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Editorial: Advances in understanding lateral blue carbon export from coastal ecosystems

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Editorial on the Research Topic
Advances in understanding lateral blue carbon export from coastal ecosystems

'Blue Carbon' refers to the carbon captured by the coastal systems or ocean and was coined about a decade ago (Nellemann et al., 2009), emphasizing the carbon sequestration capacity of coastal vegetated ecosystems (e.g., macroalgae/kelp, seagrass beds, saltmarshes, and mangroves). These blue carbon systems only cover <0.1% of the ocean area, but may account for >50% of the carbon storage in marine environments, representing a large carbon sink comparable to the global river input (Alongi, 2014). The fluxes of terrestrial-derived carbon including dissolved organic carbon (DOC), dissolved inorganic carbon (DIC), and particulate organic carbon (POC) transported through surface river runoff to the ocean were well known and quantified (Ludwig et al., 1996; Regnier et al., 2022). However, increasing evidence suggests that tidal exchange dominates the transport of significant dissolved carbon from coastal ecosystems to adjacent estuarine and shelf waters (e.g., Maher et al., 2013; Tait et al., 2016; Wang et al., 2016; Chen et al., 2021). This mechanism is commonly named as carbon 'outwelling' or lateral carbon export (e.g., Teal, 1962; Odum, 1968; Wang and Cai, 2004; Sippo et al., 2017; Cabral et al., 2021; Santos et al., 2021; Tamborski et al., 2021).

Outwelling represents a potentially overlooked source of 'blue carbon', which may rival or even exceed the sedimentary burial rates of blue carbon in coastal ecosystems (Correa et al., 2022), and yet, this pathway remains understudied to date due to a lack of robust, coherent measurements quantifying lateral blue carbon exports in highly dynamic coastal ecosystems. The aim of this Research Topic was to summarize the recent advances in understanding lateral blue carbon export from coastal ecosystems. Five articles were finally collected in this Research Topic as summarized below.

Zhu et al. calculated the porewater exchange rate and fluxes of carbon outwelling and greenhouse gas emissions, based on a ^{222}Rn mass balance model in a subtropical multi-species saltmarsh in Hangzhou Bay, China. They found that DIC was the most dominant (~90%) carbon species exported through outwelling and porewater exchange, which were 3.2 and 1.2 times that of carbon burial. The emissions of CO_2 (54.6 ± 0.5 mmol m^{-2} d^{-1}) and CH_4 (0.19 ± 0.01 mmol m^{-2} d^{-1}) from creek water can offset 16% of sedimentary carbon burial. Further, the isotopic signal of $\delta^{13}C$ and ratios of C/N reveal that the organic carbon were mainly originated from the C3 plant (i.e., *Scirpus mariqueter*) rather than the C4 plant (i.e., *Spartina alterniflora*). This study emphasized that the porewater-derived carbon outwelling acts as a critical role in the long-term carbon sink, providing a scientific basis for protecting blue carbon ecosystems.

Yuan et al. assessed the annual lateral exchange of organic carbon between the adjacent water and salt marsh at the Yangtze estuary, China, to determine whether the salt marsh acted as a net source or sink for estuarine carbon. They found that the concentrations of DOC and POC peaked in autumn (3.54 mg L^{-1} and 4.19 mg L^{-1}, respectively) and declined to the lowest in winter and spring (1.87 mg L^{-1} and 1.51 mg L^{-1}, respectively), and their fluxes were significantly correlated in different seasons. In different seasons the tidal creek showed the export of organic carbon with the flux range from -12.65 to 4.04 g C m^{-2}. Further, the flux of organic carbon varied with tidal pattern and were significantly higher during spring tides than that during neap tides. Last, this study indicates that the salt marshes acted as a net source through lateral carbon export for the estuary.

Wang et al. investigated the submarine groundwater discharge (SGD) and its effect on the carbon cycle in a highly urbanized and river-dominated coastal area, i.e., the Guangdong-HongKong-Macao Greater Bay Area in China. They found that SGD-derived fluxes of DIC and DOC were $(0.77–3.29)\times10^{10}$ g d^{-1} and $(0.60–9.94)\times10^{9}$ g d^{-1}, respectively, which were nearly ~2 times larger than riverine inputs. Further, they found that SGD acted as a potential source of atmospheric CO_2 with a flux of 1.46×10^{9} g C d^{-1}. These additional inputs of carbon and nutrients were expected to enhance biological pump efficiency, stimulate new primary production, and regulate the balance of the carbonate system in marine waters. This study emphasized that SGD is important as rivers, both of which plays a significant role in carbon budgets at the regional and global scales.

Kim et al. explored the spatial patterns of DIC and total alkalinity (Alk_T) productions and DIC in a shallow beach aquifer in Cape Shores, Delaware, USA. They found that the substantial changes of DIC and Alk_T can occur along the subsurface flowpaths due to the anoxic reactions which led to the additional fluxes of DIC (191 mmol d^{-1}) and Alk_T (134 mmol d^{-1}) to the ocean per meter length of shoreline, respectively. In the saltwater-freshwater mixing zone, the ratios of DIC: Alk_T and dDIC:dAlk_T relative to the theoretical dilution line revealed that both aerobic and anaerobic reactions can actively contribute to the productions of DIC and Alk_T beneath the beach surface. This study suggests that the beach aquifers (as carbon-poor sites) can support the transformation of inorganic carbon and should not be overlooked as an important source of DIC and Alk_T like carbon-rich mangrove wetlands.

Pan et al. proposed an effective approach to track the dynamics of detached macrophytes on a semi-sheltered beach in Odense Fjord, Denmark. They conducted a monitoring survey using multiple technologies including real-time camera trap, deep learning with a network architecture and partial least squares regression analysis. The camera trap can be used as a labor-saving approach to track the spatiotemporal dynamics of detached macrophytes deposited on the beach. Further, the application of deep learning provides an important aid in image identification and ecological survey and environmental management.

Overall, these articles presented in this Research Topic represent important progress, datasets, as well as novel methodologies in understanding of lateral carbon export from various coastal ecosystems (e.g., beach, salt marsh, estuary, and coastal bay). We are convinced that this Research Topic will continue to inspire improvement of quantifying lateral carbon fluxes and developing effective strategies for management and protection of the blue carbon ecosystems.

Author contributions

KX invited the other guest editors NC, ZW, JT, DM and XY to design this Research Topic. All guest editors have edited and reviewed the editorial article, and approved the submitted version.

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