frontiers | Frontiers in Marine Science

TYPE Editorial
PUBLISHED 17 January 2023
DOI 10.3389/fmars.2023.1130839

Editorial: Advances in estuarine and coastal nitrogen cycle

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KEYWORDS

organic nitrogen, inorganic nitrogen, N forms, N fluxes, nitrous oxide, microbial metabolisms, climate change, estuarine and coastal ecosystems

OPEN ACCESS

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

RECEIVED 23 December 2022
ACCEPTED 09 January 2023
PUBLISHED 17 January 2023

CITATION
Wei J, Dong X, Liu S and Lin X (2023) Editorial: Advances in estuarine and coastal nitrogen cycle. *Front. Mar. Sci.* 10:1130839. doi: 10.3389/fmars.2023.1130839

Editorial on the Research Topic
Advances in estuarine and coastal nitrogen cycle

Dramatically increased reactive nitrogen (N) inputs over the past decades caused numerous eco-environmental problems in coastal marine ecosystems (Wei et al., 2022; Wei et al., 2023). Estuarine and coastal ecosystems are not only critical zones connecting terrestrial and marine ecosystems, but also a hotpot for greenhouse gas nitrous oxide (N_2O) emissions and diverse N biogeochemical processes such as denitrification, anammox, and N burial in sediment (Figure 1). In estuarine and coastal ecosystems, N cycling is temporally and spatially complex and dynamically influenced by multiple interrelated ecosystem components (Liu et al., 2020; Murray et al., 2020). It is necessary to deepen our knowledge of N cycle in estuarine and coastal ecosystems (Tian et al., 2020; Harris et al., 2022). Within this aspect, this Research Topic focuses on spatiotemporal N variations, N fluxes, as well as their controlling factors and environmental implications. Sixteen articles were finally collected in this Research Topic as summarized below.

Variations in natural forcing and environmental conditions affect spatiotemporal patterns of nitrogen cycle processes. Zhang et al. investigated the influence of the tidal cycle on total nitrogen (TN) and N speciation in a coastal bay. They reported that while TN concentrations during the spring and neap tides did not differ, significant differences in particulate nitrogen (PN) and NO_2^- were observed between the spring and neap tides. Furthermore, the net exchange flux of TN during spring tide was 4.3 times higher than that of neap tide. They also reported an above 50% contribution of the total dissolved nitrogen (TDN) pool in TN. Among TDN, dissolved organic nitrogen (DON) accounted for higher proportion during the spring tides compared to neap tides. Xu et al. show that both local and remote forcing, such as winds, upwelling, and climate factors like El Niño-Southern Oscillation, Pacific Decadal Oscillation, and North Pacific Gyre Oscillation, affected the variations of sedimentary nitrogen isotope ($\delta^{15}N_{sed}$) in the Santa Barbara Basin (SBB). Sedimentary nitrogen isotopes has often been used as a proxy for the denitrification process to track temporal record. For instance, the long-term variations of the SBB $\delta^{15}N_{sed}$ signature with decreasing and increasing trend from 1940 to 2019 reflect changes in denitrification

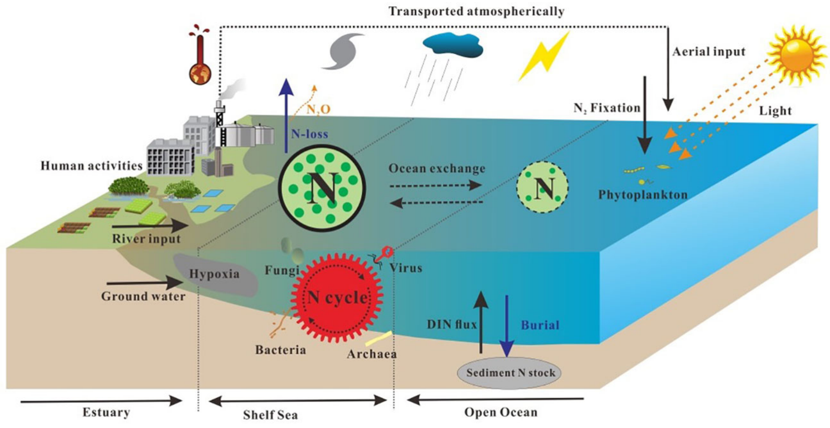

FIGURE 1
N cycle in estuarine and coastal ecosystem.

induced by the strength of tropical trade winds in the eastern tropical North Pacific. Yan et al. studied high-resolution N dynamics in the upper water column of the South China Sea to interpret mechanisms controlling N cycling in the water. They resolved the dominant N sources and processes, including atmospheric N deposition (AND)/ N_2-fixation, assimilative fractionation, and nitrification, and quantitatively evaluated their contributions in the vertical distribution of NO_3^- in the water column. They showed variations in nitrification and AND/N_2 fixation sources of NO_3^- assimilated by phytoplankton between different water layers.

In addition to natural processes, human activities can affect nitrogen stocks and fluxes in estuarine and coastal ecosystems. Dun et al. found that seawater intrusion and human activities affect the hydrochemical characteristics of groundwater in the Pearl River Estuary, which resulted in elevated NO_3^- concentrations. They also revealed zonation of groundwater depending on distinct major controlling factors of groundwater characteristics. Li et al. found that long-term grazing prohibition significantly increased nitrification and denitrification rates in the salt marsh on Chongming Island, which indicated that the implementation of reasonable grazing prohibition policies in salt marshes has great potential to restore their ecosystem functions and achieve their goal of sustainable development. Qin et al. examined seasonal changes in various N subpools of plant-soil subsystems in embanked and adjacent S. alterniflora natural salt marshes on the coast of Eastern China. The embankment with purpose of holding seawater back from salt marshes significantly reduced both litter and root N storage by varying extent over either all or specific seasons. The different nitrogen pools such as soil organic nitrogen (SON), labile organic nitrogen (LON), recalcitrant organic nitrogen (RON), and ammonium concentrations also declined significantly by different levels, over the four seasons following the embankment construction. Liu et al. found that the conversion of natural marshland to shrimp aquaculture ponds significantly promoted sediment N fixation rates, which may be mainly attributed to the change of sediment electrical conductivity (EC), total organic carbon (TOC) and Fe^{2+}/Fe^{3+} rather than the change of N fixation gene abundance. In addition, increasing inhibiting effect of inorganic N concentration with reclamation time has been revealed from no obvious difference in sediment N fixation rates between 5-year-old shrimp ponds and 18-year-old shrimp ponds. In another shrimp aquaculture study, Sun et al. reported that denitrification was responsible for the majority of the total NO_3^- reduction, surpassing anammox in the sediment from eight studied shrimp ponds. Their results of high NO_3^- reduction rate and N loss indicate that coastal reclamation is a non-negligible way to remove nitrogen in the artificial aquatic environment of shrimp ponds. In three types of aquaculture ecosystems (seabass, white shrimp, and green crab ponds), Lin et al. showed higher fluxes of total mineralized N relative to immobilized N fluxes in aquaculture surface sediment from the Guangdong-Hong Kong-Macao Greater Bay Area, indicating that the sediment serves as an important source of eutrophication in reclaimed aquaculture system of coastal wetland.

Microbes such as bacteria, archaea, and fungi are key components responsible for many N transformation and consumption processes. The review by Wei et al. who conducted a scientometric analysis on a co-citation network consisting of 835 references derived from 354 citing articles and summarized the distribution of denitrifying anaerobic methane oxidation (DAMO) in both freshwater and coastal environments. DAMO involves two possible pathways mediated either by bacteria or archaea. They found archaea pathway is generally under-studied compared to bacteria pathway and coastal systems are generally under-studied in comparison to freshwater systems. The emerging research topics in this area include coupling of alternative electron acceptors with AMO processes and their role as CH_4 sinks. Several areas that require further research were identified from Wei et al. and future research including comparisons of DAMO with other N cycling pathways and environmental conditions in the context of the river-estuary sea continuum has been proposed. Tang et al. investigated microbial uptake and oxidation processes of two reduced N forms, ammonium and urea, in a eutrophic estuary. They showed that shallow light penetration depth leaves 76% of estuary water bodies to stay in dark throughout a day and thus ammonium oxidation, which favors dark conditions, dominates the estuarine regenerated-N cycle. Microorganisms' high preference for ammonium over urea showed the following rank: ammonia oxidation > ammonium uptake >> urea uptake ≈ urea oxidation. Maxwell Lazo-Murphy et al. isolated four fungi strains (*Purpureocillium lilacinum, Trichoderma harzianum, Trichoderma virens*, and *Rhodotorula glutinis*) from salt marsh sediments in North Inlet, South Carolina, USA and discovered that up to 22.8% of nitrite provided in growth media was converted to N_2O by isolated fungal strains, implying of an additional significant source of N_2O emission from fungi. Using isotope mass balance approach, they showed that the site preference (SP) of N_2O produced by salt marsh sediment fungi, which changes in intramolecular distribution of ^{15}N and is used as a tracer to identify the source of N_2O among bacteria, archaea, and fungi, ranged from 7.5 ± 1.6‰ to 33.4 ± 1.2‰ in the four isolates and expanded our standing of relative contribution of fungi to N_2O production in salt marsh sediments.

Detection of microbial targeted genes can also indicate N-related dynamics. For examples, copper-containing nitrite reductase gene (*nirK*) and cytochrome cd1-containing nitrite reductase gene (*nirS*) are two gene markers that are widely used to study denitrifying microbes (Wolsing and Priemé, 2004; Santoro et al., 2006). Zhao et al. showed that the *nirK*-type denitrifying bacteria were more sensitive to a macroalgae green tide than the *nirS*-type denitrifying bacteria, as bacterial community structures differed depending on the algal bloom stages with the more stable and complex *nirK*-type denitrifying bacterial interactions during the bloom outbreak phase in contrast to the more stable and complex *nirS*-type denitrifying bacterial interactions during the bloom decline phase. Their results demonstrated that different type denitrifying bacteria may occupy different niches during the green tide in coastal Qingdao areas. Comparing gene markers between two nitrogen removal processes (denitrification and anammox) in the surface sediments from Yangtze Estuary and adjacent sea, results from Teng et al. suggested that the gene abundances of *nirS* and *nirK* for denitrifiers were higher than that of AMX 16S rRNA for anammox bacteria, indicating of denitrification as the dominant nitrogen removal pathway in the studied region. Teng et al. also found different spatial distribution patterns between the genera composition of *nirS*- and *nirK*-encoding denitrifiers communities. Furthermore, they discovered novel bacteria genera with anammox oxidation capacity in marine sediments. Besides nitrogen removal, nitrogen fixation process can also be studied through targeted genes such as *nifH* gene. Song et al. demonstrated the main soil physicochemical factors shaping diazotroph communities in coastal saline soils. For instance, they showed that the copy number of *nifH* gene, which encodes the Fe protein subunit of the nitrogenase in the nitrogen fixation process, was significantly affected by soil physiochemical factors, the abundance of diazotrophs in the rhizospheric soil samples was positively related with soil physicochemical properties, and diazotrophic community structure significantly varied with environmental parameters including soil salinity, moisture, pH and total nitrogen, carbon, sulphur and nitrite content.

N cycle is sometimes intertwined with other elemental cycles. Hu et al. demonstrated that the facilitation effect on litter accumulative CO_2 release by N amendments was more and more obvious over the litter decomposition time in the estuarine marsh. Increase of accumulative CO_2 release varied among N amendment treatments with different dose. These observations highlight that N deposition could cause high losses of litter C and emissions of greenhouse gas CO_2.

Overall, these articles presented in this research topic represent important progress, datasets, as well as novel methodologies in understanding of N cycle in estuarine and coastal ecosystem.

Author contributions

XL invited the other guest editors JW, SL, and XD to design this Research Topic. All guest editors have edited and reviewed the editorial article, and approved the submitted version.

Funding

This study was supported by Guangdong Major Project of Basic and Applied Basic Research (2020B0301030004), Fundamental Research Funds for the Central Universities (202262007), Guangdong Province Key Laboratory for Climate Change and Natural Disaster Studies (Grant 2020B1212060025), Innovation Group Project of Southern Marine Science and Engineering Guangdong Laboratory (Zhuhai) (No. 311021009), and the National Natural Science Foundation of China (U21A6001).

Conflict of interest

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