Wetland Plants across China

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Accelerating and severe wetland loss has made wetland restoration increasingly important. Current wetland restorations do not take into consideration the ecological adaptability of wetland plants at large scales, which likely affects their long-term restoration success. We explored the ecological adaptability, including plant life forms and phylogenetic diversity, of plants across 28 wetlands in China. We found that perennial herbs were more common than annual herbs, with the proportion of perennial herbs accounting for 40–50%, 45–65%, 45–70%, 50–60%, and 60–80% of species in coastal wetlands, human-made wetlands, lake wetlands, river wetlands, and marsh wetlands, respectively. A ranking of phylogenetic diversity indices (PDIs) showed an order of marsh < river < coastal < lake < human-made, meaning that human-made wetlands had the highest phylogenetic diversity and marsh wetlands had the lowest phylogenetic diversity. The nearest taxon index (NTI) was positive in 23 out of 28 wetlands, indicating that species were phylogenetically clustered in wetland habitats.

Keywords: wetland restoration ; invasive ; dominant ; clustered ; species screen

1. Introduction

Wetlands, known as the "kidney of the earth", are one of the world's three major ecosystems and provide indispensable resources for humans and biodiversity [1]. Wetlands have diverse roles from nutrient cycles (e.g., water, carbon) to human health [2][3][4][5]. However, serious wetland loss has occurred globally, driven by agricultural development, urbanization, fish farming, and climate warming [1][6].

Even without the provision of supporting evidence, Davidson (2014) [7] estimated that 64–71% of global wetlands had been lost since 1900 AD; meanwhile, Hu et al. (2017) [1] showed a 33% decrease in global wetlands until 2009 by calculating the Precipitation Topographic Wetness Index and global remote sensing training samples.

In the past six decades, Flanders (northern Belgium) has lost 75% of its wetland habitats [8], and the wetland area of the Sanjiang Plain—which contains the largest marsh wetland in China—has declined by 73.3% (about 2.77 million ha) since 1954 [9]. Wetland loss severely reduces or eliminates ecosystem services, such as biodiversity loss [8], water availability [4], and greenhouse gas capture [10]. Therefore, we must urgently implement effective wetland restoration projects.

Species screening is one of the central factors affecting the success of wetland restoration. Past wetland restorations have focused on screening for some common aquatic species to improve water quality and landscape values [11][12]. However, most of these efforts have neglected assessing the long-term stability (including the stability of a current situation to resist changes and to recover) of human-made plant communities because ecosystem structure and function recovery is typically slow after restoration [13][14]. Thus, exploring the ecological adaptability of wetland plants at large scales would be beneficial in species screening to improve the probability of successful wetland restoration in the long run.

With an area of 53.6 million ha, wetlands in China account for about 10% of the world's wetlands [15]. Here, we selected 28 wetlands (including lake, marsh, coastal, river, and human-made wetlands) in China to explore the plant life forms and phylogenetic diversity of wetland plants, with the goal of deepening our fundamental understanding of ecological adaptability of wetland plants.

2. Discussion on Wetland Plants across China

2.1. Perennial Herbs

The higher frequency of perennial herbs in wetland habitats is consistent with previous findings, such as in agricultural landscapes after wetland restoration in the USA [16] and 74 different kinds of wetlands in Canada [17]. Perennials, such as *Carex* spp. and *Phragmites australis*, tend to have larger root systems that may augment the ecosystem's adaptability to water level fluctuations and tolerance to long-term seasonal submergence. Many perennials can spread or propagate vegetatively, which may also benefit wetlands with fluctuating conditions. Annuals, with smaller root systems and typically without vegetative reproduction, may be at a disadvantage in wetland habitats.

2.2. Phylogenetic Diversity

It was not surprising that wetland species were phylogenetically clustered, as Asteraceae, Poaceae, and Cyperaceae are among the largest plant families (Figure S1). However, it was interesting that dominant species tended to be phylogenetically distinct from non-dominant species, which might impact wetland restoration strategies.

In China, marsh wetlands had a low species richness and phylogenetic diversity relative to other wetland types. This may be because most marsh wetlands were distributed in the northeast region, Yunnan–Guizhou region, and Qinghai–Tibet Plateau, which have colder climates and lower diversity [18]. It is also possible that the diversity was low in marsh wetlands because they occupy only small areas, usually distributed near rivers and lakes [18]. Consistently, marsh wetlands had a lower phylogenetic diversity compared to the Gobi, salt marshes, and sand dunes in the Jiayuguan Caohu Wetland of China [19].

Lake and human-made wetlands had a higher species richness and phylogenetic diversity. One explanation for this might be that these two kinds of wetlands were mainly distributed in the southeast part of China, which has a warmer climate and a higher regional species richness [20]. Moreover, human activities are extremely frequent in the southeast part of China, which likely leads to more aquatic species being planted and alien species being introduced, such as *Eichhornia crassipes* (water hyacinth) and *Alternanthera philoxeroides* (alligator weed).

Many tree species have been planted at the junctions between wetlands and adjacent landscapes, which might contribute to the high diversity of human-made wetlands. However, some tree species can lead to wetland degradation. For example, rapid-growth species of *Populus* were introduced into Dongting Lake, the second largest freshwater lake in China, for forestry and paper [21]. *Populus*, also known as "the pump of the wetland" [21], accelerated the drying of the wetlands and changed the structure of the wetland soil. To protect the Dongting Lake wetland, the local government implemented the removal of *Populus* plants in 2017 [21]. To avoid the high cost of tree removal projects, as seen at Dongting Lake, it is important to follow ecologically sound vegetation addition practices.

Here, alien invasive species were phylogenetically distinct from native species in wetland habitats (Figure S6). Consistently this is supported by a functional trait approach, where the differences between alien invasive species and native species improve the success of invasiveness [22]. A total of 478 aquatic plants species have been introduced to China, 95% of which were introduced for their landscape value, such as ornamental and soil and water conservation [23]. For instance, *Eichhornia crassipes* (water hyacinth) and *Alternanthera philoxeroides* (alligator weed) have already led to the destruction of ecological services and caused severe economic losses [24]. However, alien mangrove plants, such as *Sonneratia apetala* and *Laguncularia racemosa*, have restored ecosystem services in mangrove forests without causing invasions in China [25]. We must be very cautious when introducing species and fastidiously monitor the impact of introduced species on local ecosystems.

2.3. Suggestions on Wetland Restorations

By exploring the life forms and phylogenetic diversity of wetland plants, we offer some suggestions for species screening in wetland restoration to maximize the ecological, landscape, and environmental values of wetlands. We suggest to (1) screen for native annual herbs and perennial herbs in proportions that occur naturally; (2) consider the phylogenetic similarity to dominant native species: for instance, we could screen for plant species that are phylogenetically similar to local dominant species to improve the probability of successful wetland restoration in the long run.

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