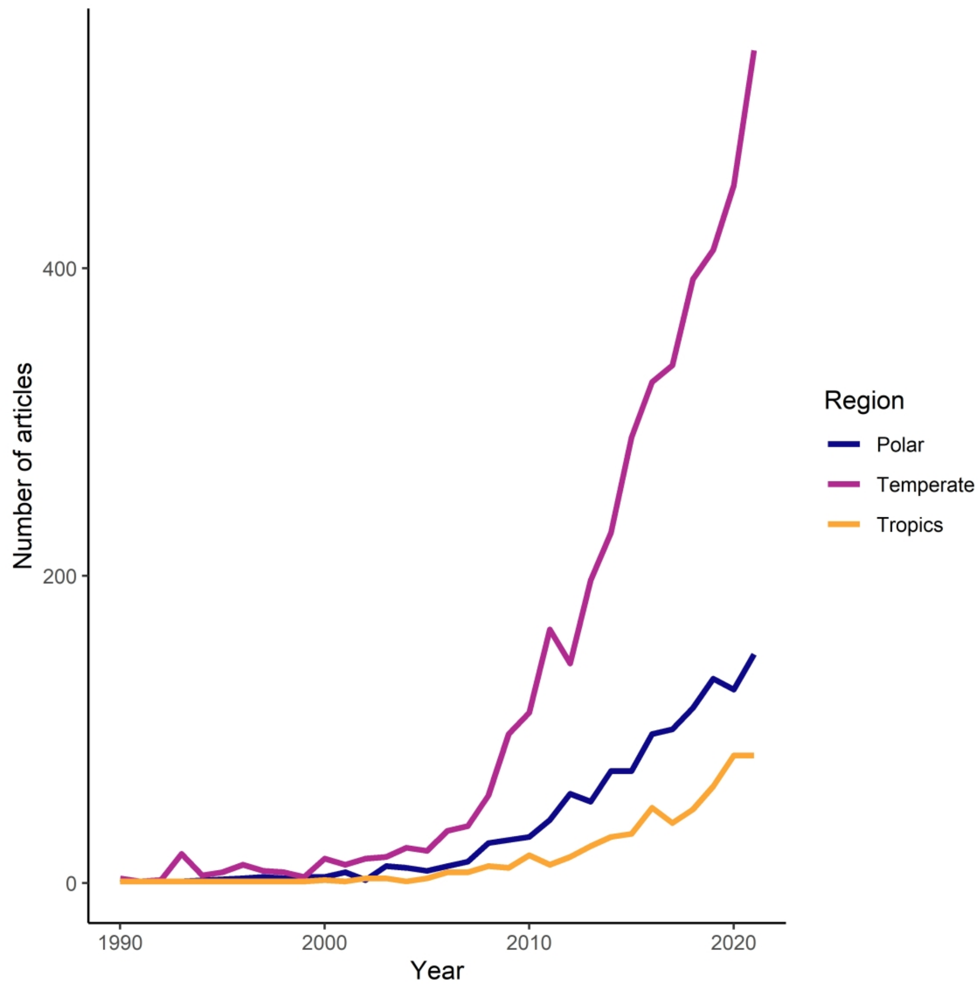

Number of research articles published focused on the biogeochemistry of polar, temperate, and tropical regions. As of July 2023, tropical regions have 639 publications, polar 1349, and temperate 4677. Data extracted from Web of Science.

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