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TYPE Editorial
PUBLISHED 06 February 2023
DOI 10.3389/fmars.2023.1146877

Check for updates

OPEN ACCESS

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SPECIALTY SECTION
This article was submitted to Coastal Ocean Processes, a section of the journal Frontiers in Marine Science

RECEIVED 18 January 2023
ACCEPTED 30 January 2023
PUBLISHED 06 February 2023

CITATION
Zhang W, Yu L, Schmidt S, Orfila A and Dias JM (2023) Editorial: Regional coastal deoxygenation and related ecological and biogeochemical modifications in a warming climate.
Front. Mar. Sci. 10:1146877.
doi: 10.3389/fmars.2023.1146877

Editorial: Regional coastal deoxygenation and related ecological and biogeochemical modifications in a warming climate

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KEYWORDS

coastal deoxygenation, climate change, anthropogenic activity, eutrophication, ecological modification

Editorial on the Research Topic
Regional coastal deoxygenation and related ecological and biogeochemical modifications in a warming climate

Coastal ecosystems play tremendous roles in socio-economic development, but their functions are degrading due to human activities. One of the most alarming degradations is coastal deoxygenation, driven primarily by the over-enrichment of anthropogenic nutrients and organic matter (eutrophication) in the coastal waters. The coastal deoxygenation has led to the worldwide spread of hypoxic zones (where dissolved oxygen concentration is less than 2 mg/L), with the number of reported hypoxic sites increasing from 45 in the 1960s to around 700 nowadays. Besides being perturbed by human activities locally, coastal waters respond more rapidly than the open ocean to global climate change such as ocean warming. Warmer water temperature reduces oxygen solubility, weakens the mixing of oxygen-rich surface water with oxygen-poor bottom water, and enhances biogeochemical oxygen consumption, exacerbating the coastal deoxygenation situation.

Coastal deoxygenation has received much public and scientific attention during the last decades. In this Research Topic, a collection of 6 papers contributes to improving the knowledge about coastal deoxygenation and related ecological and biogeochemical modifications in a warming climate. A combination of *in situ* observations and numerical modeling simulations are used in these papers to investigate mechanisms controlling algal bloom (Fung et al.) and dissolved oxygen dynamics (Lu et al.; Liu et al.; Dubosq et al.), to quantify benthic contribution to hypoxia (Hulot et al.), and raise awareness of the possible negative effects of seasonal hypoxia on wild Pacific salmon stocks (Rosen et al.).

Using long-term time series observations, Fung et al. detected an abrupt shift in chlorophyll-a in Weeks Bay, a small subtropical estuary. Relationship analysis between chlorophyll-a concentration and river discharge, nitrogen, and phosphorus revealed that the detected abrupt shift in chlorophyll was due to the combined effect of a sharp increase in riverine input of total phosphorus and low river discharge rates and variability. Not all monitoring stations experienced the abrupt shift in chlorophyll-a concentration, highlighting the complexity of phytoplankton response to environmental modifications and significant spatial differences that appeared over such a small estuary.

Combining *in situ* observations and a coupled physical-biogeochemical model, Lu et al. quantified the relative importance of external and internal factors to hypoxia formation in an urban harbour in Hong Kong. They found that the bottom water hypoxia generation in the harbour is controlled externally by lateral advection of low-oxygen water, anthropogenic nutrients and organic matter and internally by local hydrodynamics and biogeochemical processes. Specifically, sediment oxygen demand is identified as the dominant oxygen sink, contributing ~93% to hypoxia formation, while vertical diffusion and vertical motion are the major oxygen sources (~57% and ~24%, respectively) that contribute to counteract the hypoxic condition in the port.

Liu et al. investigated the role of wind forcing in determining the spatial patterns of bottom water hypoxia in Mobile Bay, a shallow stratified estuary, using a high-resolution, three-dimensional numerical model. They developed a new approach, the vertical dissolved oxygen variance (VDOV), to quantitatively separate the physical and biogeochemical contributions to the formation and destruction of bottom water hypoxia. The analysis revealed that wind-enhanced vertical dissipation was the primary factor of hypoxia reduction, and that wind-induced alteration in coastal circulation patterns and vertical mixing events stimulate significant variations in near-bottom dissolved oxygen concentration.

Seasonal deoxygenation of bottom waters has been reported for the first time in the Bay of Biscay off the Gironde estuary (Dubosq et al.). Depth profiles revealed a distinct seasonal variation of dissolved oxygen in the Bay of Biscay: the water column was well-oxygenated in winter, oversaturated with oxygen at the upper 20-m water during the spring bloom, and progressively losing dissolved oxygen in the bottom until reaching an oxygen concentration minimum in fall. Seasonal stratification, potential advection of low-oxygen water, and settling organic matter from the upper layer are the main drivers of this seasonal bottom water deoxygenation. Quantifying the relative importance of these different processes calls for long-term and continuous *in situ* monitoring efforts.

Benthic oxygen and nutrient fluxes can significantly affect oxygen dynamics and hypoxia formation in the water column (Hulot et al.). Seasonal hypoxia still occurs in the Loire estuary despite 20 years of eutrophication control, implying the importance of the less quantified benthic contribution to hypoxia. Deep sediment erosion occurred during an exceptional flood, and the methane efflux created severe fractures in the sediment. This stimulated water-sediment exchanges, which then progressively decreased in intensity as these fractures were gradually filled in. A simplified modeling revealed that the phosphorus efflux from sediment contributes to the delay of the mitigation of eutrophication. Further investigation is needed to improve the quantitative understanding of benthic contribution to water column nutrient cycling and oxygen dynamics.

Rosen et al. identified seasonal near-surface hypoxia in Herbert Inlet, British Columbia using monthly time series of *in situ* profiling observations. The near-surface hypoxia appeared seasonally at multiple stations, being shallower and most severe in summer, and dissipated in winter. Further investigation integrating long-term, multidisciplinary studies is required to identify the potential of this near-surface hypoxic condition on local species, including wild Pacific salmon.

In all, these papers provide new results and insights to advance our understanding of deoxygenation in different coastal systems, the underlying mechanisms, and their impacts on biogeochemical cycles and ecosystem functioning. The findings of this Research Topic should be of interest to a broad community of researchers and stakeholders worldwide.

Author contributions

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

Funding

This work was funded by the Science and Technology Committee of Shanghai Municipal (No. 21ZR1421400), the National Science Foundation of China (No. 41706015), and by MCIN/AEI/and by "ERDF A way of making Europe" (PID2021-123352OB-C31). We acknowledge financial support to CESAM by FCT/MCTES (UIDP/50017/2020+UIDB/50017/2020+LA/P/0094/2020), through national funds. The present research was carried out in the framework of the AEI accreditation `Maria de Maeztu Centre of Excellence" given to IMEDEA (CSIC-UIB) (CEX2021-001198).

Acknowledgments

We thank all authors, reviewers, and editors that have contributed to this Research Topic.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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