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EDITED AND REVIEWED BY
Marta Marcos,
University of the Balearic Islands, Spain

*CORRESPONDENCE
Patricia M. Glibert
glibert@umces.edu

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# Editorial: Eutrophication, algal bloom, hypoxia and ocean acidification in large river estuaries

Jianfang Chen[1], Wei-Jun Cai[2], Patricia M. Glibert[3]* and Daji Huang[4]

[1]Key Laboratory of Marine Ecosystem Dynamics, Ministry of Natural Resources, Second Institute of Oceanography, Ministry of Natural Resources, Hangzhou, China, [2]School of Marine Science and Policy, University of Delaware, Newark, DE, United States, [3]University of Maryland Center for Environmental Science, Horn Point Laboratory, Cambridge, MD, United States, [4]State Key Laboratory of Satellite Ocean Environment Dynamics, Second Institute of Oceanography, Ministry of Natural Resources, Hangzhou, China

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Editorial on the Research Topic

Eutrophication, algal bloom, hypoxia and ocean acidification in large river estuaries

Estuaries are transitional regions of river freshwater to seawater, and biogeochemical parameters such as salinity, nutrients and biological parameters typically show strong gradients in the offshore direction. Estuaries occupy a small portion of the global ocean area (about 0.2%) but play an important role for marine fisheries and contribute disproportionately to the global carbon budget. Furthermore, estuaries are under multiple strong anthropogenic and climate change pressures, such as eutrophication, wetland degradation, and overfishing, and the ecosystems of many estuaries have dramatically changed, leading to hypoxia, harmful algal blooms, ocean acidification and changes in biodiversity.

In this Research Topic, papers were solicited on estuarine systems that exemplify the changes and the complexities of interactions that are occurring in response to anthropogenic and climate change influences. The ten papers on this Research Topic focus largely–but not exclusively–on Asian waters. Asian waters are among the most rapidly changing and progressively impacted by nutrient enrichment and climate change. One of the major themes of these papers is the coupling between physical and biological processes. The themes herein of physical-biological coupling and impacts on water quality changes were also developed in papers on the Chesapeake Bay and the Salish Sea. Modeling, time series analysis and advanced analytical techniques were all brought to bear in the analyses reported.

Wang et al. described how anthropogenic pressures from the Pearl River have been increasing, but how hypoxia of the receiving Hong Kong waters has remained comparatively rare. They showed, using 29 years of data, that wind events disrupt hypoxia formation and maintenance. However, over time, with changing climate, winds have become less strong, leading to an increased potential for hypoxia to become established in the future.

Han et al. also explored the theme of physical-biological coupling using a three-dimensional coupled physical-NPZD ecosystem model for the South China Sea and the effects of wind-driven downwelling. In this case, downwelling of nutrient rich waters is induced by widening coastal shelf typography. In particular, the downwelling transport resulted in marked phytoplankton blooms in the bottom-trapped waters, a phenomenon that moved algal blooms seaward and offshore.

Ma et al. also used time series data in examining hypoxia of the East China Sea and its relationship to El Niño. Although they found an insignificant linear trend, they did observe that in summers of El Niño, large river discharge and strong stratification enhances hypoxia off the Changjiang Estuary but El Niño is not a prerequisite for hypoxia to occur.

Combining observation and a numerical model, Meng et al. broadened the understanding on the response of hypoxia to a passing typhoon, in particular to the typhoon-induced advection. This study revealed that this typhoon did not completely destroy the stratification by local mixing, but the typhoon-induced oceanic advection increased transport of particulate matter, furthering potential for hypoxia.

Khangaonkar et al. examined the effect of a different event–the heat wave of 2015–on production in the Salish Sea, the inland estuary of the northwest Pacific comprised of Puget Sound and associated bays. They found that increased biological activity resulted from stronger estuarine exchange and higher nutrient loads, and was not due to direct temperature effects per se.

Shifting back to Chinese waters, this time the warm temperate Yellow River Delta, Liu et al. examined the community structure of the benthic diatom abundance and its relationship to environmental variables. Using DNA extracted from sediment samples and subsequent sequence analysis, they compared richness and diversity among seasons and found significantly higher diversity in spring and winter than in summer and fall. Seasonal fluctuations in nutrient inputs from the Yellow River as well as temperature were highly correlated with seasonal patterns of the benthic diatom assemblage.

Ok et al. aimed to develop a predictive model for phytoplankton blooms in regions of aquaculture cages for the coastal waters off Yeosu, South Korea. In this region, harmful algal blooms are frequent and have caused substantial economic harm to the aquaculture industry, Using experimental data collected over many months, they developed a series of best-fit equations using nutrient and chlorophyll *a* concentrations. This model allows them to predict–one week in advance–the magnitude and timing of blooms. Such a predictive capability can be helpful for aquaculturists to take preemptive actions such as moving their cages or harvesting their fish, thereby reducing economic losses.

Focusing on Chesapeake Bay, the largest estuary of the USA, the relationship between algal blooms of the dinoflagellate *Prorocentrum minimum* and ocean acidification were explored by Li et al. using a coupled carbonate chemistry- harmful algal bloom model. This model, one of the few efforts to couple 3D hydrodynamic carbonate chemistry and HAB models for a dynamic estuary, not only represented conditions of a recent year, but projected effects of increasing $pCO_2$ for mid- and late-21$^{st}$ century. Overall, they found that ocean acidification may cause a modest amplification of such blooms in the future.

Two studies of this Research Topic applied stable isotopes to explore fate and transport of nitrogen in large estuaries of China. Tian et al., used dual stable isotopes of nitrate along with particulate isotopic composition to examine sources and rates of regenerated nitrogen in the Yellow Sea in spring and summer and found that the south part of the region is facing an increasing ecological risk due to nitrogen discharge from the Changjiang. A multiple isotope approach was also applied by Zhong et al. to understand the cycling and dynamic nature of dissolved organic nitrogen from the Changjiang Estuary to the coastal East China Sea.

In all, these papers have yielded new insights into complexity of physical, biogeochemical, and biological dynamics in large river estuaries heavily impacted by anthropogenic nutrient enrichment. The stresses on these systems are large and, as climate effects increase, will continue to grow. The findings of these efforts, and the approaches employed–from physical-biological coupled models to time series and advanced analytical and experimental tools–should be of interest to estuarine scientist and managers worldwide.

## Author contributions

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

## 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.

## Publisher's note