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EFFECTS OF INTERACTION BETWEEN NITROGEN INPUT AND ENVIRONMENTAL FACTORS ON COASTAL WETLANDS

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Abstract: The impact of exogenous nitrogen (N) input on coastal wetland ecosystems is complex and uncertain. Taking single factor to double factor interaction as the main line, the impact of single N input and N input interaction with temperature, moisture, and plant invasion on coastal wetland ecosystems was studied, and the research situation and development direction in this field were clarified. The results showed that the effects of single N input and interaction between N input and environmental factors on coastal wetland ecosystems were of three types: promotion, inhibition and no effect. The fitting curves between N input and various indicators of coastal wetlands show three types: linear, nonlinear and invalid. Future research should be based on controlled experiments and focus on the impact of multi-factor interactions on plant populations and community characteristics in coastal wetlands; combine short-term control experiments with long-term fixed monitoring to explore the temporal variation characteristics of plant-soil interactions.
Keywords: Basic disciplines of environmental science and technology; Nitrogen input; Interaction; Control experiment; Coastal wetland

1 INTRODUCTION

The coastal wetland ecosystem is located in the intersection zone of terrestrial ecosystem and marine ecosystem, and is sensitive to environmental stress [1]. According to reports, more than 50% of the coastal wetland ecosystem on the east coast of the Caribbean has been degraded, and mangrove (Rhizophora apiculata) wetlands in Singapore, the Philippines, and Thailand have lost 97%, 78%, and 22% respectively [2]. In the past half century, more than 60% of my country's coastal wetlands have been destroyed, which is the fastest disappearing wetland type [3-4]. Coastal wetlands have become one of the most severely damaged ecosystems in the world [1].

Nitrogen (N) is an important material basis and ecological factor of coastal wetland ecosystems, and coastal wetland ecosystems are important sources, sinks and converters of N [5-6]. However, affected by human activities, exogenous N input to coastal wetland ecosystems, such as atmospheric dry or wet deposition, terrestrial N input, sea-land sediment-water interface exchange, etc., continues to increase [7]. This will inevitably have an impact on coastal wetland organisms and their environment on a time scale [8], thereby changing the material cycle process and balance of payments of the coastal wetland ecosystem [9], directly or indirectly posing a threat to the coastal wetland ecosystem. [8,10]. With the deepening of understanding of global change, research on the impact of N input on coastal wetland ecosystems has gradually shifted from a single environmental factor to a multi-environmental factor dimension. However, due to the lack of understanding of the interaction of multiple factors, although previous research on the relationship between a single N input and coastal wetland ecosystems has been relatively sufficient [11-12], the impact of the interaction between N input and environmental factors on coastal wetland ecosystems has not been fully studied. The research is not yet systematic and in-depth.

2 SINGLE N INPUT

From the perspective of impact effects, the impact of exogenous N input on coastal wetland ecosystems mainly manifests itself in three types: promotion, inhibition and no impact. Existing studies are mostly based on short-term (days to months) control experiments. The test results show that N addition can significantly promote the fresh weight and dry weight of Suaeda salsa seedlings in coastal wetlands ($NaNO_3$: 0, 1 mmol/L, 5 mmol/L, 10 mmol/L, N addition type and dosage, the same below) [13], height, total N content ($NaNO_3$: 0, 200 mg/kg) increased [14], extending its above-ground biomass The peak growth period (extended by about 20 d) and the higher value of underground biomass in the early growth period are shortened (shortened by 20 to 50 d) (such as $CO(NH_2)_2$: 18 g/(m2·a) [15], It also promotes the increase of NH_4^+-N and NO_3^--N contents in coastal wetland soil (NH_4NO_3: 500 μg/g) [16], and increases the mineralization rate of soil organic carbon (SOC) (NH_4Cl: 500 μg/g) [16], methane (CH_4) oxidation rate (NH_4NO_3: 500 μg/g) [17], enriching the metabolic functional diversity of soil microbial communities (Shannon index and McIntosh index) (NH_4NO_3: 3 g/(hm2 ·a), 6 g/(hm2 ·a) [18]; For Suaeda salsa seed germination rate ($NaNO_3$: 0, 1 mmol/L, 5 mmol/L, 10 mmol/L) [13], Spartina alterniflora underground biomass (NH_4^+-N, NO_3-N: 0 ~ 400 μmol/L) [19], total underground N content of soil (soil and roots at 40 ~ 50 cm) (NH_4Cl: 25 g/(m2 ·a) [20] has a significant inhibitory effect; on the underground and aboveground biomass of reed (Phragmites australis) seedlings (NH_4NO_3: 0.23 mmol/L, 0. 46 mmol/L) [21], CH_4 oxidation rate (NH_4Cl: 500 μg/g) [17], carbon dioxide (CO_2) and CH_4 production, oxidation rate time changes (NH_4NO_3: 2 g/m2 or 500 μ g/g), CO_2 (NH_4NO_3: 2 g/m2) and the effect of nitrous oxide (N_2O) emission flux (KNO_3: 24 g/(m2 • a) [17, 22-23] is not significant.

From the fitting curve, there are three types of fitting curves between N input and coastal wetland indicators. One is the linear type, such as with N input (urea: 0, 10 g/(m2·a), 20 g/(m2 ·a), 40 g/(m2 ·a), 80 g/(m2 ·a), 160 g/(m2 ·a), 320 g/(m2 ·a) increased, Salicornia virginica) The swamp CH_4 emission flux increases linearly with the amount of inorganic N deposition, while the potential net N mineralization decreases linearly [24]; the second is the nonlinear type. For example, as the N input increases, the aboveground biomass and leaf N of the Salina community increase. The content gradually becomes saturated, and the amount of inorganic and organic N deposition increases exponentially [24]. The growth of Scirpus mariqueter generally shows a low N mass ratio (urea: containing N 46.3%, 100 ~ 200 mg/kg) promotion, high N mass ratio (400 mg/kg) inhibition [25]; the third is the ineffective type, such as Salicorna root biomass, sediment respiration, potential carbon (C) mineralization, The response trend of potential net nitrification to N input is not obvious [24].

3 N INPUT INTERACTS WITH ENVIRONMENTAL FACTORS

3.1 N Input vs. Temperature

Statistics show that in the past 50 years, my country's temperature rise rate (0. 23 ℃/10 a) has accelerated significantly, which is about twice the global rate [26]. The "Special Report on Global Warming of 1.5°C" proposed that controlling global warming to 1.5°C above pre-industrial levels rather than other higher temperatures can avoid a series of climate change impacts [27]. With global warming, the temperature of coastal waters has gradually increased. It is worth exploring what impact the interaction between exogenous N input and temperature has on coastal wetland ecosystems.

At present, domestic and foreign research on the impact of the interaction between N input and temperature on coastal wetland ecosystems mainly focuses on the impact of the interaction between eutrophication and temperature on algae. Research shows that the interaction between the two has different effects on different phytoplankton algae, and changes their physiological characteristics and community structure [28-30]. Vaquer-Sunyer et al. [31] believed that in the Baltic sea area, the input of dissolved organic N in wastewater from wastewater treatment plants increased the response of the metabolic rate of phytoplankton to warming, causing the respiration rate of phytoplankton to significantly accelerate and be higher than the primary production rate, resulting in The hypoxic environment in the area has further deteriorated. Tatters et al. [32] believed that compared with 19 ℃, the combination of N addition (nitrate, CH_4N_2O) and CO_2 at 23 ℃ had different effects on different diatom species in the California coastal area, and had significant effects. differences, thereby changing the species composition structure of diatoms. Xiao et al. [33] conducted a 14-year study (2002-2015) on phytoplankton in the East China Sea and found that diatoms prefer lower temperatures (10-24°C) and higher nutrient concentrations (NO_x: 0. 1-6 μmol/L; PO_4: 0. 1 ~ 0. 4 μmol/L), while dinoflagellates (Dinoflagellates) are less sensitive to temperature and nutrient concentration, but at higher N/P (16 ~ 300) The growth is more vigorous under the conditions. It is estimated that by 2100, the number of diatoms in the East Coast of my country will decrease by an average of 19%, while the number of dinoflagellates will increase by an average of 60%. Frequent outbreaks of dinoflagellates will have an impact on the function of coastal ecosystems [33]. Not only that, N input interacting with temperature can also have effects on benthic algae. For example, Puche et al. [34] believed that the interaction between N input (NO_3^--N: 1. 5 to 5 mg/L, 3 to 10 mg/L) and temperature (20 ℃, 24 ℃) affects the growth of different charophytes in the Mediterranean coastal area (Charophytes) species depend on differences in population origins and ecological characteristics of the species themselves, which will further change the species diversity of charophytes.

3.2 N Input and Moisture

As the temperature increases, the spatial pattern of precipitation changes significantly, and extreme precipitation events occur frequently [35]. At the same time, large areas of glaciers are melting, causing global sea levels to rise [36]. It is estimated that by the summer of 2050, the Arctic Ocean may enter an ice-free mode [37]. Sea level monitoring and analysis results from the State Oceanic Administration show that my country's coastal sea level changes generally show a fluctuating upward trend. From 1980 to 2017, my country's coastal sea level rose at a rate of 3.3 mm/a, which was higher than the global average during the same period [37]. It is estimated that by 2050, my country's coastal sea level will be 145 to 200 mm higher than normal (1975-1986, 0 mm) [36]. Coastal wetlands are located in a special geographical location. They are affected by the triple influence of continents, rivers, and oceans. Changes in precipitation and sea level change the time and frequency of fresh and salt water flooding in coastal wetlands [38], causing plant growth to often be restricted by flooding or Drought stress[6]. In this context, the impact of the interaction between N input and moisture (flooding or drought) on coastal wetlands has gradually received attention.

Control experiments show that the interaction between N input and flooding on plant growth in coastal wetlands mainly manifests as promotion, inhibition or no significant effect, and is regulated by flooding duration, frequency, depth, etc. Zhang Linhai et al.[6,39-40] studied Cyperus malaccensis var. brevifolius in the Minjiang Estuary wetland and found that adding $NaNO_3$ (N8: 8 g/(m2·a); N16: 16 g/(m2 ·a) and flooding conditions (T1: 2 to 3 hours of flooding per day; T2: 11 to 12 hours of flooding per day) on the plant height, daily average net photosynthetic rate, and aboveground biomass of short-leaf A. There is a promotion effect on the above-ground C content and above-ground fixed C content, but there is no significant effect on the above-ground C and N content and above-ground C/N of A. brevifolia. At the same time, the dominant factors of N and flooded plants in different growth stages are different. In the early and middle stages of growth (6 to 13 months), NaNO3 input and short-term flooding (T1) respectively increased the height and density of A. short-leaf; in the late growth period (15 months), NaNO3 input and longer-term flooding (T1) T2) respectively increased the density and height of C. brevifolia [6, 39]. Zhang Yaohong et al. [41] believed that the above-ground biomass, leaf area, leaf number, leaf length, and leaf width of Spartina alterniflora in the coastal wetland of Wanggang Port, Dafeng City, Jiangsu Province were significantly affected by the addition of NH4 NO3 (2. 7 g/m2) and intermittent flooding conditions (flooding height maintained at 5 cm every 1 d) increased significantly, while the increase was suppressed when NH4 NO3 was added and continuous flooding conditions (always maintained at around 5 cm). This may be due to the fact that plant growth in the study area is limited by N. N addition and appropriate flooding conditions can enhance plants' absorption of N and their water use efficiency [39, 41]. In addition, water depth will also affect plant growth and survival [38], but this effect will be changed by N addition, and there are interspecific differences. Adam et al.[42] studied the tidal flat wetland of the Rhode River Estuary in the United States and found that the growth of the above-ground parts of most coastal wetland plants showed a hump-shaped curve in response to seawater depth. After the addition of NH4 Cl (25 g/m2), the optimal water depth for the above-ground productivity of the grass plant Spartina patens increased from -35 cm to -15 cm, but it did not enhance its ability to resist flooding (2011); The optimal water depth (0 cm) for the above-ground productivity of the sedge plant Schoenoplectus americanus did not change, but the peak value of the curve increased and strengthened the ability of the sedge plant to resist flooding. When the seawater depth is + 20 cm or + 30 cm, almost no or very few plants survive. From the perspective of the plant community in this area (Pseudomonas aeruginosa + Spartina community), NH4 Cl input and seawater depth have a significant positive interaction on plant aboveground biomass (2010), and have a significant positive interaction on total biomass, aboveground and underground biomass. The interaction effect of the ratio is not significant (cumulative between 2010 and 2011) [42].

Compared with the research on the interaction between N input and flooding, there are fewer studies on the impact of the interaction between N input and drought on coastal wetland ecosystems. For example, Jia et al. [14] conducted a greenhouse control test on Suaeda salina in the coastal wetlands of the Yellow River Delta and found that NaNO3 (200 mg/kg) and drought (moisture content of 14% and 26%) had an impact on the fresh weight and dryness of Suaeda salina. There were no significant interactions. Existing studies have also shown that the addition of N can improve the drought resistance of creeping bentgrass (Agrostis palustris) [43]. It can be seen that there is still a large space for research on the impact of the interaction between N input and drought on coastal wetland ecosystems.

3. 3 N Input and Plant Invasion

In 1998, Gordon [44] reported for the first time that plant invasion can potentially change the surface elevation, tidal gully morphology and other topographic features of coastal salt marsh wetlands. In 2003, China announced the list of invasive alien species for the first time (the first batch) [45], and successively announced a total of 40 species of invasive plants in 2010 (the second batch) and 2017 (the third and fourth batches). Coastal areas are one of the areas most severely affected [46-48]. At present, the invasion of alien plants has become one of the three most difficult environmental problems in the world [49]. It not only changes the habitats of animals and plants in coastal areas, but also poses a serious threat to the biodiversity of coastal wetlands [50]. It is closely related to N The interaction of inputs is profoundly affecting coastal wetland ecosystems. At present, the interaction between N input and Spartina alterniflora invasion has been extensively studied at home and abroad. In my country, the main research areas include eastern and southern coastal wetlands, such as the Yellow River Delta, the Yangtze River Delta, and the Minjiang River estuary. Studies have confirmed the hypothesis that N enrichment significantly contributes to the successful invasion of plants [51-53]. Not only that, in the context of exogenous N input, the success rate and competitive ability of plant invasion are also related to the maximum potential body size of the plant itself. There is a unimodal functional relationship between the two, that is, plants that are too large (or too small) will inhibited by competition. Moreover, there is a strong nonlinear relationship between the maximum potential body size of plants and N supply. Therefore, under the influence of the maximum potential body size of plants, small differences in N will lead to huge differences in plant invasion competitiveness and success rate [54]. In turn, when Spartina alterniflora successfully invades, the increase in exogenous N input (CO(NH2) 2: 30 ~ 120 mg/kg) will promote the reproduction, growth and biomass of Spartina alterniflora [53]. The mutual promotion of N input and Spartina alterniflora (Fig. 1) further aggravates the threat of the two to coastal wetland ecosystems.

The interaction between N input and invasion of Spartina alterniflora will affect the interspecific relationships of coastal wetland plants. For example, in the coastal wetland plant community of the Yellow River Delta, adding N (0 to 15 g/(m2 ·a) makes Spartina alterniflora The relationship between grass, reeds, and Suaeda salsa has changed from promotion to competition [55]. However, it is also possible that the interspecific relationship does not change with the increase in N addition. For example, competition experiments show that in low N (CO (NH2) 2: 30 mg/kg) and high N (CO(NH2) 2: 120 mg/kg) Under horizontal conditions, both Spartina alterniflora and Phragmites australis show a competitive relationship [53]. This may be related to the different environmental background conditions in the study area.

The interaction between N input and Spartina alterniflora will further regulate the material cycle of coastal wetland ecosystems. In terms of C recycling, it can promote the accumulation of C. Mou Xiaojie et al.[56] studied the tidal flat wetland of S. brevifolia in the Minjiang River estuary and found that the interaction between low-dose (1 g/m2) and high-dose (4 g/m2) NH4 Cl input and the invasion of Spartina alterniflora promoted the CH4 oxidation in tidal flat soil.

Moreover, increased N input can also promote the increase in plant (including native and invasive plants) productivity and further enhance the accumulation of C in coastal wetland ecosystems [52]; at the same time, it can also promote the loss of C. The study found that the interaction between medium-dose (2 g/m2) NH4 Cl input and Spartina alterniflora invasion inhibited the oxidation of CH4 in the tidal flat wetland soil of A. shortleaf in the Minjiang estuary [56]. The addition of NH4 NO3 (N1: 21 g/(m2·a), N2: 42 g/(m2·a) and the invasion of Spartina alterniflora promoted the increase in the average CH4 emission flux of the tidal flat soil in this area. However, whether it is NH4 Cl or NH4 NO3, the intensity of the impact of the combination with Spartina alterniflora invasion on soil CH4 oxidation/emission fluctuates with time [56-57]. In terms of N recycling, it can promote the accumulation of N. This is because the N concentration of invasive plants is generally higher than that of indigenous plants [58], so the invasion of plants can change the N cycle process of the invaded ecosystem, causing more N to enter the invaded ecosystem [59]; at the same time, it also The loss of N can be promoted. The interaction between adding NH4 Cl (0. 15 g/L) and Spartina alterniflora invasion can promote N2 O emissions from mangrove swamps in southern Shenzhen, but it is lower than that under the combination of NH4 Cl and Kandelia obovata [60]; The interaction between adding NH4 NO3 (2.7 g/m2) and invasion of Spartina alterniflora can also promote N2 O emissions from swamp wetlands at the mouth of the Minjiang River, but it is lower than that under the combination of NH4 NO3 and reed [61]. This may be due to the rapid growth of Spartina alterniflora, which can consume most of the available N in the soil, thereby inhibiting the production of N2 O [60].

Based on domestic and foreign research, exogenous N input affects coastal wetland organisms, soil, etc. through interaction with temperature, moisture, and plant invasion, and further regulates the material cycle of coastal wetland ecosystems. Overall, it shows promotion, inhibition, and no impact3 types of effects (Table 1).

4 CONCLUSION AND OUTLOOK

In the same type as the single factor effect of exogenous N input on coastal wetland ecosystems, exogenous N input affects coastal wetland organisms, soil, etc. through interaction with temperature, moisture, and plant invasion, and further regulates the material cycle of coastal wetland ecosystems., also shows three types of effects: promotion, inhibition and no effect. However, the interactions of multiple environmental factors are complex, uncertain and difficult to predict. Therefore, systematic and in-depth research on the impact of the interaction between exogenous N input and environmental factors on coastal wetland ecosystems requires the following main issues to be resolved.

1) For N input and double or multiple factors such as temperature and drought

Table 1 Impact of interaction between exogenous N input and environmental factors on coastal wetland ecosystems

interaction type	Research object	Type of action			refer to literature
		Promote	inhibition	No effect	
N input + temperature	Algae (planktonic, benthic)	Planktonic: Increased respiration rate, increased number of dinoflagellates. Benthic: Changes in charophyte species diversity.	Planktonic: Increased numbers of diatoms.		[31-34]
N input + moisture	Spartina brevifolia population, Spartina alterniflora population, Suaeda salsa population, Spartina population, American Spartina population, American Spartina + Spartina community	Short-leaf Cortex spp.: Plant height, daily average net photosynthetic rate, aboveground biomass, and aboveground fixed C content increased. Spartina alterniflora: Aboveground biomass, leaf area, leaf number, leaf length, and leaf width increased (intermittent flooding state). Spartina: Optimal sea level rise for aboveground productivity. American Spartina+ Spartina community: The total aboveground biomass of plants increased.	Spartina alterniflora: Aboveground biomass, leaf area, leaf number, leaf length, and leaf width increased (continuously flooded state).	Cortex brevifolia: aboveground C and N content, aboveground C/N. Suaeda salsa: fresh weight, dry weight; Wanwan, USA: Optimum sea level for above-ground productivity. American Elephant + Spartina group Fall: The ratio of total plant biomass and above-ground to below-ground biomass.	[6, 14, 39-42]
N input + plant invasion	Mangrove community, Spartina alterniflora population, Phragmites australis population, Suaeda salsa population, Brachyphylla brevifolia population, Kandelia candel population and soil	Spartina alterniflora and Phragmites australis and Suaeda salsa: changes in interspecific relationships. Plant communities (native and invasive): Increased productivity. Soil: CH4 oxidation/emission, N2 O emission.	Soil: CH4 oxidation, N2 O emission.		[52-53, 55-61]

The lack of research on the impact of interactions on plant populations and community characteristics in coastal wetlands should be based on controlled experiments to explore the effects of double or multi-factor interactions between N input and temperature, drought, etc. on typical plant population density, interspecific relationships, and community species diversity in coastal wetlands. This provides a scientific basis for revealing the vegetation succession rules of coastal wetlands and optimizing the vegetation reconstruction model.

2) To address the issue of temporal variability of plant-soil ecological characteristics under the interaction of N input and environmental factors, short-term control experiments should be combined with long-term fixed monitoring, focusing on plant-soil ecological characteristics indicators of coastal wetlands under the interactive effects of multiple factors. time scale to scientifically explain the temporal variation characteristics of plant-soil interactions.

3) In view of the unclear mechanism of the interaction between N input and environmental factors on C and N pools in coastal wetland ecosystems, isotope labeling and molecular biology techniques should be used to comprehensively study N input and the environment from the dimensions of plants, soil, and microorganisms. The impact of factor interaction on C and N pools in coastal wetland ecosystems, clarifying the proportion of C and N accumulation and loss, provides theoretical support for coping with global change and improving the ecological functions of coastal wetlands.

COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

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